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Introduction

The development of new technologies, new trends in economics of technology, mathematical and computer process modeling have been a legitimate reason to start the edition of a new international journal under the name ECONTECHMOD (INTERNATIONAL QUARTERLY JOURNAL ON ECONOMICS IN TECHNOLOGY AND MODELLING PROCESSES). This is a quarterly published in English (Volume 1 and 2) and Russian (Volume 3 and 4), in a book and electronic form. This edition presents the first issue of the new journal. We hope that the problems raised in the works obtain the approval of readers and in the near future this quarterly magazine will be listed on the list of journals scoring by the Ministry of Science and Higher Education. The themes of the papers published in the journal ECONTECHMOD and its international character resulting from the participation of many prominent writers and recognized academics from Central and Eastern Europe will further increase the cooperation among our countries, and in particular with Ukraine. It is worth emphasizing that the Program Council of the magazine consists of scientists of many countries in Europe, which ensures that the publications will be a perfect opportunity for a wide, multilateral exchange of scientific ideas and the lessons learned will be used for further international integration, regardless of geographic location. It should also be noted that the organization and publication of the magazine is our great achievement on an international scale. As mentioned earlier, the involvement of numerous outstanding scientists from many countries gives even more credibility to the fact that this project will maintain a high scientific level of the published works. Special congratulations are due to Professor Eugeniusz Krasowski, who, in spite of the accumulating difficulties, with vigor improves and creates new forms of cooperation on the international arena.

With the above-mentioned facts in mind, prof. Eugene Krasowski, representing the Polish Academy of Sciences Branch in Lublin, as the Editor-in-Chief of TEKA and MOTROL, has invited the representatives of different scientific centers to collaborate in the creation of the new international journal ECONTECHMOD: Rector of the Lviv Polytechnic National University prof. dr Yuriy Bobalo, Director of the Foundry Research Institute in Cracow prof. dr Jerzy Sobczak, Head of the Department of Technology Fundamentals at the University of Life Sciences in Lublin prof. dr Andrzej Kusz and Professor of the Department of Management and International Entrepreneurship at the Lviv Polytechnic National University prof. dr Nestor Shpak.

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Modelling of the kinetic energy loss in a vehicle on the basis of cumulative frequency of speed profile parameters

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Abstract. This paper presents the modeling of energy intensity of vehicles in terms of loss of kinetic energy during driving on a motorway, dual carriageway and national road. The analysis was based on elements of mathematical statistics on the prevalence of sensitivity of the total speed and variation of its occurrence. The analysis was performed on a statistically significant number of vehicles using the envelope of oscillograms of the tachographic record of continuous motion.

Key words: transport logistics, modeling, energy intensity of movement, tachographic record, mathematical statistics of oscillogram.

INTRODUCTION

Energy consumption of a vehicle movement is an essential component of the energy balance. It is the sum of energy expenditure to overcome the resistance to motion and gravity, inertia forces. The share of each component in the equation of motion depends on the realized velocity profile, which is largely determined by the acceleration phase parameters [12].

For longer journeys with variable speed a significant impact on energy consumption is the frequency of movement phases of acceleration and their intensity [1].

According to the previous research [13, 7] city driving has almost five times larger share of energy expenditure to overcome the inertia forces than road riding. Road riding has more than a double share of energy expended to overcome air resistance, due to higher average speed.

This is confirmed by studies of energy loss resulting from the difference between acceleration and deceleration phase of driving in urban infrastructure and road [4, 5, 9, 10, 11].

AIM OF RESEARCH

In the previously conducted studies, the energy intensity of vehicles has been largely boiled down to a theoretical analysis of the impact of balance sheet items of the vehicle energy dialogue, energy intensity of the basic phases of a movement or a complex profile of driving speed in the strictly defined so called Elementary Profiles [13].

These included successively: acceleration, constant speed driving and delayed traffic.

The operational, randomly variable conditions of real driving were included to a lesser extent. In this case the energy expended to travel the section of road is also dependent on the frequency and intensity of phase delay [3, 8].

The main direction of research concerned the speed limit in various communication infrastructure, with no apparent connection to its energy intensity and rather related with the safety of road users [6, 14, 16, 17].

Therefore, an important issue arising from the progressive geodelization of transport (Shapovalov, Nezhinsky 2010) proved to be an increased use of speed profile in the so called. tachografic record

This paper presents the results of the analysis of energy consumption at speeding up and slowing down with the method of mathematical analysis in the global count of losses occurring between these phases.

RESEARCH METHODOLOGY AND STATISTICAL CALCULATIONS

The assumed methodology used the tachographic records of vehicles statutorily required to use analogue and digital tachographs. The routes included the national and international roads (motorways and ways of fast motion). In order to find out the expended kinetic energy of velocity phase profile of the vehicle's motion, the computations were performed of the so called distribution of the empirical frequency of acceleration phase (F1) and delay phase (F2) in the corresponding section of the infrastructure of distance traveled.

As the basic statistical parameters of speed profile the frequency of occurrence of the mean value (x), median (Me), and dominant (Do) were assumed. To assess the variability of occurrence of individual driving phases in the global profile, the following values were calculated: (S2), standard deviation (s), and coefficient of variation (Wz) [15].

CALCULATION RESULTS AND ANALYSIS

1. EVALUATION OF THE BASIC PARAMETERS OF THE GLOBAL STATISTICAL PROFILE OF DRIVING SPEED

Tab. 1 shows the distribution of empirical numbering frequency of the arithmetic mean (x) of the upper (F1) and lower (F2) speed profile on the national road (1, 2), way of fast motion (3, 4) and motorway (5, 6). Analogous data have been presented for the empirical distribution of the median (Me) - Tab. 2 and the dominant (Do) - Tab. 3.

The maximum values of the median (Me) of acceleration phase (F1) are in the range 70-80 km / h and represent

Table. 1. Numbering the empirical distribution of the frequency of the upper (F1) and lower (F2) speed profile of the arithmetic mean (x) on the national road (1,2), way of fast motion (3.4), and motorway (5.6)

No	Velocity v	Arithmetic mean x					
		national road		way of fast motion		motorway	
		F1	F2	F1	F2	F1	F2
1.	10	-	-	-	-	-	-
2.	20	-	0,04	-	-	-	-
3.	30	-	0,12	-	-	-	-
4.	40	-	0,28	-	0,07	-	-
5.	50	0,15	0,60	0,02	0,23	-	0,06
6.	60	0,26	0,72	0,04	0,68	-	0,12
7.	70	0,69	0,84	0,20	0,95	-	0,45
8.	80	0,96	1,00	0,70	0,98	0,20	0,90
9.	90	1,00	-	0,97	1,00	0,82	1,00
10.	100	-	-	1,00	-	1,00	-
11.	110	-	-	-	-	-	-
12.	120	-	-	-	-	-	-
13.	130	-	-	-	-	-	-
14.	140	-	-	-	-	-	-
15.	150	-	-	-	-	-	-
16.	160	-	-	-	-	-	-
17.	170	-	-	-	-	-	-

Table. 2. Numbering the empirical distribution of the frequency of the upper (F1) and lower (F2) speed profile of median (Me) on the national road (1,2), way of fast motion (3.4), and motorway (5.6)

No.	Velocity v	Median					
		national road		way of fast motion		motorway	
		F1	F2	F1	F2	F1	F2
1.	10	-	-	-	-	-	-
2.	20	-	-	-	-	-	-
3.	30	-	0,03	-	0,06	-	-
4.	40	0,04	0,11	0,06	0,09	-	-
5.	50	0,08	0,38	0,09	0,13	0,02	-
6.	60	0,17	0,53	0,13	0,27	0,05	-
7.	70	0,30	0,57	0,27	0,59	0,05	0,03
8.	80	0,65	0,74	0,59	0,67	0,08	0,48
9.	90	0,91	0,96	0,65	0,74	0,66	0,87
10.	100	1,00	1,00	0,74	0,84	1,00	0,90
11.	110	-	-	0,84	0,88	-	0,97
12.	120	-	-	0,88	0,88	-	1,00
13.	130	-	-	0,93	0,93	-	-
14.	140	-	-	,093	0,93	-	-
15.	150	-	-	0,99	0,99	-	-
16.	160	-	-	1,00	1,00	-	-
17.	170	-	-	-	-	-	-

36.3% of the total number (Tab. 2). The corresponding values of the dominant (Tab. 3) are in the range (70-80) km / h (F1) and represent 33.3% of the total number, for (F2) - (50-60) km / h (44%).

For ways of fast motion the arithmetic mean (x) of the acceleration phase (F1) is in the range (70-80) km / h, which represents 50% of the total number. For the motion delay phase (F2) it represents 46%, in the range 50-60 km / h. The median (Me) values account for 41% of the number, in the range (80-90) km / h (F1), and for F2 - 36.5% in the range (60-70) km / h. The arithmetic mean (x) for the motorway is 61.5% of the number in the range (80-90) km / h (F1) and for (F2) - 78.8% of the number in the range of (60-80) km / h. The highest values of the number of incidence frequency of median (Me) for (F1) are in the range (80-100) km (90%), for (F2) - 84, 9%, in the range (70-90) km/h.

These figures are reflected in the course of accelerating the phase distribution function (F1) and deceleration speed (F2). The difference between them reflects the size of kinetic energy loss on the considered transport infrastructure routes (Table 1-3). The lowest energy loss occurs on the motorway. Loss of kinetic energy on the national road coincides with the motorway, regardless of the statistical parameter in question.

STATISTICAL EVALUATION OF VARIABILITY OF A GLOBAL PROFILE OF SPEED PARAMETERS

According to the obtained calculations (Table 4), the lowest standard deviation (s) obtained for the motorway was (5-20) km / h, then for the national road (10-30) km / h, and for the motorway (5-40) km / h. This is due to the frequency of its incidence. For the motorway 100% of its value is contained in the range from (0-20)%, while for the remaining infrastructure of F1 and F2 it stays in the range between (35-60)%.

According to the obtained calculations of variance (δ2) of the analyzed profiles F1 and F2 (Table 5), a significant variation in its value occurred within their increased volatility. This was especially observed for high speed road (3, 4).

Table. 3. Numbering the empirical distribution of the frequency of the upper (F1) and lower (F2) speed profile of dominant (Do) on the national road (1,2), way of fast motion (3.4), and motorway (5.6)

No.	Velocity v	Dominant					
		national road		way of fast motion		motorway	
		F1	F2	F1	F2	F1	F2
1.	30	-	-	0,04	0,04	-	-
2.	40	-	0,04	0,06	0,09	-	0,05
3.	50	0,11	0,20	0,13	0,25	0,12	0,11
4.	60	0,18	0,64	0,17	0,34	0,15	0,11
5.	70	0,25	0,82	0,32	0,53	0,20	0,14
6.	80	0,59	0,92	0,39	0,76	0,25	0,55
7.	90	0,74	1,00	0,71	0,86	0,67	0,88
8.	100	0,85	-	0,86	0,88	0,87	1,00
9.	110	0,92	-	0,95	0,97	0,97	-
10.	120	0,96	-	1,00	1,00	0,97	-
11.	130	1,00	-	-	-	1,00	-

Table. 4. Numbering the empirical distribution of total frequency of standard deviation incidence (s) of the upper (F1) and lower (F2) speed profile on the national road (1,2), way of fast motion (3,4) and motorway (5,6)

No	Value	Standard deviation					
		national road		way of fast motion		motorway	
		F1	F2	F1	F2	F1	F2
1.	5	0,03	-	0,02	0.02	0,21	0,03
2.	10	0,24	-	0,06	0.02	0,52	0,06
3.	15	0,61	0,03	0,49	0.06	0,74	0,39
4.	20	0,76	0,26	0,83	0.20	1,00	0,69
5.	25	1,00	0,65	0,98	0.47	-	0,93
6.	30	-	0,96	1,00	0.75	-	1,00
7.	35	-	1,00	-	0.93	-	-
8.	40	-	-	-	1.00	-	-

The coefficient of variation (Wz), is an important statistical parameter, which combines the characteristics of standard deviation (s) and mean value (x). According to the data in Tab. 6, for the motorway, 100% of the value contains the range of variation coefficient (0-30)%. Its highest value (40-60)% was obtained for the profile of traffic delay phase for the national road and way of fast motion.

CONCLUSIONS

Effect of acceleration and deceleration of the speed of vehicles on the kinetic energy losses due to its profile should be considered, depending on many factors: the transport infrastructure, road conditions, the management of its speed, psychological and physical features of drivers, etc. The study conducted on the statistically significant number of the vehicles involved in international freight transport, however, allowed for a global approach to this problem.

It was proved possible to determine the basic, dominant frequency ranges of statistical parameters of vehicle acceleration and deceleration phases. They express both the mean value distribution and the median and dominant distribution. While a greater variation of the summary value occurs in the case of the way of fast motion and the national road (40-60)%, for the motorway it is (85-90)% of the total.

The evaluation of the quoted results of calculation of the core statistical values of the global speed profile, in relation to the existing road testing studies of other authors (Gaca 2001, Szymanek 2001) allows for the following statements:

– Compared to the national road and way of fast motion, the motorway is characterized by large incidence clusters of both the analyzed phases in the speed range, thus there is a small area of energy loss between the empirical distribution functions;
– Motorway is a special case of frequency diversity of the analyzed parameters, resulting on one hand from a high speed limit, on the other hand from a need to reduce it due to the requirements of road safety.
– An example of this problem is introduction of collision-free traffic engineering solutions, e.g. the use of

Table. 5. Numbering the empirical distribution of total frequency of variance (δ2) of the upper (F1) and lower (F2) speed profile on the national road (1,2), way of fast motion (3,4) and motorway (5,6)

No	Value	Variance					
		national road		way of fast motion		motorway	
		F1	F2	F1	F2	F1	F2
1.	100	0,03	-	0,13	0,20	0,51	0,05
2.	200	0,22	0,03	0,20	0,04	0,69	0,25
3.	300	0,33	0,07	0,51	0,14	0,82	0,47
4.	400	0,63	0,15	0,82	0,21	0,97	0,67
5.	500	0,70	0,30	0,98	0,28	1,00	0,75
6.	600	0,78	0,53	0,97	0,52	-	0,91
7.	700	0,86	0,61	1,00	0,59	-	1,00
8.	800	1,00	0,84	-	0,69	-	-
9.	900	-	0,89	-	0,85	-	-
10.	1000	-	1,00	-	0,88	-	-
11.	1100	-	-	-	0,97	-	-
12.	1200	-	-	-	1,00	-	-

Table. 6. Numbering the empirical distribution of total frequency of variance factor (Wz) of the upper (F1) and lower (F2) speed profile on the national road (1,2), way of fast motion (3,4) and motorway (5,6)

No.	Value	Variance					
		national road		way of fast motion		motorway	
		F1	F2	F1	F2	F1	F2
1.	10	-	-	0,10	0,04	0,45	0,04
2.	20	0,20	0,08	0,21	0,04	0,78	0,54
3.	30	0,48	0,17	0,82	0,13	1,00	0,87
4.	40	0,80	0,34	0,95	0,27	-	0,96
5.	50	0,96	0,56	0,99	0,51	-	1,00
6.	60	1,00	0,87	0,99	0,83	-	-
7.	70	-	1,00	1,00	0,90	-	-
8.	80	-	-	-	0,95	-	-
9.	90	-	-	-	1,00	-	-
10.	100	-	-	-	-	-	-

small roundabouts significantly reducing the number of accidents (up to 70-90%) but at same time causing higher fuel losses when compared with the national roads with generally lower speed limits.

– The common choice by drivers in the globalization of international transport of the ways of fast motion rather than toll motorways may turn out significant in the overall costs of transport management.

Evaluation of variation in the incidence analyzed in global terms, can-tion, showed a considerable range of their occurrence. Calculations of variance, standard deviation and coefficient of variation in particular are the result of compliance with speed limits and driving bone psychological factors can affect the personality of drivers.

This is shown by their own research [2] and other authors (Humeniuk 2001). And in this case the highest values of the coefficient of variation museum and saw on the highway.

Especially in the case of highway Should Be Carried out refurbishment work on the „Unblocking" the improvement of physical resources to optimize for speed reduction, the kierochizacji with a division of functions Particular Between episodes. The date and Further work on research topics Presented Should allow the Development of the physical model of the kinetic energy loss in the actual operation of vehicles transport logistics contacts.

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Perspectives of the use of renewable energy sources in enhancement of environmental and energy security of belarus

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Abstract. Interest in renewable energy sources (RESs) has been growing all over the world in recent years. The market for alternative energy resources is quickly growing in Western Europe and in Asia. The development of renewable energy is caused by two major factors, one of which is an environmental requirement. Its importance increases from the legislative point of view and from the conditions accepted by the Convention on Climate in December 1997. The second requirement concerns energy production capacity. According to this requirement the preference is given to production forms which can be created and developed quickly. The development of RES in many cases is closely connected with the maintenance of energy safety of the country, influencing its sovereignty and independence.

Key words: renewable energy sources, alternative energy sources, Belarus

INTRODUCTION

Energy safety problems in Belarus are mainly characterized by the fact that the Republic must buy up to 85% of energy resources. The basic domestic direction for maintaining energy safety includes a number of fundamental ways to prevent threats, thereby reducing the probability of their occurrence and easing the consequences. On the one hand, there are energy wasteful industrial and household sectors in the country; on the other hand, there are essential energy-saving reserves (including RES use), both in the energy and in other sectors of the national economy [4, 6, 11, 15, 19, 18]. Nowadays, satisfaction of needs in fuel and energy resources (FERs) of Belarusian consumers, maintenance of efficient fuel-energy balance structure of the country, and the quest for additional energy sources became three of the main problems posed for the fuel and energy complex in the Republic (see "The program of increase in the use of local fuel types and alternative energy sources for 2003-2005 and up to 2010"). The involvement of RES in the economic turnover serves as an energy-saving component which is directed to realization of legal, organizational, scientific, industrial, technical, and economic measures of effective utilization of energy resources.

The Republic of Belarus does not have sufficient amount of its own FERs to maintain national economy needs. National resources of available fossil fuel are few and they are depleted practically up to (80-90)%. The country imports about 84% of the consumed FERs. Obsolete capital assets in energy, industry, agriculture, and habitation are used up to (70-90)% [13, 12]. Therefore, as a result of low supply with its own energy sources (at a level of (15-18)% from the general need) the problems of energy safety are the major components of the national and economic security for the country. The necessity for increasing energy safety is mainly caused by the need to quickly solve this problem, because, if the delivery of energy resources is restricted, the Republic can suffer a loss from gross domestic product (GDP) underproduction to the sum of $400-450 with the expectation of 1 ton of standard coal (TSC). It repeatedly exceeds the cost of FER import from any existing or new suppliers according to world prices. In case of emergency conditions in fuel systems or in the event of switching-off the heat supply systems during the winter period, the size of damage can be increased many times [10, 19].

The most important branch of the economy in any developed country is power engineering. The moving forces and trends of its development reflect the processes of economical state and development of the country, geopolitical situations, and historical prospects. Realization of the measures taken by the government during 1995-2000 allowed a suspension in the decrease in production in the Republic. By the end of 1996, positive dynamics of main macroeconomic processes were achieved, year-to-year increases of GDP, and consumer and industrial goods production was provided. Investment activity has quickened. We succeeded in stabilizing the situation in the domestic consumer market as well as financial enterprises. From 2001 to 2005 GDP grew by more than 43%. In Europe, from 2000 to 2004 GDP increased on the average 1.7% a year, in the USA 2.8%, in Japan 1.9%, in Belarus this parameter reached 9.2% in 2005.

In 1990, the total FER gross consumption came to 54,965 million TSC, in 2000 it was only 34.5 million TSC, in 2005 (according to evaluation data) it was 36.8 million TSC (Fig. 1). The main reasons for the sharp decrease in energy resource consumption in Belarus during 1990-2000 was the decrease in industrial production, structural changes in the energy sector of the national economy, as well as tough governmental policy on every possible economy of energy resources. At the same time, the composition of used fuel has been changing. The consumption of heavy oil fuel (black fuel, mazut) is decreasing and the consumption of imported Russian gas is increasing. The average price of Russian gas is about $50 per 1000 m^3 now (2009) and it is constantly increasing, approaching the world level.

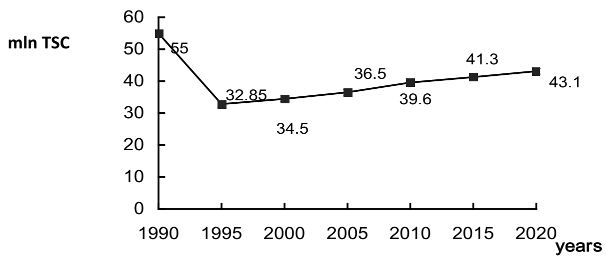

Fig. 1. Time history of fuel and energy resources (FER) in Belarus (according to the data given by the Ministry of statistics of Belarus and national development energy programs)

In the long-term outlook the total FER gross consumption will grow. According to the formal forecast, by the year 2020, the size of total consumption will reach 43.1 million TSC, which is only 65- 70% of the consumption level that existed in 1990. In the future, the development of the national economy of the Republic should be followed by an increase of the efficiency of energy use, related to its consumption, development, and transportation. During 2001-2005, the GDP power consumption in the Republic decreased at a rate of (4.7-5.4)% per year. In 2006-2010, average annual rates of energy consumption decrease are projected to be higher - (5.1-5.9)% per year, and by 2020 they will decrease to (2.2-3.0)% per year.

Nowadays problems lacing power engineering specialists can be divided into two parts: application of new technologies using fossil fuel and development of alternative energy sources (wind and seasonal solar energy, biomass and wastes as local fuel).

ANALYSIS AND PROSPECTS OF THE USE OF ALTERNATIVE AND RENEWABLE ENERGY SOURCES

GENERAL CHARACTERISTIC OF THE PROBLEM

According to natural, geographic, and meteorological conditions in Belarus, alternative and renewable energy sources (RESs) can be the following: firewood and wood waste products, water resources, wind-driven potential, biogas from cattle-breeding wastes, solar energy, phytomass, solid domestic wastes, plant growing wastes, and geothermal resources. There are several reasons why these energy sources should be widely used in the Republic. First of all, the work on the use of RESs will promote the development of our own technologies and equipment which can be exported in the future. Secondly, these sources, as a rule, are pollution free. This contributes to environmental security of Belarus. Thirdly, the

Table 1. Economically expedient potential of use of fire wood and wood waste products for heat and electric energy production

Year	Firewood		Wood waste products (million TSC)	Total (million TSC)
	million cubic meter	million TSC		
2003	4.18	1.11	0.28	1.39
2004	4.51	1.20	0.29	1.49
2005	5.36	1.43	0.31	1.74
2006	6.30	1.68	0.32	2.00
2007	7.29	0.33	2.27	2.27
2008	8.08	2.15	0.35	2.50
2009	8.95	2.38	0.36	2.74
2010	9.40	2.50	0.37	2.87
2011	9.88	2.63	0.39	3.02
2012	10.15	2.70	0.40	3.10

development of such sources will raise energy safety of the state.

In order to cover the costs for the alternative energy sources, special attention should be paid to technical approaches using equipment produced in the Republic and with maximal use of local materials.

FIREWOOD AND WOOD WASTE PRODUCTS

The Republic of Belarus has huge forest resources. The total area of the forest resources on 1 January 2001 was 9,248,000 ha, forest timber inventory - 1340 million cubic meters. Annual basic increase is (32-37) million cubic meters. A systematical and stable growth of forest resources can be predicted (up to 1.8 times in 2020) if a simultaneous improvement of age and stock forest structure takes place [18].

The centralized logging and firewood preparation in Belarus is carried out by enterprises of the Ministry of Forestry and by the Belarussian concern of wood-paper Industry. In 2003, the annual volume of firewood, sawing, and woodworking waste utilization as boiler stove fuel was 1.4 million TSC [Table 1] [19]. At present firewood fuel consumption for production of electric and heat energy by energy generative settings does not exceed 600,000 TSC per year.

The potential of the Republic to use wood as a fuel is estimated to be (3.5-3.7) million TSC per year, which is 2.5 times higher than in 2003. It should pointed out that all regions of Belarus own firewood recourses. On the whole in the Republic, the annual volume of firewood, sawing, and woodworking utilization was about (1.0-1.1) million TSC. A part of the firewood goes to population via self-stocking which is estimated at (0.3-0.4) million ISC.

Limited opportunities for Belarus to use wood as a fuel can be defined from the natural annual firewood increase. It is estimated at 25 million cubic meters or 6.6 million TSC per year including that for the contaminated areas of the Gomel region - 20,000 m^3 or 5300 TSC.

In order to use wood as a fuel in these regions it is necessary to work out and to apply new technologies and equipment for gasification and parallel decontamination. According to the planned double growth of firewood storage by 2015 and taking into account volume increases of wood waste products, sawing wastes and firewood processing, in 2005 the annual volume of firewood increased up to 1.6 million TSC.

International Sakharov Environmental University (ISEU) together with Austrian firm KOB developed a project on installation on the territory of Educational and Research Station Volma, Dzerzhinsk region, in 2006 of two modern heat-and-power engineering stations which will use raw wood bio-material. Heat-and-power engineering station PYROT with the capacity 250 kW (ground firewood) is shown in Fig. 2 (on the left side) [4, 10].

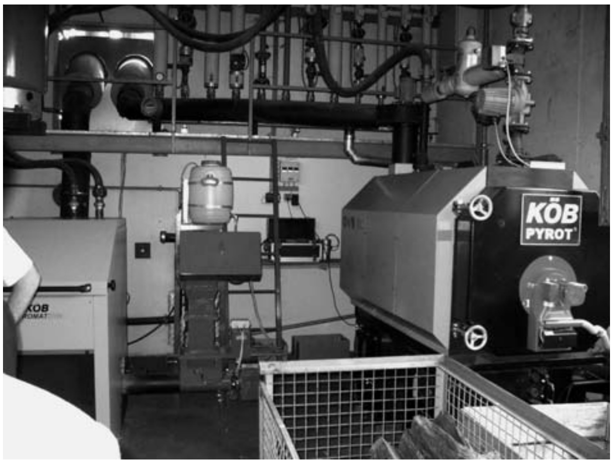

Fig. 2. Overview of heat -and-power engineering stations, KOB firm.

Along with the use of wood waste products for heating purposes, it is worthwhile to provide economically grounded involvement of wood waste products of hydrolytic factories (lignine) into the fuel balance of the Republic. In the city of Rechitsa, Gomel region, a new industrial station using lignine has been put into operation. Lignine resources are about 1 million TSC per year, and an expedient volume of use is estimated to be 50,000 TSC per year. To solve the problem we need investment support, an application of the system of fixed prices, and a normative legal base modernization specified on tax preferences for enterprises producing electric and thermal energy from firewood.

WATER POWER RESOURCES

Installed capacity of 20 hydroelectric power stations (HPSs) in Belarus was 10.9 MW on 1 January 2004. Due to water power resources about 28 million kWh of energy is produced annually. It is equivalent to the replacement of imported fuel at the rate of 7900 TSC. The potential capacity of all water channels in Belarus is 850 MW including technically accessible (520 MW) and economically expedient (250 MW) capacities [Tarasenko, Poznyak, 2005].

The main directions of the development of small hydropower engineering in Belarus are the following: construction of new HPS, reconstruction, and restoration of existing UPS. The unit capacity of each hydropower unit will be in the range of (50-5000) kW (Table 2), and the preference in that case will be given to quick mounted hydropower units of the capsular type.

Having the capacity of hydropower units from 50 to 150 kW it is possible to use asynchronous generators as the simplest and most reliable units in operation. As a rule, all restored and newly constructed HPSs should work in parallel with power supply systems that will allow, in future, the simplification of circuit and constructive decisions.

Special attention in Belarus should be paid to the problems of cascade HPS construction on the rivers Sozh, Dnepr, and Pripyat because the possible scales of water flooding of the adjacent territories are limited by the zone contaminated with radionuclides.

WIND-DRIVEN POTENTIAL

On the territory of Belarus there are 1840 sites for the installation of wind energy stations with a theoretical energy potential of 1600 MW and annual power generation of 6.5 billion kWh [19]. On 1 January 2005 the total capacity of installed wind energy stations was 1.1 MW and the replacement volume was 0400 TSC (Table 3). In fact, in 2005 in Belarus there were only three wing stations («Ecodom», Naroch-2, «Areola» Minsk-1) with the total capacity of 850 kW, and one rotor wind energy Station (Fig. 3) with the total capacity of 250 kW situated on the territory Educational and Research Station Volma, ISEU.

The development allowing the transformation of wind power into electric power by means of traditional wing wind energy stations used so far, in conditions of Belarus were economically unjustified. This fact was one of the reasons of the development of the rotor wind energy station (Fig. 3). However, modem technical development allows the creation of similar wing wind energy stations with a starting wind speed from 3 m/s and with rated operation speeds of (7-8) m/s. The cost of such stations is varying from $800 to $1200 for 1 kW of the established capacity. This makes such stations more attractive for use [5, 20, 21, 22].

The Republic of Belarus is characterized by weak continental winds with the average speed of (4-6) m/s. Therefore, choosing the sites for the wind energy stations special tests and careful studies of FER on their application are required. In order to get an objective estimation about the reserve opportunity of full wind-driven potential it is also required to complete a cycle of experimental research. The necessity of parallel work of wind energy stations with power supply system brings some complications into the general scheme and, thus, expenses for creation and operation of wind energy stations will increase considerably. At the same time while calculating the expenses also the necessity of creation and maintenance of power reserve on other types of power stations should be taken into account. According to expert predictions no more than 5% of the general potential will be developed by the year 2005, i.e., 45 million kWh which is equivalent to 12,000 TSC.

Table 2. Real and predicted volumes of the use of water and power resources for the electric energy production

Year	Input capacity (MW)	Total installed HPS capacity	Increase of replacement volume (,000 TSC per year)	Power generation (million kWh per year)	Total replacement volume (‘000 TSC)
2005	0.76	11.94	0.97	34.9	9.77
2006	0.55	12.49	0.70	37.4	10.47
2007	18.37	30.86	23.50	121.3	33.97
2008	23.30	54.16	29.80	227.8	63.77
2009	20.80	74.96	26.60	322.8	90.37
2010	15.00	89.96	19.20	391.3	109.57
2011	0.29	90.25	0.40	392.8	109.97
2012	5.50	95.75	7.00	417.8	116.97

Table 3. Real and predicted volumes of the use of wind-driven potential for electric energy production

Year	Total installed capacity of wind energy settings (MW)	Power generation (million kWh per year) (TSC)	Total replacement volume (000 TSC)
2005*	1.2	2.15	0.60
2006	1.7	3.04	0.85
2007	2.2	3.94	1.10
2008	3.7	6.62	1.85
2009	3.7	6.62	1.85
2010	3.7	6.62	1.85
2011	5.2	9.31	2.61
2012	5.2	9.31	2.61

*Actual power for today

Fig. 3. Overview of rotor wind energy station, ISEU.

One of the main directions of wind energy stations application will be their application for pump drive stations with low capacity (5-8) kW and for water heating in the farming industry. These areas of application arc characterized by minimal requirements for electric energy quality that allows a simplification and sharp reduction in the price of wind energy stations.

BIOGAS FROM LIVESTOCK WASTE

Tests results on biogas production from wastes of cattle-breeding complexes have proved that they are not economically competitive for only biogas production. The main reason is that it is possible to receive pollution-free and high-quality organic fertilizer without additional power expenses and as a result to reduce the power-consuming industry of mineral fertilizer production proportionally. The application of biogas allows us to improve environmental situation near the large-scale farms and cattle-breeding complexes, as well II on the areas under crops where livestock wastes arc spread nowadays and in addition to receive high-quality biohumus fertilizers. Potential production of commodity biogas from cattle-breeding complexes is estimated to be 160 000 TSC per year, and by 2005 it will be no more than 15,000 TSC [2, 19, 17, 16].

GEOTHERMAL RESOURCES

In the Republic of Belarus geothermal resources with a density of more than 2 TSC/m^2 and with a temperature 50°C at a depth of 1.4-1.8 km, and 90-100°C at a depth of 3.8-4.2 km are found in the Gomel and Brest regions [19, 9]. However, high mineralization, low productivity of available wells, the small quantity of wells and, on the whole, our poor knowledge of this resource does not allow the development of this RES for the next (10-15) years.

SOLAR ENERGY

According to meteorological data in Belarus on average there are 250 overcast, 85 rainy, and 30 clear days in a year. To satisfy electric power needs of Belarus in the volume of 45 billion kWh, 450 km^2 of heliostats are required. The price of heliostats is \$450 per m^2 that is equal to \$202.5 billion without the expenses for the exploitation of the synchronizers, building and construction works, cables, control systems, technical services, infrastructure, etc. The listed components will double the given sum.

Taking into account foreign experience and the experience gained from the building of a solar power station in the Crimea, specific capital investments and energy production costs are ten times higher using solar energy than using other sources. Technical progress in this area will promote the reduction of costs; however, in the case of Belarus, electric power production using solar energy will not be practical in the near future.

The main directions of solar energy utilization will be heliowater heaters and various heliostations for intensification and enhancement of drying processes as well as water heating in the farming industry [1, 14, 7].

In Belarus heliowater heaters with welded plastic collectors are worked out and are prepared for large-scale manufacture. Therefore, the expensive heavy-metal pipes are not required for solar collectors, which makes their production more economical. Having favorable conditions of economic and manufacturing facilities the widest application of heliowater heaters in southern regions of the Republic can be expected.

At the same time it is expedient to develop in Belarus the following resources:

– Self-contained power supply with capacity starting from some watts up to (3-5) kW (home equipment, lightening, power supply of residential houses, lines of communication, etc.)
– Modular photoelectric stations for rural consumers with a capacity from 0.5 to 1 kW based on the elements modern generation

The development of such sources and stations needs в number of research efforts to create modern materials, to improve the quality of the existing materials (based on silicium), to reduce its price, and consequently the price of the finished products.

In the favorable conditions of economic and manufacturing facilities a replacement of about 25,000 TSC per year of organic fuel with solar energy can be expected by 2020.

In the ISEU the solar water heating station («Doma», Austria) with a capacity of 1.0 kW and the photoelectric station («Fotovoltaik», Austria) have been used successfully for more than 5 years. They arc used for emergent lighting of the ground floor and as a training and visual appliance in the educational process (Fig. 4). In the near future it is planned to install also a photoelectric station with a capacity of 1.5 kW («Stromaufwaerts» Austrian firm) in the educational-hotel building of the University in Volma.

DOMESTIC WASTE

The percentage of organic substances in domestic waste is about 40-75. Domestic waste consists of (35-40)% carbon, (50-88)% combustible components, and

(40-70)% ash. The caloric value of domestic waste is (800-2000) kcal/g [8, 19].

In world practice, power production from domestic waste can be realized by several ways such as burning, active and passive gasification. Gasification has the greatest potential in contrast to direct burning as the latter causes environmental problems. To solve these problems, an investment twice exceeding the cost of the burning stations would be needed.

In Belarus about 2.4 million tons of solid domestic waste is collected annually. They are dumped or directed to two waste reprocessing plants (in Minsk and Mogilev). Annually, the following amount of solid domestic waste is collected there (in thousand tons):

- Paper - 648.6.
- Food wastes-548.6.
- Glass-117.9.
- Metals - 82.5.
- Textile-70.8.
- Wood-54.2.
- Leather and rubber - 47.2.
- Plastic - 70.8 [19].

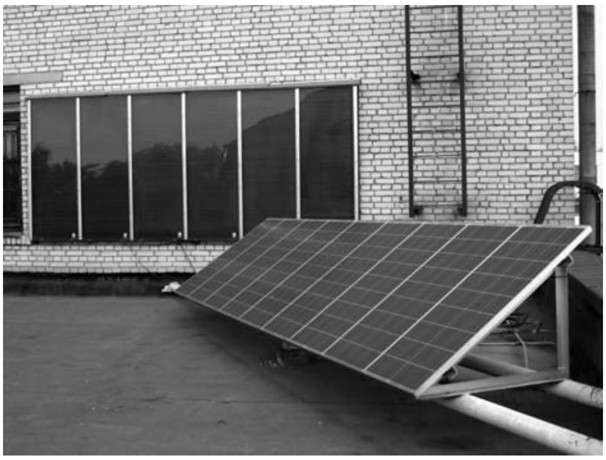

Fig. 4. Overview of solar water heating and photoelectric stations, ISEU

Potential energy of solid domestic waste collected in Belarus equals 470,000 TSC. In the case of biotreatment of these wastes with the purpose of gas production, the efficiency will not exceed (20-25)% which is equal to (100,000-120,000) TSC. Long-term stocks of solid domestic waste from all large cities should be taken into consideration due to the problems of its storage. It could be possible to get about 50,000 TSC from the processing of solid domestic waste into gas in the regional cities of Belarus, while in Minsk this number could be equal to 30,000 TSC. The efficiency of that direction should be estimated not only from the direct output of biogas, but also from the ecological component which is the basis in this problem. Certain characteristics of the effectiveness can be received on the basis of detailed design studies, creation, and operation of experimental-industrial area. By 2005, it can be possible to get up to 10,000 TSC.

PHYTOMASS

As a raw material for liquid and gas fuel production, a periodically RES -phytomass of fast-growing plants and trees - can be used. In the climatic conditions of the Republic a great number of plants in the amount of 10 t of dry substance which is equal to 5000 TSC are collected from 1 ha of power plantations. Using some additional agricultural methods the productivity of a hectare can be doubled. From this quality of phytomass it could be possible to get (5-7) t of liquid products equivalent to mineral oil. For raw material production the most appropriate would be the use of work-out peat deposits where no conditions for agricultural crops can be found. The area of such deposits in the Republic is about 180,000 ha which can become a stable, pollution-free source of energy raw material in a volume up to 1.3 million TSC per year [4, 16, 11].

The use of rapeseed oil as an energy resource has great potential for the Republic of Belarus. The Republic has experience in rape cultivation; there in also some rapeseed-processing plants there. Taking into account the fact that rape does not accumulate radionuclides, its cultivation on the areas contaminated after the Chernobyl accident becomes particularly important. There is some experience gained in that direction. Thus, for example, in 2005 a diesel power station with a capacity of 300 kW (electric energy) and 400 kW (thermal energy) running on rapeseed oil was installed and put into operation by the Institute of Radiology, Otto Hugo Munich University together with ISEU. This station was put into operation in the milk-processing plant in Khoiniki within the framework of a humanitarian project – Fig. 5.

Fig. 5. Overview of diesel power station, working on rapeseed oil in Khoiniki.

The lack of experience in the wide use of phytomass for energy production does not allow the estimation of the expenses and future prices of the fuel. Special techniques, road infrastructure, reprocessing enterprises, etc, should be developed for this purpose. However, according to the integrated calculation, the price adds up to $35 per TSC. According to the expert estimations by the year 2012, about (70,000-80,000) TSC can be received due to the use of phytomass for energy production [3].

PLANT GROWING WASTE

The use of plant growing waste for energy production is considered to be a fundamentally new direction in energy savings. Practical experience of plant growing waste application as the energy earner has been acquired in Belgium andl the Scandinavian countries, but not yet in Belarus. The total potential of plant growing waste is estimated to be about 1.46 million TSC per year (Table 4) [19]. The decisions on expedient volumes of birning plant growing waste for fuel production should be made comparing certain economic needs. By the end of the predicted period this value is estimated at a level of (40,000-50,000) TSC.

Table 4. Real and predicted volumes of the biogas production, domestic waste, phytomass for electric and thermal energy production

Energy resource (,000 TSC)	2007	2008	2009	2010	2011	2012
Biogas	6.6	13.2	19.8	26.4	32.9	39.5
Domestic wastes	4.9	9.9	14.8	19.8	24.7	29.6
Phytomass	12.4	24.7	37.1	49.4	61.8	74.1
Total	23.9	47.8	70.7	95.6	119.4	143.2

From Table 4 it can be seen that due to all renewable and alternative energy sources, as well as thermal secondary power resources, mineral oil, oil gas and peat, the volume of local energy carriers is estimated as 6.75 million TSC per year.

CONCLUSIONS

A work system on the development of the potential including educational programs for decision-making people and users of technologies should be carried out for the further development and application of alternative energy sources in Belarus. In spite of great efforts undertaken by the State Committee of Energy Efficiency and other authorities, alternative power is introduced in Belarus by a small number of pilot projects and technologies. The most successful projects are those using wood waste products for gasification with the subsequent burning and generating of thermal energy; also some small HPSs, four powerful industrial wind energy stations belonging to «Ecodom», «Areola», and ISEU; and one biogas station. Still, that is not enough. One of the low-cost ways to improve the present situation in wind-power engineering in modern econonomic conditions is to import already used wind energy stations with a capacity exceeding 100 kW. It is connected with the fact that in Europe wind energy stations with a capacity of (100-200) kW in the near future will be replaced by more powerful stations with a capacity from 600 kW up to 2.5 MW. The diagram given in Figure 6 describes the prospects of RESs and local fuel type development. A percentage of total consumption of FERs is given by nongovernmental organizations and State Committee of Energy Efficiency.

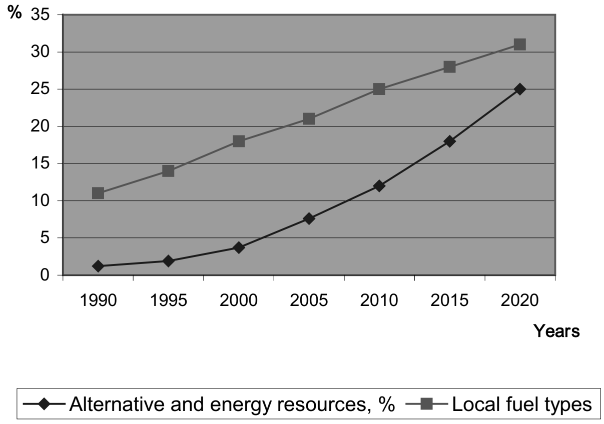

Fig. 6. Prospects of the development of alternative energy sources and local fuel types up to 2020 (ratio of total consumption FER, %)

On the whole, the described tendencies of the alternative and RESs development in the Republic of Belarus meet the same tendencies in Europe. The application of new technologies of biogas production from a renewable biomass - rapeseed oil for diesel engines and ethanol for carburetor engines - shows considerable promise for Belarus. Experience of some agricultural productions in the Grodno and Gomel regions has shown ecological expediency of the application of these technologies. It is very important to complete and update these technologies to the industrial level for local conditions and to introduce them into production by 2020. During this period the drastic cost increase for liquid mineral fuel is predicted with significant reduction of its natural resources.

The application of new technologies of biomass utilization (fast-growing wood, wood waste products) as boiler-stove fuel is also a very important question during the mentioned period. In Belarus production facilities for wide introduction of biomass gasification technologies already exist; also pilot projects on development of these technologies have been carried out there with the support of UNDP and other international organizations. The development of these technologies will be especially important for cities and towns with wood-processing power and an advanced agrarian sector.

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Spatial analysis of ghg emissions in eastern polish regions: energy production and residential sector

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Abstract. The characteristics of territorial distribution of greenhouse gas emission sources have been analyzed for eastern Polish regions. Mathematical models and information technology for spatial analysis of greenhouse gas emissions from fossil fuel consumption of heat/power plants and households have been developed in consideration of the territorial distribution of greenhouse gas emission sources and structure of statistical data for the Polish voivodships: lubelskie, podkarpackie, podlaskie, and świętokrzyskie. The results of spatial analysis for these eastern voivodeships are presented in the form of thematic maps.

Key words: information technology, spatial analysis, greenhouse gas emissions, heat/power plant, residential sector, fossil fuel.

INTRODUCTION

Global warming is a widely discussed problem in the societies and scientific communities all over the world. Most of scientists assert that the increase in concentration of anthropogenic greenhouse gases (GHGs) in the atmosphere is the main reason of global warming. That is why an agreement in the reduction of GHG emissions is a primary issue of international negotiations. Assessing GHG emissions accurately is of high importance to verify fulfilment of international obligations.

To estimate the effectiveness of GHG emission reduction measures one must have information on GHG sources and sinks at the level of individual regions, not only at the national (country) level. Therefore, countries are encouraged to develop their own mathematical models to assess the emission/absorption processes of GHGs. The results of GHG spatial inventory could be used to support decision and policy-making. They allow identifying, under competitive financial conditions, those economic activities which perform the best area-thematic scales from an emission trading point of view. The Ukrainian scientists as well as those from other countries [3, 4, 8, 6, 12, 10, 2, 5, 9] have made a large contribution to the creation of mathematical models for spatial analysis of GHG emissions in different sectors of human activity. These mathematical models were developed for a certain regions and consider the specifics of emission sources regionally. The development of mathematical models for spatial analysis of GHG emissions for other countries/regions is a relevant task.

In Polish regions the spatial GHG inventory has not been conducted that would fully encompass a certain sector of human activity. For example, in the lubelskie and podkarpackie voivodeships spatial GHG inventory has been done only in "residential sector", which is a source category in the Energy sector [20, 16]. So, there is a need to modify the mathematical models for GHG spatial inventory taking into account regional characteristics and structure of statistical data on the economic activity of other regions.

This paper focuses on the spatial analysis of GHG emissions in eastern Polish regions from two types of sources: heat/power plants as huge point sources and residential sector as area sources.

GHG INVENTORY IN POLAND

Annually Poland produces GHG inventory reports as a part of its international obligations (the Kyoto Protocol to the United Nations Framework Convention on Climate Change – UNFCCC). According to the latest national inventory report 2011 [13, 18, 19] the subsector "1.A.1.a Public Electricity and Heat Production" is the largest contributor to emissions. It covers over 95% of total GHG emissions in the Energy sector. The use of solid fuels is dominant (mainly hard coal and lignite). In 2009, the use of hard coal was almost 62% of the entire energy of all fuels used in this subsector (1.A.1.a).

Lignite made approximately 30% of the energy, accordingly. Despite the significant share of solid fuels (approximately 93%) in the total energy related fuel use, a slow decreasing trend can be noticed since the late 1990s (from about 98% in 1998 till 93% in 2009). At the same time, the share of gas as well as the share of biomass has increased in the last decade. The internal load production of heat and power plants, according to the source classification by IPCC (the Intergovernmental Panel on Climate Change) are included in another category of the Energy sector: "1.A.2. Manufacturing Industries and Construction". However, most of these plants generate energy/heat not only for their own use but for residential consumers as well. So, sometimes it is difficult to identify to which category this plant should be included. That is why this article focuses not only on public heat/power plants but also on entities producing for internal needs. The study covers the following greenhouse gases: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

GHG emissions from fossil fuel burned by households (residential sector) are around 10 % of national totals. During the last 2 decades GHG emissions in this category are reported to be decreasing due to the increasing use of gaseous fuels.

CHARACTERISTICS OF ADMINISTRATIVE DIVISION

The territory of Poland is divided into the following administrative units: voivodeships (in Polish – województwo), provinces (in Polish – powiat) and communes (in Polish – gmina). Voivodeship is the largest territorial and administrative unit in Poland. Province is a unit with local government. Commune is the smallest administrative unit in Poland, for example a city, a village or a group of villages and towns. In total, Poland has 16 voivodeships, which are divided into 308 provinces, and the last one into 2469 gminas.

The Polish voivodeships: lubelskie, podkarpackie, podlaskie and świętokrzyskie are located in the eastern part of Poland. A partial spatial inventory of GHGs, namely only in the category of households has already been made for the lubelskie and podkarpackie voivodeships [20, 16]. For the two other voivodeships (podlaskie and świętokrzyskie) that are also located in the eastern Polish region the spatial inventory of GHGs has not been done before.

GHG INVENTORY IN THE ENERGY SECTOR

Most of the estimates of carbon dioxide emissions in the Energy sector are based on data concerning fossil fuel consumption. Emissions are calculated as the product of amount of fuel burned and emission factors, that take into account the carbon content and fuel consumption efficiency (for example, the proportion of fuel that is not oxidized). Fuel fraction which is not oxidized is quite small in modern systems of fuel consumption. The IPCC recommends the assumption that 100% of carbon in fuel is oxidized. The amount of consumed fuel could be measured but it is really difficult to measure carbon content. There is a good correlation between the share of carbon in the fuel and amount of energy released from burning, so the transfer of consumed fuel per unit of mass or volume to energy units enables to take into account its carbon content [1].

Quantity of consumed biomass (biofuels) is reported according to the UNFCCC, but the corresponding emission of carbon dioxide – is not. In the process of growing, biomass absorbs CO_2 from the atmosphere, but when it is burned the gas is emitted again to the atmosphere. Therefore, the resulting emissions are considered to be "zero". However, emissions from consumed fossil fuel during processes of production, harvesting and transporting biomass are reported in the appropriate categories. When biomass is combined with another type of fuel or waste, emissions caused by the burning part of the other fuels are only reported. When, for example, pure ethanol is combined with gasoline as fuel, only the emissions caused by gasoline consumption are reported.

Carbon dioxide emissions are estimated using the next steps [1, 22, 23]:

- analysis of the energy sources in the region,
- calculation of carbon in conventional units,
- assessment of contained carbon in products that are made from fossil fuels,
- calculation of the share of burning carbon,
- calculation of CO_2 emissions for all fuels.

Carbon dioxide emissions are calculated as the product of quantity of consumed fuel, the calorific value, and the rate of oxidation. The general formula for calculating CO_2 emissions (IPCC, 2006):

$$E = D_{stat} \cdot K_{en} \cdot K_C \cdot F_C, \tag{1}$$

where: E is the amount of emission, Gg; D_{stat} are the activity data in physical units, t; K_{en} is the amount of energy released during combustion of 1 ton of material, J/t; K_C are the emissions of carbon dioxide per unit of obtained energy, Gg/J; F_C is the carbon oxidation factor (in numerical experiments realized it was assumed that $F_C = 1$).

For different categories of human activities and properties of different fuel types these parameters have different values. For better estimation of GHG emissions it is recommended to use emissions factors that were estimated for a certain region and category.

For other greenhouse gases (CH_4, N_2O) emission estimates are based on statistical data for various sectors of human activity. The amount of emissions depends on fuel type, processes, and conditions of production, type of equipment, and methods of monitoring.

Emissions of N_2O, CH_4 and other gases are estimated by the next steps:

- estimating an amount of consumed fuel per year for the certain human activity;
- estimating the basic factors for each type of activity;
- calculating emissions.

The structure of statistical information on consumption of fossil fuels by category in the Polish regions is [21]:

- heat/power plants (according to the IPCC sector classification - 1.A.1),
- industrial boilers and other heating units (1.A.1),
- non-industrial boiler-houses (1.A.1),
- industry and manufacturing (1.A.2),
- transport (road, rail, etc.) (1.A.3),
- other sectors including: agriculture and forestry, households, and other (1.A.5).

To carry out spatial analysis of GHG emissions the geographic information system (GIS) was used. GIS allows forming a database on GHG emission sources as geographic features that are characterized with spatial coordinates and results of simulation on digital maps.

As input data for spatial inventory the digital maps were used with information on administrative division and population, and statistical data on the consumption of fossil fuels obtained from special yearbooks prepared by State Departments of Statistics in each Polish region. Based on these data, the spatial (georeferenced) database was created. The process of spatial analysis of emission is divided into the following steps:

1) collecting statistical data and forming input databases (for example, Excel, Oracle or Access),

2) splitting the digital maps of investigated areas into elementary objects using grids (for example, grid with the resolution of 2 km x 2 km) and disaggregating data on population proportionally to the area of newly created objects,

3) running modules that simulate the processes of greenhouse gas emissions in different sectors of human activity for each elementary object,

4) forming thematic maps that illustrate the spatial distribution of greenhouse gas emissions.

After splitting regional maps into elementary objects the programmed modules that are based on the developed mathematical models calculate emissions from stationary and mobile sources. The final step is the spatial analysis of the achieved thematic maps with information on GHG emissions at the level of elementary objects.

MODELLING OF GREENHOUSE GAS EMISSIONS: HEAT/POWER OR COMBINED HEAT AND POWER PLANTS

In accordance with the structure of national Polish statistics on fossil fuel consumption the stationary emission sources include: heat and power plants, combined heat and power plants; boiler and heating installation of industrial facilities; non-industrial boilers; fuel combustion in industry and construction; fuel combustion in agriculture, forestry and fisheries; households.

Heat and power plants are the largest emission point-type sources. The heat and power supply involves power plants, public and internal load combined heat and power plants, public and municipal heat plants. Public heat and power plants or combined heat and power plants generate energy and heat for residential consumers. Internal load entities generate electricity and heat wholly or partially for their own use.

As statistical data are available only concerning total amounts of consumed fuels by category in each voivodeship, this amount should be disaggregated by a certain parameter. Analysis of statistical publications concerning data on fuel consumption shows that Polish Energy Agency published only amount of coal used by plants (public or internal load) only till 2007, all later publications include only total sum of coal used in all heat/power or combined heat/power plants. So, it was assumed that the proportion between coal used in public and internal load plants in 2007 remained the same for the later years (for example, 2009).

The emissions of an elementary object (point) for a particular voivodeship w_i could be calculated by the following formula:

$$E_{EN,g}(\xi_l) = \sum_{f \in F} \frac{D_{EN,f} \cdot K_{EN,f,en} \cdot K_{EN,f,g,em} \cdot q(\xi_l)}{\sum_{\xi_j \in (\xi_j \cap w_i)} q(\xi_j)}, \qquad (2)$$

$$\xi_l \in \Xi, l = 1,..,L,$$

where: $E_{EN,g}(\xi_l)$ is the emission of gas g from burning fossil fuels by heat and power plants for the elementary object ξ_l that is located in voivodeship w_i; $D_{EN,f}$ is the amount of fuel f burned by heat and power plants; $K_{EN,f,en}, K_{EN,f,g,em}$ are calorification and emission factor of gas g for fuel f burned by heat and power plants; $q(\xi_l)$ is a disaggregation parameter for the point source ξ_l; Ξ is a set of point sources ξ_l, L is a number of elements in the set Ξ.

The choice of disaggregation parameter $q(\xi_l)$ depends on available data on fuel used by plants. For example, for public power plants and heat plants or combined heat and power plants it was assumed that amount of fuels used is proportional to energy or heat production for the year of investigation. If there is no data available on energy and heat production for every plant for a certain voivodeship, the power of a plant was taken as a disaggregation parameter.

In case of autoproducing plants there is a huge lack of information. So, for every voivodeship the approach was different. The first step was figuring out the main emission sources in this region upon analysis the environmental reports. The second step was checking whether this list contains internal load plants: if not – the emissions from internal load plants are negligible, and the fuels used could be disaggregated equally; if yes – the corresponded coefficient should be chosen to this main emitters, and the rest of fuels used should be disaggregated equally by other small sources.

MODELLING OF GREENHOUSE GAS EMISSIONS: RESIDENTIAL SECTOR

In contrast to heat/power plants, the residential sector covers areas of settlement as area type sources. The general approach for GHG spatial inventorying in residential sector involves allocating amount of fuel burned by residents and spatial localization of the corresponding emissions. Specific emission factors for GHGs that take into account fossil fuels characteristics and technology of combustion should be considered. While estimating emissions in the living areas (for a particular city or region as a whole) it is difficult to calculate emissions from fossil fuel burning at a particular house or apartment due to the lack of statistical information. In addition, such detailed information is not necessary because our research is conducted at the level of elementary objects that are created by splitting grid with a specified resolution. Therefore, the sources of GHG emissions in residential sector are considered to be some residential areas (settlements). At the level of an elementary object, emissions are calculated as the sum of emissions from all sources that are partially or fully located in its territory (for example, one elementary object could contain two or more villages and a part of a city).

The following formulas estimate emissions for a certain gas g in households for elementary object δ_n that is located in voivodeship w_i:

$$E_{RES,g}\left(\delta_n\right) = \sum_{f \in F} D_{RES,g,f}\left(\delta_n\right) \cdot K_{RES,f,en} \cdot K_{RES,g,f,em}, \delta_n \in \Delta, n = \overline{1,N}, \quad (3)$$

$$D_{RES,g,f}\left(\delta_n\right) = \sum_{s \in \tilde{S}^{Rur}} \left(D_{RES,g,f}\left(w_i\right) \cdot I_{RUR,f,g}\left(w_i\right) \times \frac{p(s) \cdot area(s \cap \delta_n)}{area(s)} \right) + \sum_{s \in \tilde{S}^{Urb}} \left(D_{RES,g,f}\left(w_i\right) \cdot I_{URB,f,g}\left(w_i\right) \times \frac{p(s) \cdot area(s \cap \delta_n)}{area(s)} \right), \quad (4)$$

where: $D_{RES,g,f}(w_i)$ is an amount of fuel f burned in voivodeship w_i; $D_{RES,g,f}(\delta_n)$ is an amount of fuel f burned in elementary object δ_n; $K_{RES,f,en}, K_{RES,f,g,em}$ are calorification and emission factor of gas g for fuel f burned in residential sector; Δ is a set of elementary objects δ_n; N is a cardinality of Δ; $p(s)$ is a population of settlement s; $I_{URB,f,g}\left(w_i\right)$, $I_{RUR,f,g}\left(w_i\right)$ are the coefficients that show the fraction of fossil fuel for urban and rural areas, respectively (per resident) of total fuel used in voivodeship; $\tilde{S}^{Urb} = \left\{S_1^{Urb},...\right\}$, $\tilde{S}^{Rur} = \left\{S_1^{Rur},...\right\}$ are the sets of urban and rural settlements respectively; $area(s)$ is an area of settlement s.

The described model requires the following data:

– national energy statistics data:
  - country-specific emission factors for the residential sector and fuel for each gas [17],
  - data on the amount of fuel combusted in the residential sector [21],
  - data on the population for settlements [14, 15],
– GIS-based data:
  - digital map of administrative division in Poland (voivodeships, provinces and communes).

COMPUTER REALIZATIONS

Geoinformation technology based on the developed mathematical models was created using GIS tools. With its help the spatial analysis of CO_2, N_2O, and CH_4 emissions in the categories of energy production and residential sector for eastern Polish region (lubelskie, podkarpackie, podlaskie and świętokrzyskie voivodeships) was performed. The results were presented in the form of thematic maps.

As input data a specialized file (in Excel format) was created. It consists of several sheets: sheet 1 contains data on the fossil fuels consumption for the voivodeships and for all types of power plans; sheet 2 contains information on public plants; sheet 3 contains information on internal load plants; sheet 4 contains information on fuel combusted by regions for each fuel; sheet 5 contains emission factors by source category and fuel used; sheet 6 – remarks and references.

Also, the digital maps with information on geographical borders of Polish voivodships, provinces, and communes (area objects), as well as settlements (point objects), were used as input data. Based on methodology described in the previous section four program modules were created: 1) disaggregation of fuel used in public heat, power, and combined heat and power plants; 2) disaggregation of fuel used in internal load heat/power, and combined heat and power plants; 4) disaggregation of fossil fuel used in residential sector; 5) calculation of emissions.

Figure 1 presents the geographical distribution of main power/heat plants and combined power and heat plants that use coal or natural gas for electricity generation in eastern Polish region. One of the main features of energy/heat production in Poland is high dependence on coal that characterizes the large GHG emission factors.

Figure 2 lists the Polish provinces of eastern regions with the largest GHG emissions that emitted more than 100 000 tones in CO_2 – eqv. The largest emissions were observed in Polaniec, Świętokrzyskie Voivodeship. According to the statistics, in this voivodeship public plants used a lot of coal for energy and heat generation. The combined heat and energy plant in Polaniec consumed most of this amount of coal as it is the fifth largest plant in whole Poland [11].

Other large emission sources in eastern Polish are very powerful combined and heat power plants in the

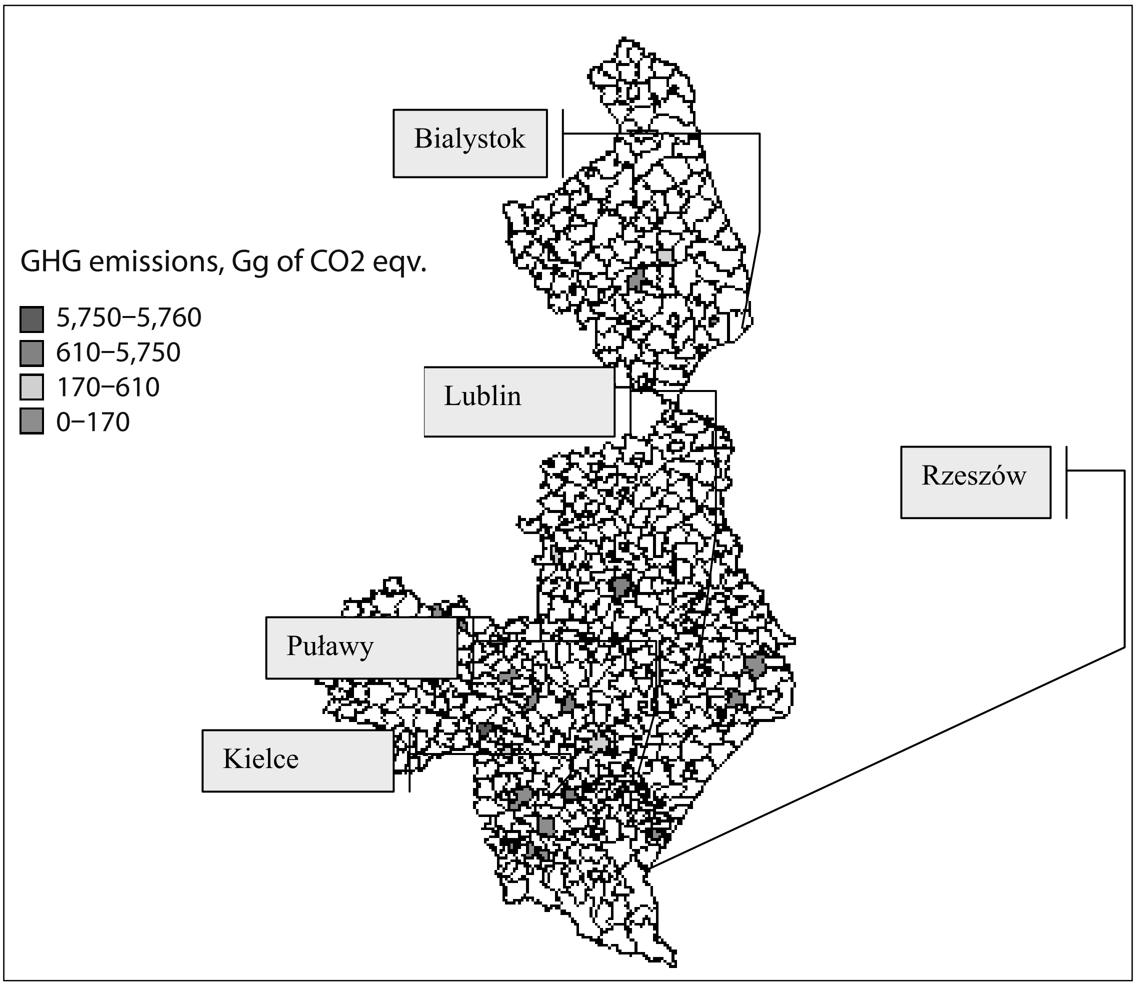

Fig. 1. Main sources of greenhouse gas emissions in eastern Polish region: Electricity production

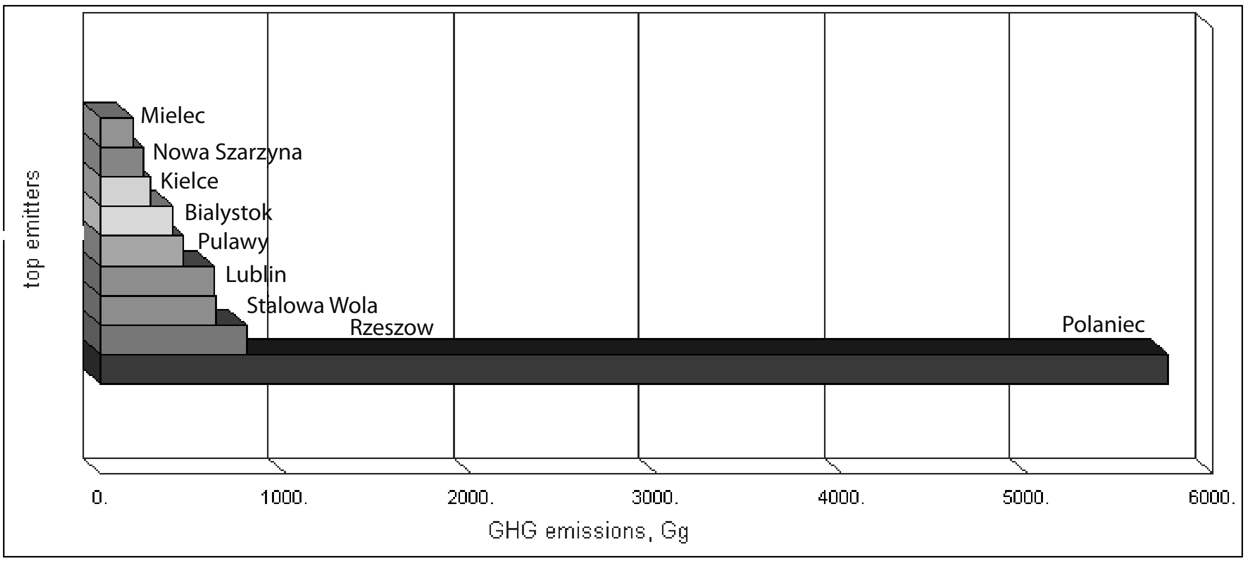

Fig. 2. Top-largest sources of greenhouse gas emissions (>100 Mg of CO_2eqv.)

lubelskie voivodeship, such as Lublin-Wrotków Sp. Z; internal load combined heat /power plant Zaklady Azotowe PUŁAWY S.A. (only coal); and MEGATEM - EC Lublin Sp. z o.o. (mainly natural gas); etc. In total, the greatest greenhouse gas emissions were observed in the świętokrzyskie voivodeship (Polaniec) due to the high coal consumption.

The results of GHG spatial inventory in the residential sector are presented in *Figure 3*. The largest GHG emissions were observed in Lublin, the capital of the lubelskie voivodeship. The largest specific emissions (per square km) were also observed in the lubelskie voivodeship. The shares of particular voivodeships' GHG emissions in total emissions of the eastern Polish regions are: 34,57% for the lubelskie voivodeship, 32,78% for the podkarpackie voivodeship and 19,36% for the świętokrzyskie voivodeship. The lowest emissions are in the podlaskie voivodeship – 13,29%. The results in *figure 3* were obtained at the level of elementary objects created by the grid with resolution 10km.

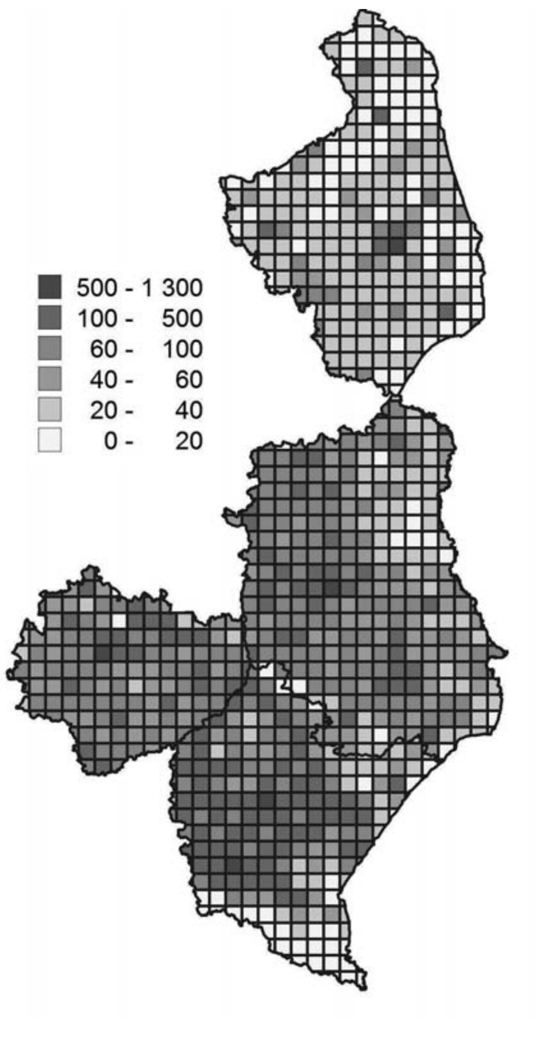

Fig. 3. Total GHG emissions in CO_2-equivalent (t/sq.km) in residential sector

CONCLUSIONS

The mathematical models for greenhouse gas spatial inventory and corresponding geoinformational technology were developed concerning the structure of statistical information and specificity of emission sources of area and point types. The developed models reflect processes of GHG emissions from stationary sources: power/heat plants, and combined heat and power plants, fossil fuel consumption in households. Based on the presented mathematical models of emission processes, the corresponding software modules were programmed using GIS tools. The spatial analysis of CO_2, N_2O, CH_4 emissions of point-type and area-type sources were carried out for the voivodeships: lubelskie, podkarpackie, podlaskie and świętokrzyskie. The results are presented in the form of digital maps.

The distribution of GHG emission sources in eastern Polish voivodeships is very uneven. The largest point-type emission sources are located in świętokrzyskie, podkarpackie and lubelskie voivodeships. For example, the power station in Polaniec, two powerful heat/power plants in Lublin, the similar plants in Rzeszów and Stalowa Wola, Puławy and Białystok, Nowa Sarzyna, Mielec and Kielce. The largest area-type source in residential sector is Lublin, the capital of Lublin vovivodeship. The achieved results are useful for economical and ecological decision-making for effective ways of low carbon development.

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Influence of technical infrastructure on economic efficiency of farms with various production trends

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Abstract. The study presents how farms are equipped with technical means of production. Moreover, it gives the number of equipment per one farm and the reproductive value. The technical infrastructure index of farms as well as the standard gross margin value per a field area unit was also determined.

The researched facilities were divided into three groups, which differed with a trend of performed activities, for the purpose of comparative analysis. Therefore, farms, which carried out plant, animal and mixed production, were compared.

The statistical analysis was carried out and on its basis, differences in the value of the above mentioned indexes were determined between the production trends as well as the influence of the technical infrastructure on the standard gross margin.

Key words: reproductive value of a machinery park, technical infrastructure index, standard gross margin, production trend

INTRODUCTION

As a part of Common Agricultural Politics (Polish: WPR) most of our commodity family farms are subject to technological and ecological modernisation based on the change of farm infrastructure into fixed assets, since it is difficult to increase plant crops and animal productivity with decreasing production costs at the same time, without modern technical equipment [7, 21, 11]. Only modern technical means, which are selected adequately to the production trend and which are necessary for implementation of new highly productive and energy saving technologies, will provide for products of better quality [18, 3, 22, 10]. Therefore, capital-intensive modernisation, from which high economic effectiveness is required, guarantees both high quality and high cost of commodity production [8]. Substitution of man labour with machine work and increase of work efficiency should constitute notable effects of modernisation. However, as [17] emphasises, increase of the substitution index and increase of work productivity at the same time is possible only if the technical means of production are rationally used. Increased need for machinery and devices which increase productivity and facilitate physical work on a farm results from the growth of production intensity. According to [14] and [20], such farms must be adjusted to the new technologies, which result from the requirements of the sustainable agriculture and from a multifunctional model of a Polish country. The agricultural requirements for machinery and devices are very diverse. This situation results from both the structure of existing agricultural farms as well as from the production trends, which are carried out, since rational machinery selection and operation is closely related to the trend of production activity. Except high quality commodity production, a rational selection must include economic aspects of the machinery park operation.

PURPOSE, SCOPE AND METHODOLOGY OF RESEARCH

The purpose of the study was to determine interdependence of the reproductive value of a machinery park, the technical infrastructure index of farms and the standard gross margin obtained on farms.

The research covered 116 developing agricultural farms located on the territory of Małopolskie province. Data for calculation was collected from applications for investment, which farmers submitted to The Agency for Restructuring and Modernisation of Agriculture – the Cracow Branch, as a part of UE aid programmes. Collected information concerned managing conditions of, among others, land utilization, a machinery park, material inputs, production size, and the trend of the production processes performed on farms.

Calculation of the standard gross margin (SGM) was applied with the method of its calculation in order to determine economic efficiency of farms:

$$SGM = FPgross - DC,$$

where:
FPgross –gross value of final production
DC – direct costs incurred on production [1].

Whereas, the technical equipment index *(WT)* expressed in [PLN /man-hour^{1}] was described as a ratio of the reproductive value of a machinery park *(WO)* and the input of labour *(SR)* [6]:

$$WT = \frac{WO}{SR} [zł \cdot rbh^{-1}].$$

The reproductive value of a machinery park was estimated as the value of new, fully efficient machines, without considering the degree of their physical and economic wear.

For the purpose of the comparative analysis, the researched facilities were divided into three groups, which differ with a production trend. The farms, where contribution of the particular activity was above 2/3 of the total value, were qualified as single-trend farms, specialist farms (plant and animal farms) while the rest were qualified as mixed farms.

DESCRIPTION OF THE RESEARCHED FARMS

116 farms located in few Małopolska communes were accepted for the research. Straight majority, that is 90 farms (78%) were qualified as the plant production oriented. 35 facilities in this group performed the plant cultivation activity and did not possess any animals. While the vegetable cultivation activity was the main branch, on 66 farms, the orchards cultivation activity - on 7 farms and the general plant activity - on 17 farms. Such intensification of the vegetable production is the only source of income for the fragmented Małopolska agriculture.

The mixed type of production, that is, the plant and the animal production and in some cases the service production was carried out on 18 farms in total. While, 8 farms specialising in livestock husbandry constituted the least numerous group; 2 of them specialised in the milk production, 5 of them in pig fattening and 1 in sheep breeding.

Mean area of arable land was 13,71 ha, out of which 82% constituted cropland, 14% - grasslands, and 3% - orchards and perennial plantations (table 1). Similar situation was on the plant farms and the mixed production farms, while contribution of grasslands in the structure of land utilization on the animal farms increased and it was 43%. It shall be stressed, that almost 34 % of arable land was leased. Almost half of arable lands were intended for grain cultivation. This structure of sowing was diverse because of the production trend. On farms specialising in the animal and the mixed production, grain growing predominated and constituted adequately 69 and 65 % of arable land area, while vegetables predominated on the plant production farms (42% of cultivated area).

Mean livestock density per a field area unit was 0, 47 LSU. While, on the animal farms it was 1, 56 LSU·ha^{-1} and it was also comparatively high on the mixed production farms – 0, 92 LSU·ha^{-1} (table 2). Pigs constituted almost a half (56%) in one structure.

Table 1. Land utilization [ha]

Specification	Average	Production trend		
		Plant production	Animal production	Mixed production
Arable land [ha]	**13,71**	**10,62**	**24,26**	**24,44**
including: own	8,98	8,07	11,03	12,49
leased	4,73	2,53	13,23	11,95
Cropland [ha]	**11,29**	**9,54**	**13,57**	**19,04**
grain	5,55	3,85	9,40	12,39
root crops	1,45	1,33	0,75	2,33
industrial	0,28	0,17	1,00	0,52
fodder	0,49	0,14	1,86	1,63
vegetables	3,52	4,05	0,56	2,18
Grasslands	**1,97**	**0,55**	**10,34**	**5,27**
Orchards and perennial plantations	**0,45**	**0,53**	**0,36**	**0,13**

Source: own study

RESULTS OF THE RESEARCH

Organization of the work process must be adjusted to the conditions and the factors of production. However, first, it requires effective application of agricultural technique in the process of management [15].

The researched farms were quite well equipped in technical infrastructure. 126 farm tractors, 107 sidecars, 62 delivery trucks were recorded in the analysed objects but 410 machines and cultivation devices as well as 405 harvesting machines constituted the majority. There were not many machines and devices for animal production on the farms. There were only 46 units, including 22 machines for feed preparation such as feed mills, feed mixers, and shredders.

19 machines, tools, and technical devices averaged out per one farm, and 1, 37 per 1 ha of arable land. There were about 2 farm tractors, 1 sidecar, 4 cultivation machines and devices and 3 fertilization and plant protection machines on every farm, irrespective of the production trend (Fig.1). While the number of the remaining groups was diverse in relation to the type of the activity. Differences were also noticed in the number of machines per field area unit, which constituted 1,73, 0,78 and 0,82 unit/ha^{-1} of arable land respectively for farms specialising in the plant, the animal and the mixed production. Whereas, arable land per 1 farm tractor averaged out at 7, 23 ha, therefore it was considerably less than the mean of the country (10, 6 ha, according to PSR (*Polish Agricultural Census)* 2010). The index was very diverse in the analysed core groups, because it was only 5, 79 ha per a farm tractor^{-1} in the farms specialising in the plant production, however it was higher than the mean throughout Poland on the animal production farms and on the mixed farms and it was respectively 12, 94 i 11, 58-ha·farm tractor^{-1}.

Mean reproductive value of a machinery park was 44, 40 thousand PLN·ha^{-1} of arable area (Table 3). Farms, which owned a machinery park of the highest value of 48,43 thousand PLN·ha-1, were plant production oriented.

Table 2. Livestock density [LSU·ha^{-1} of arable area]

Specification	Average	Production trend		
		Plant production	Animal production	Mixed production
Dairy cattle	0,10	0,05	0,33	0,24
Beef cattle	0,10	0,07	0,01	0,30
Pigs	0,26	0,15	1,20	0,38
Horses	0,01	0,01	0,00	0,00
Sheep	0,00	0,00	0,02	0,00
Total	**0,47**	**0,28**	**1,56**	**0,92**

Source: own study

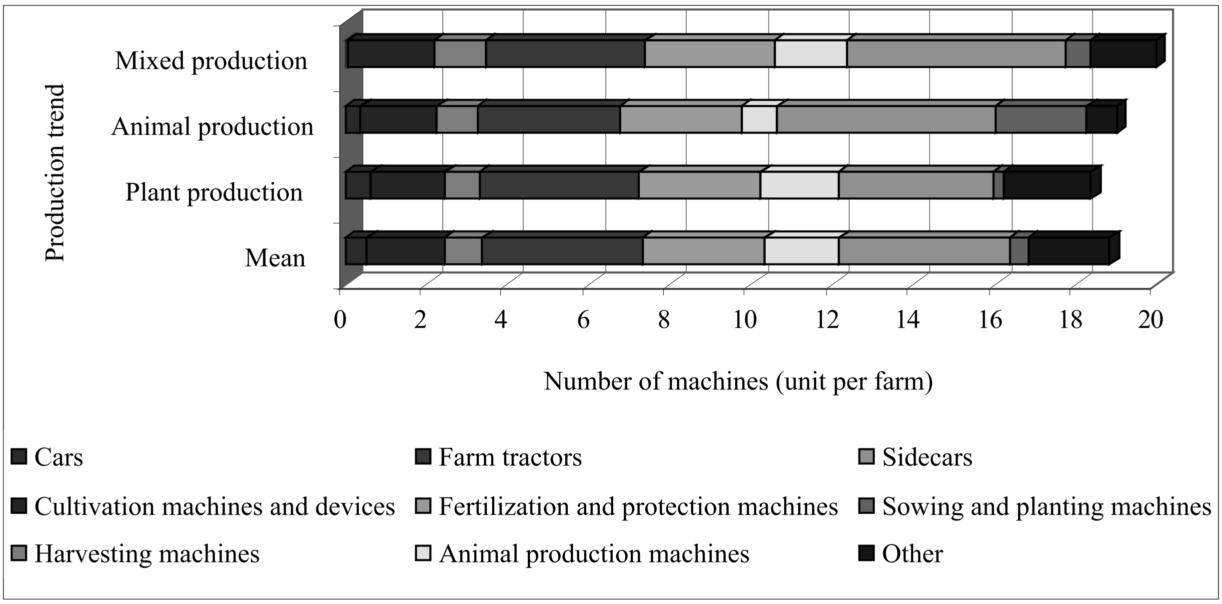

Fig. 1. Number of machines per one farm

Source: own study

In the remaining core groups, it was 33,23 thousand PLN·ha^{-1} and 29,23 thousand PLN·ha^{-1} respectively for the animal and the mixed production farms.

Harvesting machines and farm tractors had the biggest contribution in the core groups in the technical value structure of the production means. They averaged out at 34, 7% and 26, 8% respectively for harvesting machines and farm tractors. Reproductive value of the remaining groups of machines does not exceed 10% of the total technical values of the production means.

Mean value of the technical equipment index on the examined farms was 100,38 PLN·man-hour^{1} (Fig. 2). Both the lowest and the highest value was noticed on the plant production farms, while the smallest technical infrastructure was 3,81 PLN·man-hour^{1} and it concerned the farms specialising in the general plant production and the biggest of 348,93 PLN·man-hour^{1} – concerned the farms which specialised in vegetable growing. While, the differences of the mean values between the core groups were considerable. Basing on [5], it may be stated, that the most capital-intensive process of production was performed by the livestock farms since the technical equipment index was the highest there and the less capital- intesive process of production was performed by the mixed production farms.

Table 3. Reproductive value of machinery park [thousand. PLN·ha^{-1} of arable area]

Specification	Average	Production trend		
		Plant production	Animal production	Mixed production
Cars	6,88	8,41	4,64	0,25
Farm tractors	11,89	12,97	8,25	8,11
Side cars	1,68	1,81	0,91	1,35
Cultivation machines and tools	1,49	1,68	0,78	0,81
Fertilization and protection machines	3,21	3,59	1,78	1,92
Sowing and planting machines	1,56	1,78	0,45	0,9
Harvesting machines	15,42	15,67	14,68	14,48
Animal production machines	0,22	0,16	0,95	0,19
Others	2,06	2,34	0,80	1,2
Total	**44,40**	**48,43**	**33,23**	**29,23**

Source: own study

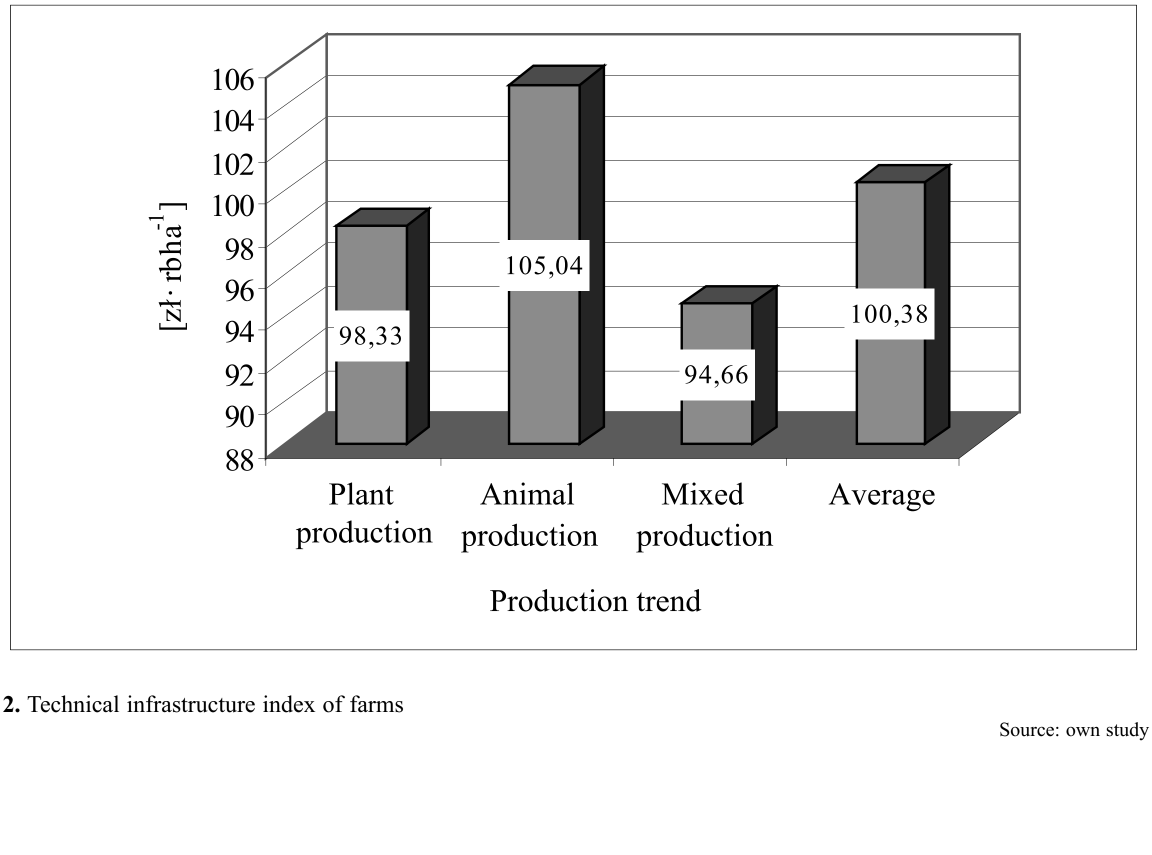

Fig. 2. Technical infrastructure index of farms

Source: own study

The technical infrastructure index is calculated as a quotient of the technical values of the production means and labour force. Then, the labour force resources, as one of the most active factors of production, essentially influence the production process on agricultural farms. Numerous publications which analyse the labour resources [3, 13, 23, 24, 19, 9] prove a significant role of this factor in the management process as well as in the farm organization. The plant production turned out to be decisively the most labour-intensive among the examined core groups, especially vegetable cultivation, which took 587 man-hour/ha^{-1} of arable land. Work input on these farms was almost two times higher than in the two remaining core groups.

The standard gross margin value is one of the measures, which allows for estimation of the production economic efficiency [16]. According to [4], it depends more on the human labour input than on the technical infrastructure of farms, what proves that a man performs a large amount of work.

The final production, which constituted the output value for calculation of this measure, average out at 14, 36 thousand zl·ha^{-1} of arable land. After reducing this production category of costs value incurred on the purchase of mineral fertilizers, plant protection products and sowable material, the standard gross margin value was obtained on the level of 11, 03 thousand PLN/ha^{-1} of arable land Table 4). Meanwhile, its value on the plant production farms was 68%, and over 100% higher than on the animal and the mixed production farms. It is confirmed by the variable analysis carried out in a single classification, which presented how essential were the differences between the standard gross margin value in the core groups. Based on the variable analysis we may reject a zero hypothesis that the standard gross margin average value is equal to 0,000319 (table 5). Considerable deviation of the standard gross margin value on the plant production farms was noticed in the list of the mean values in comparison to the animal and the mixed production farms. Therefore, Duncan test was conducted and on its basis it may be stated, that the plant production farms obtained the highest standard gross margin mean value (12, 36 thousand PLN·ha^{-1} of arable land and it was statistically different from the mean value obtained in the remaining two core groups.

Duncan Test; variable: Standard gross margin (variable analysis). Marked differences are essential with p < ,05000

Standard Gross Margin	**{1} M=5,96**	**{2} M=12,36**	**{3} M=7,36**
Mixed production{1}		***0,009352***	0,547213
Plant production{2}	***0,009352***		***0,033492***
Animal production {3}	0,547213	***0,033492***	

Source: own study

The variable analysis was also carried out in order to compare mean reproductive values of a machinery park and the technical infrastructure index for the production trends, which were mentioned. However, it cannot be stated, based on the conducted research, that no essential differences in mean values of the examined features occurred.

Correlation and regression analysis was conducted in order to check if there was a relation between the reproductive value of a machinery park, the technical infrastructure index and the standard gross margin value. This analysis was conducted for all examined farms, as well as for the selected core groups. Statistically essential positive relation (r = 0, 75) between the reproductive value of a machinery park and the technical infrastructure index occurred only in the animal production farms. Other correlations were irrelevant from the statistical point of view.

CONCLUSIONS

19 machines, tools, and technical devices averaged out per one farm. No essential differences in quantitative equipment of farms with the technical means of the production were noticed in the core groups. Arable land per one farm tractor averaged out at 7, 23 ha. Essential

Table 4. Standard gross margin in selected production branches [thousand PLN/ ha^{-1} of arable land]

Specification	**Average**	**Production trend**		
		Plant production	**Animal production**	**Mixed production**
Gross final production	14,36	15,55	13,92	8,59
Direct costs	3,33	3,18	6,56	2,63
Standard gross margin	11,03	12,36	7,36	5,96

Source: own study

Table 5. Variable analysis and Duncan test in a single classification. Standard gross margin in relation to production trend.

Variable	**SS**	**df**	**MS**	**SS**	**df**	**MS**	**F**	**p**
SGM	729,49	2	364,74	4763,97	113	42,16	8,65	0,000319

differences were visible in the core groups since, on the animal and the mixed production farms the area was about two times bigger than on the plant production farms.

It may be stated, based on the technical infrastructure index that one man-hour was potentially balanced by 93, 33 PLN of the capital invested in a machinery park. The farms specialising in livestock husbandry were the most capital-intensive because the technical infrastructure index was the highest there and it amounted to 105, 04 PLN man-hour^{-1}. It is worth noticing that the lowest labour input was noticed on these farms.

The plant production farms carried out the most economically efficient activity, since the standard gross margin value, which is its measure, considerably exceeded the value obtained in the remaining core groups. Those differences turned out to be statistically essential.

However, the statistical analysis did not prove any essential relation with the technical equipment, which was determined with the reproductive value of machinery park, with the technical infrastructure index and the standard gross margin value.

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Production technology and management of energetic plants with lignified shoots

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Abstract. In the paper agricultural science solutions for small and middle-sized plantations of energetic plants as well as for diffusing management of biomass in low-power co-generation systems have been presented. Technical solutions have been worked out by authors and a part of them is still developing. The technology of technical features allowing for municipal sludge management in production of energetic plants has been proposed.

Key words: biomass production, biomass use, Stirling engine.

INTRODUCTION

Biomass demand assigned on energetic needs increases quickly. Enlarging cultivated areas of industrial and energetic plants endanger traditional cultivation destined for eatables production. Withdrawal of surcharge for production of energetic plants is the evidence of limit attainment of possibility of further enlargement of plantation area at the cost of eatables and feed production.

One of the methods to improve the situation is management of increasing amount of derelict and underdeveloped land. It is connected with the necessity of supplying specialized machines to the agricultural market with operating efficiency adjusted to cultivated land characteristic, which are cheaper and use a farm tractor as the primary energy source to machine drive in rural environment.

The characteristic feature of agriculture in South Poland is disintegration of cultivation area, diversified land hypsography and often the cultivation areas are difficult to access. The primary disadvantageous phenomenon for work organization and possibility of their mechanization is possession of several arable plots of land, often considerably distant and with different soil value. Generally, there are usually areas of several or more hectares that are not always suitable for production of preferred plants. Considerably varied political and economic situation of agriculture in the consequence of changes at the turn of the XX/XXI century has caused arising of new problems that generally worsen the conditions of production and economical effectiveness of small farms.

In that complex situation, after the analysis of purposefulness and profitability of energetic plant production at the Rzeszów University of Technology a decision was made to improve the situation by an introduction on the market of new constructional solutions. Their task is the facilitation of agrotechnical operations as regards: establishment of plantation, tilling the soil, protection, logging and processing of the crop for energetic purposes of the plants with lignified shoots. The typical representatives of perennial plants with lignified shoots are clones of *Salix viminalis* willow, colloquially named energetic plants. The climate of Poland is good for this willow because it is traditionally used for economic purposes as purple willow for basket fabrication, furniture, wattle fence and fuel. The cultivation of willow does not require particularly advantageous conditions as to soil valuation and fertilization. The long-term favourable politics of the European Union as regards biomass usage has created advantageous conditions for realizing the aims of seeking new constructional solutions and introducing them to agricultural practice according to current principles of balanced development and environmental protection. The current energetic policy of the European Union member states favours plant production destined to energetic aims by direct combustion of lignified parts of plants or by processing them into other energy carriers.

MATERIALS AND METHODS

The schedule of works includes long-term plans regarding the constructional development of machines and equipments whose productive and working parameters could be adapted to: terrain hypsography, cultivation area, environment protection requirements and purchase price by small farm owners. Furthermore a wide utilization of municipal sludge as fertilizer on the established plant plantation was assumed. The basket willow was the primary plant subject to the research. Its use for heat power engineering needs was planned. Application of the municipal sludge for fertilization is an essential step in the process of its economic utilization. Taking into consideration the danger for human and natural environment resulting from sludge utilization, a special lysimeter was designed. The lysimeter enables to continue the sampling of soil water on the established plantations in order to monitor the propagation in the underground water of harmful substances contained in municipal sludge.

The description of situation regarding the biomass utilization for energetic purposes in Podkarpackie Province may be found in the Data Base of Renewable Energy of Podkarpackie Province. In Podkarpackie Province there are approximately 200 000 hectares of waste lands. Moreover, an increase of amount of idle land has been noticed, which is difficult to estimate because of data deficiency in this scope and the fact that the situation is subjected to fluctuation. Furthermore, the scale of waste lands does not mean a full possibility of utilization of areas for energetic plant production. Limitations result from physiology of plants, land accessibility and costs of waste land restoring. The following obstacles have been indicated by potential small biomass producers: the lack of specialized means of production adapted to area of land and their high price [4, 6, 9].

The selection of optimal production conditions of energetic willow were made on the basis of literature information [1,2,3], the author's own non-published researches and experiences on the large-lot production of willow in the Co-operating Group of Producers of Energetic Plant "Agroenergia" in Boguchwała.

The specification of machines to be used for production of biomass with lignified shoots was carried out on the basis of the author's own observations, information obtained from small and middle-sized biomass producers in Podkarpackie Province. Primary criterions of selection constructional characteristics of machines and their work parameters have been technical considerations connected with he adaptation of their construction to existing stock of machines, agrotechnical conditions and standards as well as legal considerations in the laws [5, 6] and decrees [7, 8, 9].

The principal assumption of taking operations connected with the construction of new machines for planting, logging and processing of the biomass of plants with lignified shoots is high-productivity machines. The proposed solution is to fill a gap between efficient and expensive machines destined for work in large-lot farms and small and middle-sized plantations where mechanization degree of operations is quite small.

RESULTS AND DISCUSSION

The main results of the works realized up till now have been verified in the operating conditions of the technology of municipal sludge management (Fig. 1).

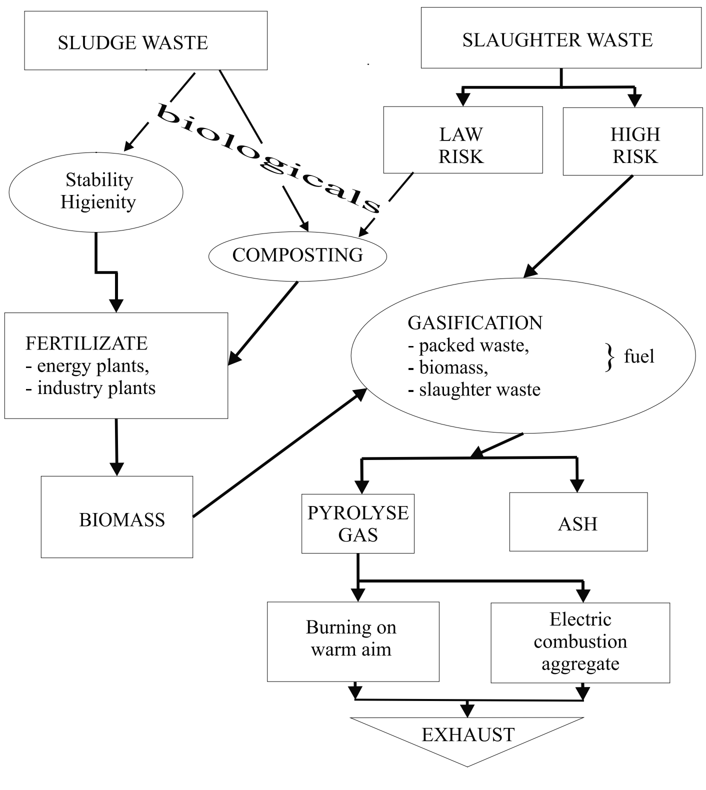

Fig. 1. The technology of organic waste processing.

Table 1 presents the main stages of sludge and other fertilizers management on energetic plant plantations and stages of their cultivation, protection and processing. Furthermore, suggestions of usage of new machines and equipments elaborated for small and medium-sized plantations have been presented.

An additional advantage of the proposed technology is the processing of wood biomass into final form having better store characteristics. While stored in flitches, chips are characterized by slow loss of moisture contained in biomass and fast deterioration of energetic characteristics resulting from decay processes. Instead of this, the biomass is processed into chaff of wood characterized by better properties in this regard.

Analysis of properties of different kinds of renewable energy sources (RES) [10] leads to the conclusion that in the Polish conditions biomass is a kind of RES characterized by the best technique-operating parameters. It is connected with general accessibility and simultaneously low costs per unit, high availability and egzergy comparable with mineral chemical fuels. This may allow for general usage of biomass as universal energy source for dissipated power engineering based on co-generation systems.

Energetic willow, with its different species according to the local climatic conditions, allows for obtaining high amounts of wood mass per hectare in a short time. Due to its high productivity, energetic willow can ensure the basic raw material for different applications in order to obtain compacted wooden products like solid bio-fuel or direct combustion products to produce energy. Production efficiency of energetic plants depends on the applied agronomy, workmanship and sequence of protective treatments during cultivation plants in order to get plentiful crop with high quality.

However, due to the biomass properties, high advantageous economic and ecological effect may be obtained

Table 1. List of machines and instruments applied in the production technology of energy plants.

Operation	Place and realization method	Law condition
Sludge processing: -stabilization, -thickening, -treatment.	Sewage-treatment plant	Technology of sewage treatment realized in sewage-treatment plant
Transport of sludge in arable land	Road: - highway, - private.	Highway code
Fertilizer dosage on established plantation	Preparation and fertilization of arable land: - superficial, - injectional W- 39050 (1985), **P-382062** (2007)	Acts, decrees and good agricultural practice
Investigation of interaction on human and environment	Ecosystem components studied in surround of established plantation: - soil - water W-116896 (2007)	Acts, decrees and decisions
Production and storage of cuttings	Farm area [11] - cuttings production **P -384427** (2008)	Industrial safety requirements and conditions of cutting storage
Planting, sowing	Area of land - planter **W-119940** (2011)	Good agricultural practice and nutritional plant requirements
Cultivation and protection of plantation	Area of land: - manual work - mechanical work	Program of protection and cultivation in agreement with good agricultural practice
Harvest produced biomass	On plantation: - manual, - mechanical **P -386842,** (2008), **W-119895** (2011)	According to processing aim
Initial processing of the biomass	On plantation or nearest of them: - manual, - mechanical **W-116926**, (2007), **W-119154** (2010), **W-119895** (2011)	According to processing aim

Legend: Numbers mean the obtained or applied for patents and utility models and date of application.

1. Device for disbursing a liquid underground of soils and meadows. W-39050 (1985 r.).
2. Device for injectional dosaging of loose organic fertilizer into soil. P-382062 (2007 r.).
3. Device for sampling and measurement of infiltrational water in environmental conditions. W-116896 (2007 r.).
4. Chaff cutter for wood. W-116926 (2007 r.).
5. Apparatus for chips production. P-384427 (2008 r.).
6. Mover for a tree plants. P-386842 (2008 r.).
7. Feeder of cutting material in wood cutter. W-119154 (2010 r.).
8. Harvester for cropping and shredding for lignified plant shoots and branches. W–119895 (2011 r.).
9. Planter of chips of plants with legnified shoots. W-119940 (2011 r.).

only when biomass is utilized locally, using dispersed co-generation low-power systems. The processing of biomass in co-generation systems may be realized in a few principal technologies: anaerobic fermentation or gasification using internal combustion piston engines, biomass power station realizing Rankin's cycle based on microturbines or steam engines and biomass boilers with external combustion engine. The last of the above-mentioned technologies are characterized by simple transformation of chemical energy or thermal energy and the greatest potential minimization.

The review of solutions utilized in Stirling engines in energy systems including systems operating based on biomass have been presented in [11]. Even though on home market commercial constructional solutions are accessible, there are no biomass systems. A majority of systems are in the stage of development and waiting for the working out of a technology for commercial solutions.

CONCLUSIONS

1. Proposed technical solutions for the production of plant with lignified shoots fill a gap between highly efficient and expensive machines and manual work.

2. Constructional solutions of the proposed agrotechnical machines possess the originally confirmed constructional characteristics and take into account the needs of small and middle-sized producers.

3. Machines and equipments proposed for the operation in small and medium-sized plantations of energetic plants are characterized by simple construction and do not require highly skilled workers.

4. Utilization of municipal sludges for the fertilization of energy plant plantation combined with the application of proposed equipment for sampling of soil water allow to increase crops and simultaneously control the influence of applied technology on the natural environment.

5. Presented technology of municipal sludges application protects humans by trophic chain against the dangerous substances contained in sludge.

6. Storage of lignified biomass as chaff instead of chips allows for the obtainment of better storage and energetic parameters of biomass.

7. Efficient utilization of the produced energetic biomass should be realized locally in low-power co-generation systems, with the Stirling engine especially distinctive.

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The algorithm of bifurcation points forecasting in the analitical researches of complex agro-ecological systems

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Abstract. An original development is described in this work of the forecasting of so-called rare events concerning the agro-ecological systems. Under definition "rare" it is necessary to understand events which take place during some observed process, time intervals between them are so great that it is possible to consider that they practically do not influence each other. The beginning of the rare events can be called as a "bifurcation point" of the observed process. Both the multistage procedure of the forecasting based on principles of inductive modeling and the selection criterion of the best forecasting models are described.

Keywords: inductive modeling, algorithm of modeling, criterion of models selection, agro-ecological system, forecasting, bifurcation points, rare events.

INTRODUCTION

In the projects of the complex agro-ecological systems researches it is necessary to decide tasks when some phenomena have a substantial influence on the result, but they take place very rarely and are hardly predictable. Time intervals between such events are so great that it is possible to consider that they practically do not influence each other, i.e. it is possible to consider that cross-correlation dependence between them is absent. Such phenomena have got the name of «rare» events and the beginning of such rare events can be called as a "bifurcation point" of the observed process. The classic example of rare events can be a date (a top) of freezing of the river or water storage in a natural environment. Although in the middle zone of Europe freezing takes place practically annually, time intervals between its occurrences are so great, that it is possible to assume that each instance of it has no influence on any other. It is also possible to include natural cataclysms, for example typhoons, hurricanes, earthquakes etc. to the category of rare events which can have the substantial negative affect on the agrarian sector of economy and on the mankind habitat in general.

Another example of a rare event can be an application of some complex technical unit (engine, computer etc.) which is characterized by a natural similarity and almost identical operating conditions. It is possible to continue this list of rare events. Therefore, undoubtedly, the successful forecasting of rare events is essential for the decision of many tasks in the ecology, economics and in research of reliability while complex technical systems are being tested.

In [1] the decision of the forecasting task of the water basin freezing date determined with the harmonic algorithm of Group Method Data Handling (GMDH) [2]. The rare event was the moment (on forecast interval) in which the forecast value of the process passed its critical point.

In the present article [3] the original approach for the forecasting of rare events is offered. It uses a technique that is effectively used by experienced specialists in diagnosing and predicting failures of technical devices. By 'rare' it is suggested to understand an event, coming in the object under analysis, for which there have been no precedents in recent past (not exceeding the maximum time of delay τ_{max}).

THE PROBLEM OF RARE EVENTS FORECASTING IN AGRO-ECOLOGICAL SYSTEMS

Under the object of modeling design in the agro-ecological systems we will understand the same physical object investigated on a time interval long enough for the multiple (*n* times) observations of an interesting event, or few (*n*) observations of the same type ecological objects, which is observed at the same conditions in a time interval including only one event. Obviously, these cases can take place both in ecological and in technical applications. However, usually the first case goes to the ecological systems (where the same water basin is explored during the sufficient amount of years from the point of view of modern modeling methods of the freezing moment). The second one is closer to the technical systems. An example is when simultaneously the monitoring of a group of the same type engines or other technical devices takes place, from the beginning of exploitation to the moment of their failure.

Obviously, in case of our agro-ecological (ecological) modeling systems both cases can take place and both procedures of initial information reception are acceptable.

Traditionally, it is possible to formulate the task of forecasting as follows. There is the prehistory of an object's behavior on the observation interval $\grave{O}_{obs} = [t_0, t_k]$, fixed in a corresponding datasheet (in the database). It is required to synthesize a model describing the behavior of this object on the forecast interval $\grave{O}_f = [t_{k+1}, t_{\acute{o}}]$.

We will formulate the task of forecasting of the rare event ("bifurcation point" of the process) as follows: let (1) – the result of monitoring of some system on the interval $\grave{O}_{obs} = [t_0, t_k]$ n times of interesting us event ξ_i, $i = 1, 2, \ldots, n$. Or (2) - monitoring of n same type agro-ecological systems in which the event once took place. Further, we will follow the scheme (1).

Obviously, is possible to split up all the interval $\grave{O}_{obs}$ into n intervals: $\grave{O}_{obs} = [t_0, t_{S_1}, \ldots, t_{S_{i-1}}, t_{S_i}, \ldots, t_{S_{n-1}}, t_{S_n}]$, where t_{S_i} is the moment of i-th event. Such splitting follows the indicated assumption that only one event ξ_i took place on interval $[t_{S_{i-1}}, t_{S_i}]$. In addition, every interval $[t_{S_{i-1}}, t_{S_i}]$ is broken into l of narrower intervals $\Delta t' = [t'_{j-1}, t'_j] = const$, $j = 1, 2, \ldots l$ and in its knots the control of parameter tests of object are produced. Thus, there is the set of n moments of events ξ_i, $i = 1, 2, \ldots, n$ in our task. The forecast of $(n + 1)$-th moment of time is the subject of our researches.

Such a problem can be described through the following regressive equation of a model:

$$y_f = f\{x_{1(0)}, x_{1(-1)}, \ldots, x_{1(-\tau_1)},\\ x_{2(0)}, x_{2(-1)}, \ldots, x_{2(-\tau_2)},\\ \ldots\\ x_{m(0)}, x_{m(-1)}, \ldots, x_{m(-\tau_m)}, \theta_f\}, \quad (1)$$

where: y is the output (forecast) value, x_i, $i = 1, 2, ..., m$ - arguments, $\tau_1, \ldots, \tau_m$ are the delays of each argument taken into account, θ is the vector of the estimated parameters.

More laconically, model (1) can be presented as

$$y_f = f(X, \theta_f). \quad (2)$$

The difference of such approach from traditional forecasting procedures: (1) among the arguments of function $f(\bullet)$ the delay arguments of output value y are absent and (2) - output value is the time between the last supervision (control measuring) and beginning of rare event (bifurcation point of process). Thus, on the interval $\Delta t' = [t'_{j-1}, t'_j]$ of rare event, the occurrence $y \leq \Delta t'$, and on the interval of «non-occurrence» (precedence) – $y > \Delta t'$.

In [3], for the solution of the same problem, the original and effective method of initial informative base forming is also presented. This procedure got the name «floating scale» to indexation of delay arguments. «Floating» indexation means that index «0» appropriated to the control moment of event has occurred. In this case we have a situation $y \leq (t'_{j-1} - t'_j)$. «Floating» indexation must be used for the creation of datasheet. Values $x_{i(-\tau_i)}$ must correspond to the delays of i-th interval, $i = 1, 2, ..., n$.

PROCEDURE FOR PREDICTION OF RARE EVENTS IN AGRO-ECOLOGICAL SYSTEMS

The feature of the agro-ecological systems is that in complex processes in such systems the rare events of interest can take place in very limited times. If to consider the second variant of rare events research, i.e. the similar agro-ecological systems, then the amount of rare events in them can be rather small. In both cases the statistical data of initial supervisions are very limited. Thus, to the algorithms which could be possible to use for the modeling and decision of prediction task of rare event, strict requirements are demanded:

1) algorithms must save operability at limited low times of supervisions (n);
2) algorithms must save operability at high ratio signal/noise to be antijamming;
3) algorithms must have high speed and be able to process large datasheets for the modeling of optimal results in the form (1).

For today, the techniques of inductive self-organization of complex systems correspond to such strong conditions [4, 5]. Our multistage procedure of rare event forecasting can be presented as a next kind.

The 1-st stage: the designing of primary informative base (datasheets). Informative delay arguments (on τ) are needed to determine the extremum of autocorrelation function or rank correlation. It allows to take into account only those delays which mostly influence the investigated process in the agro-ecological system and to eliminate a large bust of all possible combinations of delay, which greatly simplifies the output expression (1).

The 2-nd stage: a synthesis of equation (1) - is teaching of a model. This stage is not less responsible than the stage of basic data preparation. Here, it is appropriate to apply the so-called combinatory (at small m) or multistage (at sufficient m) algorithms of Group Method of Data Handling (GMDH). Simplifying denotations, it is possible to present for example the chart of combinatory algorithm in another way.

Step 1. The equation of the model contains only 1 member (if necessary it is possible to include a free member of a_o) in the equation:

$$y = f(a_0, x_i),\ i = 1, \ldots, m \tag{3}$$

Step 2. Equation (1) contains 2 (with free member - three) elements:

$$y = f(a_0, x_i, x_j),\ i, j = 1, \ldots, m,\ i \neq j. \tag{4}$$

Step *s*. Equation (1) contains *s* (with free member – *s*+1) elements:

$$y = f(a_0, x_1, \ldots, x_2, \ldots, x_s).$$

The 3-rd stage: the prediction of $\xi_{(n+1)}$. Let on $(n+1)$-th interval $[t_{sn}, t_{s_{n+1}}]$ the regular observations under the above conditions be made. While reaching the length of the interval equal to the maximum delay in equation (5), *y* is calculated. If $ó > \Delta t'$, the next control measuring is produced. Such procedure is performed until the output value becomes smaller than interval $\Delta t'$. In this case, the value of *y* will be the time after expiration of which an event will occur after the last moment of observation $\xi_{(n+1)}$.

The increase of model complication takes place until reaching the minimum of selection criterion or until the moment of its stabilization takes place. In the last case the model corresponding to the minimum complexity is selected. Under "complication" in an inductive modeling, the amount of members in the right part of equation (1) is understood.

Thus, the teaching of model (1) is the task of identification which, from the positions of inductive modeling, is exhaustively formulated in [6], as follows. The task of identification consists of forming, from the observation data $W = (X \vdots y)$ of the same set of $\Im$ models having different structures of the kind $\hat{y}_f = f(X, \hat{\theta}_f)$, where θ is the vector of the estimated parameters and selecting the optimal model under the minimum criterion $CR(\cdot)$:

$$f^* = \arg\min_{f \in \Im} CR(y, f(X, \hat{\theta}_f)) \tag{5}$$

where: estimations of parameters $\hat{\theta}_f$ for each $f \in \Im$ are the decision of task

$$\hat{\theta}_f = \arg\min_{f \in R^{sf}} Q(y, X, \hat{\theta}_f), \tag{6}$$

where: $Q(\cdot) \neq CR(\cdot)$ is the criterion of decision quality in the parametric identification task of private model of complexity s_f generated in the task of structural identification (1).

Most the often applied criterion of the models selection in the indicated algorithms is the criterion of regularity:

$$AR(s) = \left\| y_B - \hat{y}_{B_s} \right\|^2 = \left\| y_B - \hat{y}_{B_s} \hat{\theta}_{A_s} \right\|^2. \tag{7}$$

This criterion, as well as all the criteria in the inductive modeling of the complex systems, has the properties of external addition [2] which assume the breaking up of the set $W = (X \vdots y)$ into two non-overlapping subsets: teaching *A* (for the evaluation of models parameters) and verification (for the calculation of model errors, $A \cap B = \varnothing$). The form of record and the denotations are stored by the theoretical work [6].

Among the often applied criteria of selection $CR(\cdot)$ it is necessary, first of all, also to name the minimum of deviation criterion and the balance of forecasts criterion. Information about these criteria, conditions and ways of their applying can be found in [2, 4, 5, 7].

We will mark in the conclusion, that the described approach in one or another way was successfully used both in the tasks investigations of complex ecological processes (forecasting of large reservoirs of freezing, forecasting of processes of territories contamination and other ones) and at solving complex technical problems (forecasting the occurrence of anode effect, etc.).

CONCLUSIONS

In this article the original approach for forecasting of the so-called rare events taking place in the agro-ecological systems is described. Under term "rare" in the agro-ecological (ecological) systems it is necessary to understand the events which take place during some observed process, and time intervals between them are so great, that it is possible to consider that they practically do not influence each other. Two possible approaches to the forming of initial informative base (of data tables) for identification of such processes and phenomena with possibility of forecasting of a rare event beginning moment are described. A multistage procedure of forecasting based on inductive modeling principles as well as a criterion of selection of the best forecasting models is described.

The described approach has a wide range of application in agro-ecological, in technical, medical, biological and many other fields, where it is necessary to have a forecast of not only output value of a process (temperature, for example) but also the knowledge of the peak of rare event in the investigated process.

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Investigation of parametric models of differential equations systems stability

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Abstract. We study the practical stability of systems of ordinary differential equations depending on parameters for the numerical calculation of the stability regions of the set of initial conditions and parameters considered in the given structural form. This approach can significantly extend the range of the investigated problems related to the problem of sensitivity.

Key words: practical stability, tolerances on the parameters, the perturbation parameter of the system.

INTRODUCTION

The problem of designing real dynamic objects includes a number of pressing problems in the theory of sensitivity and stability: the calculation of tolerances for parameters, guaranteed by the sensitivity of stability [1–3]. Within this framework, the stability analyses of parametric systems are encouraged to be implemented with the help of Lyapunov's second method for a finite time interval [4]. At the same time, the parameters can take arbitrary constants or variables that characterize the features of the system, including the initial conditions. In order to obtain numerical algorithms for an analysis of the initial conditions of stability and phase, restrictions are set in concrete form.

The aim is to develop algorithms for calculating the sets of initial conditions and parameters in a given structure of the methods of practical stability for parametric systems.

Statement of problems of practical stability for systems depending on parameters. Assume that the motion of the object is described by the system of ordinary differential equations of the form:

$$\frac{dx}{dt} = f\left(x,t,\alpha\right)\ ,t \in \left[t_0,T\right], \tag{1}$$

where: $x(t,\alpha)$, α − the vectors of states and parameters of dimension n and m respectively; $f(x,t,\alpha)$ − n-dimensional vector function that satisfies the conditions of existence and uniqueness of solutions for any $\alpha\in G_\alpha$.

Definition 1. Unperturbed solution $x(t,0) = 0$ of system (1) named $\left\{G_0^x, G_0^\alpha, \Phi_t, t_0, T\right\}$ - stable if the trajectory of system (1) do not exceed permissible values for a set $\Phi_t, t \in \left[t_0,T\right]$ of initial conditions $x(t_0,\alpha)$ from the field G_0^x and arbitrary $\alpha\in G_0\subset G_\alpha$.

At the same time $f(0,t,0) \equiv 0$, $0\in\Phi_t, t\in[t_0,T]$.

According to the common productions of applications it is sometimes considered advisable to introduce consistent dynamical restrictions on phase coordinates and parameters $\Phi_{t,\alpha}$, $t\in[t_0,T]$ and evaluate the region $G_0^{x,\alpha}$ of initial conditions and system parameters (1).

Definition 2. Unperturbed motion $x(t,0) = 0$ of system (1) will be called $\left\{G_0^{x,\alpha}, \Phi_{t,\alpha}, t_0, T\right\}$ - stable, if $x(t)$, $\alpha\in\Phi_{t,\alpha}$, $t\in[t_0,T]$ only just $x(t_0)$, $\alpha\in G_0^{x,\alpha}$.

Let us take into account disturbing factors in the study of practical stability of the system of the form:

$$\frac{dx}{dt} = f\left(x,t,\alpha\right) + R\left(x,t,\alpha\right),\ t \in \left[t_0,T\right], \tag{2}$$

where: permanent disturbance $R(x,t,\alpha)$ are selected from some areas Ω_R.

Definition 3. System (2) is called internally $\left\{G_0^x, G_0^\alpha, \Phi_t, t_0, T, \Omega_R\right\}$ - stable, if $x\left(t,\alpha\right) \in \Phi_t, t \in \left[t_0,T\right]$ for arbitrary perturbations of initial conditions and parameters that satisfy relations

$$R\left(x,t,\alpha\right) \in \Omega_R,\ x(t,\alpha) \in G_0^x, \alpha \in G_0^\alpha \subset G_\alpha.$$

Definition 4. System (2) is a foreign $\left\{D_0^x, G_0^\alpha, \Phi_t, t_0, T\right\}$ - stable, if there is at least one point of time $t_1\in[t_0,T]$ for which $x(t_1,\alpha)\in\Phi_{t_1}$ for any $R(x,t,\alpha)\in\Omega_R$, $x\left(t_0,\alpha\right) \in D_0^x, D_0^x \supset \Phi_{t_0}, \alpha \in G_0^{\alpha_1} \subset G_\alpha$.

Similar definitions are introduced and relevant for the stability of system (2) in respect of restrictions on the joint state vector and parameters.

The concepts introduced in this way are sufficiently rich in content, in the sense that includes various formulations of the problems of practical stability and sensitivity, defined by all possible combinations of their constituent sets. Thus, based on Definition 1, the following tasks can be seen e.g.: to assess the known limitations $\Phi_t, t \in [t_0, T]$ of the set G_0^x and G_0^α on the sets G_0^x, G_0^α, to find the estimate $\Phi_t, t \in [t_0, T]$ and if, in particular, the set G_0^α consists of one point − to investigate the problem of $\{G_0^x, \Phi_t, t_0, T\}$- stability [2].

General theorems of practical stability for systems with perturbations. Within the above definitions, using the second method of Lyapunov and unambiguous continuously differentiable functions $V(x,t,\alpha)$, by analysis and evaluation of stability for the unknown or bounded disturbances:

$$R(x,t,\alpha) \in \Omega_R^{(1)} = \{R(x,t,\alpha):$$
$$: \left(\int_{t_0}^{T} \left\| R(x(t,\alpha),t,\alpha) \right\|^p d\tau \right)^{\frac{1}{p}} \le \overline{R}, \alpha \in G_\alpha \Bigg\},$$

$$R(x,t,\alpha) \in \Omega_R^{(2)} = \{R(x,t,\alpha):$$
$$: \left| R_i(x,t,\alpha) \right| \le \overline{R}_i(t,\alpha), i = 1,2,...,n, \alpha \in G_\alpha \}.$$

In particular, there are the following theorem.

Theorem 1. If the system (1) there is positive-expert procedures for variable x on $[t_0,T]$ function $V(x,t,\alpha)$ and the number $0 < \varepsilon < 1$ for which the conditions:

$$\{x: V(x,t,\alpha) \le 1\} \subset \Phi_t, t \in [t_0,T], \alpha \in G_0^\alpha,$$
$$\left(\frac{dV(x,t,\alpha)}{dt} \right)_{(1)} + \sum_{i=1}^{n} \left| \frac{\partial V(x,t,\alpha)}{\partial x_i} \right| \overline{R}_i(t,\alpha) \le 0. \tag{3}$$

for arbitrary $x(t) \in \Phi_t / \{x: V(x,t,\alpha) < 1-\varepsilon\}$, $t \in [t_0,T], \alpha \in G_0^\alpha$,

$$G_0^x \subset \{x: V(x(t_0,\alpha),t_0,\alpha) < 1\}, \alpha \in G_0^\alpha,$$

the system (2) internally $\{G_0^x, G_0^\alpha, \Phi_t, t_0, T, \Omega_R^{(2)}\}$- rack.

Theorem 2. If the system (1) found positive-expert procedures for variable x function $V(x,t,\alpha)$ and number $A > 0$such that:

$$\{x: V(x,t,\alpha) \le 1\} \subset \Phi_t, t \in [t_0,T], \alpha \in G_0^\alpha,$$

$$D_o^x \subset \{x: V(x(t_0,\alpha),t_0,\alpha) < A\}, \alpha \in G_0^\alpha,$$

for any n-dimensional functions $\psi(t,\alpha) \in E_n / \Phi_t, t \in [t_0,T]$, $\psi(t_0,\alpha) \in D_0^x$, $\alpha \in G_0^\alpha$ the inequality:

$$\int_{t_0}^{t} \left[\frac{\partial V(\psi(\tau,\alpha),\tau,\alpha)}{\partial \tau} + \right.$$
$$\left. + grad_x^* V(\psi(\tau,\alpha),\tau,\alpha) f(\psi(\tau,\alpha),\tau,\alpha) \right] d\tau +$$
$$+ \left(\int_{t_0}^{t} \left\| grad_x^* V(\psi(\tau,\alpha),\tau,\alpha) \right\|^q d\tau \right)^{1/q} \cdot$$
$$\cdot \overline{R} < 1 - A,$$

the system (2) external $\{D_0^x, G_0^\alpha, \Phi_t, t_0, T, \Omega_R^{(1)}\}$ - bar.

Theorem 3. If the system (1) there is positive-expert procedures on $[t_0,T]$ a function $V(x,t,\alpha)$ that satisfies:

$$\{x,\alpha: V(x,t,\alpha) \le 1\} \subset \Phi_{t,\alpha}, t \in [t_0,T],$$

(3) when $x(t), \alpha \in \Phi_{t,\alpha} / \{x,\alpha: V(x,t,\alpha) < 1-\varepsilon\}$, $t \in [t_0,T]$,

$$G_0^{x,\alpha} \subset \{x,\alpha: V(x(t_0,\alpha),t_0,\alpha) < 1\},$$

the system (2) is $\{G_0^{x,\alpha}, \Phi_{t,\alpha}, t_0, T, \Omega_R^{(2)}\}$ - internally stable.

Algorithms for calculating areas of practical stability. Consider the linear system:

$$\frac{dx}{dt} = A(t)x + G(t)\alpha + f(t), t \in [t_0,T], \tag{4}$$

where permanent disturbance $f(t)$ is assumed to be known or unknown, but bounded by the norm.

Let $G_0^x = \{x: W(x) < 1\}, G_0^y = \{y: W(y) < 1\}$, where $y = \begin{pmatrix} x \\ \alpha \end{pmatrix}$, and $W(x)$, $W(y)$ − positive-definite functions which are closed surface level $W(x) = 1$, $W(y) = 1$.

Proposition 1. For $\{G_0^x, G_0^\alpha, \Phi_t, t_0, T\}$- system stability (4) of known perturbations and should be enough to have made the ratio:

$$\{x: W[X(t_0,t)(x(t,\alpha) - G_1(t)\alpha - a(t))] < 1\}$$
$$\subset \Phi_t, t \in [t_0,T], \alpha \in G_0^\alpha.$$

Here $G_1(t) = \int_{t_0}^{t} X(t,\tau) G(\tau) d\tau$; $a(t) = \int_{t_0}^{t} X(t,\tau) f(\tau) d\tau$; $X(t,t_0)$ − normalized by moment t_0 fundamental matrix of solutions of homogeneous system (4) at $\alpha = 0$:

$$\frac{dX(t,t_0)}{dt} = A(t)X(t,t_0), X(t_0,t_0) = E. \tag{5}$$

Proposition 2. For system (4) was $\{G_0^{x,\alpha}, \Phi_{t,\alpha}, t_0, T\}$ - stand at the set $f(t)$ and should be enough to:

$$\{y: W[Y(t_0,t)(y(t) - \tilde{a}(t))] < 1\} \subset \Phi_{t,\alpha}, t \in [t_0,T],$$

where: $Y(t,t_0)=\begin{pmatrix} X(t,t_0) & G_1(t) \\ 0 & E \end{pmatrix}$,

$$\tilde{a}(t)=\int_{t_0}^{t} Y(t,\tau)\tilde{f}(\tau)d\tau,\ \tilde{f}(t)=\begin{pmatrix} f(t) \\ 0 \end{pmatrix}. \qquad (6)$$

Based on the above general statements of theorems and algorithms developed constructive evaluation of firmness of the initial sets $G_0^x = \left\{x \mid x^*Bx \le c^2\right\}, G_0^\alpha = \left\{\alpha \mid \alpha^* B_\alpha \alpha \le c_\alpha^2\right\}, G_0^{x,\alpha} = \left\{x,\alpha \mid \mid x^*Bx + \alpha^* B_\alpha \alpha \le c^2\right\}$ when specific constraints on phase coordinates and parameters [2, 3]:

$$\Phi_t = \Gamma_t = \left\{x : \left|l_s^*(t)x\right| \le 1, s=1,2,...N\right\},\ t\in[t_0,T],$$

$$\Phi_t = \Psi_t = \{x : \psi(x,t) \le 1\}, t\in[t_0,T],$$

$$\Phi_{t,\alpha} = \Gamma_{t,\alpha} = \left\{x,\alpha : \left|l_s^*(t)x + m_s^*\alpha\right| \le 1, s=1,2,...N\right\},\ t\in[t_0,T],$$

$$\Phi_{t,\alpha} = \Psi_{t,\alpha} = \{x,\alpha : \psi(x,t,\alpha) \le 1\}, t\in[t_0,T].$$

This region of initial conditions $G_0^x, G_0^{x,\alpha}$ are evaluated numerically.

So, to system (4) was internally $\{c,B,c_\alpha,B_\alpha,\Gamma_t,t_0,T\}$ - stable in the presence of known perturbations, necessary and sufficient that inequality was done:

$$c^2 \le \min_{t\in[t_0,T]} \cdot \min_{s=1,2,...,N} \cdot \min_{\alpha\in G_0^\alpha} \frac{\left(1-\left|l_s^*(t)\left(a(t)+G_1(t)\alpha\right)\right|\right)^2}{l_s^*(t)Q^{-1}(t)l_s(t)},$$

$$\left|l_s^*(t)\left(a(t)+G_1(t)\alpha\right)\right| < 1,\ s=1,2,...,N,$$

$$\alpha\in G_0^\alpha,\ t\in[t_0,T]$$

$$(Q^{-1}(t) = \mathrm{X}(t,t_0)B^{-1}\mathrm{X}^*(t,t_0)).$$

Terms and foreign $\{c,B,c_\alpha,B_\alpha,\Gamma_t,t_0,T\}$ - and $\{c,B,c_\alpha,B_\alpha,\Psi_t,t_0,T\}$ - stability under unknown disturbance can be represented respectively as follows:

$$c^2 \le \max_{t\in[t_0,T]} \cdot \min_{s=1,2,...,N} \cdot$$

$$\cdot \frac{\left(1-a_s(t)\right)^2}{l_s^*(t)Q_1(t)l_s(t) + m_s^* B_\alpha^{-1} m_s + 2l_s^*(t)G_1(t)B_\alpha^{-1}m_s},$$

$$c^2 \le \max_{t\in[t_0,T]} \cdot \min_{\bar{x}\in\Psi_t'} \cdot \min_{\alpha\in G_0^\alpha}$$

$$\frac{\left(g^*(\bar{x},t)\left(\bar{x}-G_1(t)\alpha - a_{\bar{x}}(t)\right)\right)^2}{g^*(\bar{x},t)Q^{-1}(t)g(\bar{x},t)} \qquad (7)$$

$$(Q_1(t) = \mathrm{X}(t,t_0)B^{-1}\mathrm{X}^*(t,t_0) + G_1(t)\cdot B_\alpha^{-1}\cdot G_1^*(t)).$$

Similar relations can lead to joint dynamic limits $\Gamma_{t,\alpha}$, $\Psi_{t,\alpha}$, $[t_0, T]$ for various types of disturbances.

You can also explore the system (4) for the case when the initial conditions, continuous disturbance and parameters selected from the region

$$S_c(t) = \left\{x(t_0),\alpha,f(t):\ x^*(t_0)Bx(t_0) + +\alpha^* B_\alpha \alpha + \int_{t_0}^{t} f^*(\tau)G_1(t)f(\tau)d\tau \le c^2\right\}. \qquad (8)$$

Thus, the criterion $\{S_c(t), \Gamma_t, t_0, T\}$ - stability takes the form [2]

$$c^2 \le \min_{t\in[t_0,T]} \cdot \min_{s=1,2,...,N} \cdot \frac{1}{l_s^*(t)R(t)l_s(t)}, \qquad (9)$$

where: the symmetric matrix $R(t)$ satisfies by Cauchy problem

$$\frac{dR(t)}{dt} = \mathrm{A}(t)R(t) + R(t)A^*(t) + G_1^{-1}(t) + +G(t)B_\alpha^{-1}G^*(t), R(t_0) = B^{-1}. \qquad (10)$$

As part of this trend can be seen a number of problems associated with the construction of regulatory actions that would ensure the sustainability of the system of the specified type [3]. So, using the concept of sustainability in the direction, upper bounds areas are obtained of the initial conditions for the vector of states and parameters for specific restrictions on phase coordinates.

The above formulation allows for a unified position – exploring the various practical stability in the nature of the problem of sensitivity and solving them numerically, to conduct a comprehensive analysis of parametric systems.

CONCLUSIONS

On the basis of the general theorems, numerical algorithms were developed for calculation of stability regions for systems with parametric perturbations. A number of pressing problems were considered in the theory of sensitivity associated with the design of real dynamic objects, including the formulation of A.

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The determination of the parameters of a ploughshare-rotor potato digger

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Abstract. The results of this research on the technological process of potato-digging are based on plots of land where the crop has been dug up and sorted using a ploughshare-rotor potato digger. The ideal parameters for the working components of the machine have been determined.

Key words: tubers (potatoes), technological process, sorting, ploughshare-rotor potato digger, structural technical parameters, plots, potato conveyer belt.

INTRODUCTION

The mechanization of potato harvesting is widespread in Ukraine, in both farm and village economies. Thus, this is a very up-to-date question, and it is important to provide new, simple, effective and reliable machines for this purpose.

Although there now exists the possibility, in large fields, to mechanize the process and lower the expense of labor to (0.2-0.5) man hours per 0.01 hectares, on smaller garden plots the existing mechanized methods require (12-15) man hours per 0.01 hectares, that is, 25-75 times more than in large fields.

The most promising direction for research is to develop machines that have active components that dislodge and separate the potatoes at all the stages of technological process. This problem can be solved by developing apparatuses that provide intensified technological processes, that is, a special composition of the working surface of the ploughshare, which has a special form and has a special potato-digging rotor set in above it.

Those who have previously done research on the technological process and the working parts of machines for the digging and separation of potatoes, and consequently determined the parameters of such machines, include P.M. Vasilenk. V.P. Goryachkin, L.B. Pogoriliy, P.M. Nastenko, and G.D. Petrov [7, 8].

An analysis of the existing technological processes and working parts of potato-digging and separation machines has revealed a poor level of separation and mechanical damage done to the potatoes, which is caused by an imperfect clod-breaking apparatus and a faulty composition of machine parts.

By analyzing the literature concerning this problem, we determined the weaknesses in the construction of existing potato harvesting machines and also determined how we can improve the technological process of potato digging by improving the efficiency of the digger ploughshare and putting in a spade rotor above it that provides an active breaking up of the soil layer.

The results of our research and development of the components of a new potato digger and separation machine can now provide villagers with small plots of land and adequate, efficient mechanical means for performing their work [3, 4].

RESEARCH METHODS

For the theoretical research of optimized parameters for potato digging machines, we used the methods of theoretical mechanics, higher mathematics and mathematical statistics to develop a mechanical, mathematical model of the technological process. The experimental, practical research was done in a laboratory setting, planning multivariable experiments for testing and then analyzing the results of these experiments. Theoretical calculations and the statistical processing of experimental data were conducted using processing programs on a personal computer [5, 6].

RESEARCH RESULTS

In the proposed construction of a potato digger (Fig. 1) the layer of soil and potatoes that is to be dug encounters blade 4, and undergoes a matching rotating movement along with the blade and a simultaneous lateral movement. After the blade and its "contents" have turned a certain number of degrees, a mass is thrown out on the surface of the field. As the blade strikes the field, this blow being concentrated at the end portion of ploughshare 3, the process of clod-breaking is improved and the level of separation is thus improved as well. The working parts of the digging apparatus are shown in Fig. 1.

We conducted theoretical research on the mutual interaction of the ploughshare and the soil layer the characteristics of the movement of the dug-up mass along its surface both above and below) [1, 2].

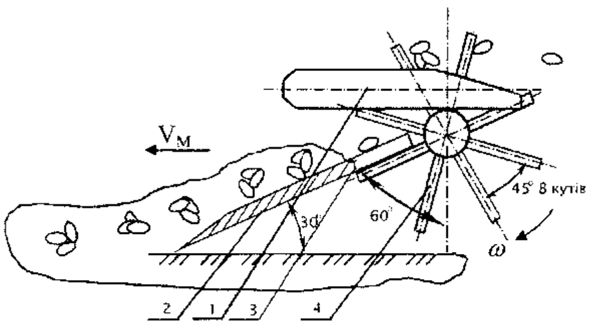

Fig. 1. Technological potato digger plan

In Fig. 2 we show the forces which act upon the ploughshare: at point A the soil layer is cut; at point E at the curvature the lower part of the layer is deformed; at point H the layer is deformed from the top side. On the surface, from point H cuts are made that begin the process of separation [6].

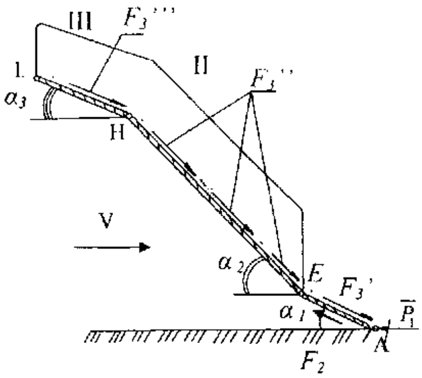

Fig. 2. Forces that act on the ploughshare

Force of resistance *of P*, which operates on the ploughshare, is represented as a vector sum:

$$\overline{P} = \overline{P}_1 + \overline{F}_2 + \overline{F}_3, \tag{1}$$

where: P_1 is the force of cutting resistance, F_2 is the force of friction between the ground and the underside of the ploughshare and F_3 is the sum of the forces of resistance between the soil and the upper surface of the ploughshare [9, 10, 11, 12].

After determining its component parts, the force of resistance P which the ploughshare encounters when in operation is equal to:

$$\overline{P} = \overline{K}_p l_3 + f_1 \overline{Q}_B + f_2 \overline{Q}, \tag{2}$$

where: KR is the specific cutting resistance, f_l is the length of the blade; mcode Q_1 is the coefficient of friction between the blade and the soil, Q_L is the force of pressure of the blade on the soil, f_2 is the coefficient of friction at the surface of the ploughshare, and Q_B is the force of pressure between of the soil on the surface of the ploughshare [15].

In choosing the form of the surface of the ploughshare it is important to maximize the effectiveness of breaking up the surface without damaging the tubers themselves. For this reason, the surface of the ploughshare is designed with a variable transversal cut area, which diminishes the direction of the cutting edge, thus causing a layer to go up, being loosened from below with motion upward. This increased efficiency of the loosening process is arrived at by rounding off the form of the lateral walls of the ploughshare. The curved surface of the ploughshare reduces sticking, which is the chief complication in the process itself.

In the cutting area of the ploughshare, the monolith of soil is broken up at the same time when the mixture of soil and potatoes enters the machine. When soil is worked up by the ploughshare, forces are exerted on the areas of contact of the transversal cut S and the cut A-An (Fig. 3) [14, 15].

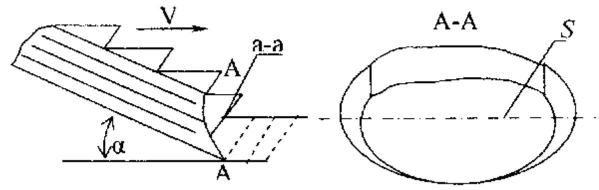

Fig. 3. Characteristics of soil output when the ploughshare of the potato digger is in motion.

It is a known fact that the soil becomes disrupted and rises up when it is pressed upon. The distribution of forces at the intersection of disruption A-An is not the same for all heights.

By experiment it was determined that total frictional force F for the movement of the soil/potato mixture along the surface of the plowshare is:

$$F = \frac{fP'L\sin 2\alpha}{S_1}, \tag{3}$$

where: f is the coefficient of friction of the soil on a ploughshare, P' is the force of pressure of the ploughshare in pounds, L is the perimeter of the cross-section of the ploughshare in meters; α is the tilt angle of the ploughshare (out of the horizontal position) in degrees; S_1 is the area of the cross-section of soil through the line a-a in m^2.

As a result of analyzing the dependence of the speed of the mixture $V_{пер}$ as it moves along the surface of the ploughshare on the speed at the potato-digger $V_{маш}$, it was determined that the maximum allowable speed for the motion of the soil/potato mixture is 0,4 m/sec, with a tilt angle of $\alpha=12°$ for the ploughshare. As $V_{маш}$ is increased, and the angle α increases, there is a danger of soil accumulating ahead of the plough surface.

Thus, on the basis of the experiments we did, an optimal form of the surface of the ploughshare has been determined (diagram 4), its geometric parameters being: the width of the front part of the ploughshare *a=415 mm*; the width of the back part of the ploughshare *b=361 mm*; the length of the ploughshare *l=475 mm*; the height of the ploughshare *h=150* mm.

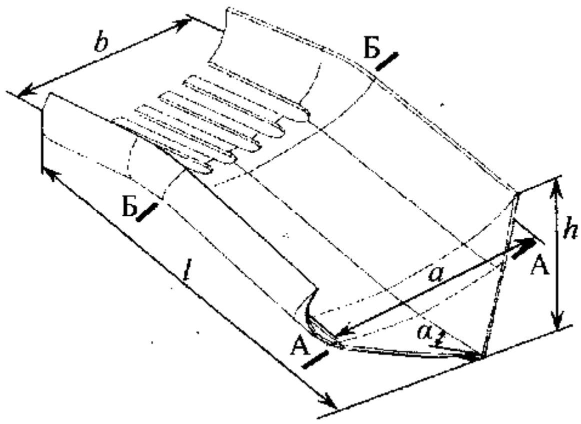

Fig. 4. The ploughshare structure

In order to determine the parameters for the rotor blade, we examined the relative motion of the tubers C (diagram 5) on the surface of the rotor blade. At a certain moment the position of the rotor blade O1K is give as the angle $\psi = \psi_0 + \omega t$, where ψ_0 is the initial position of the rotor at time t=0; ω is the angular speed of rotation of the rotor in radians/second, and t is the interval of time in seconds [19, 20].

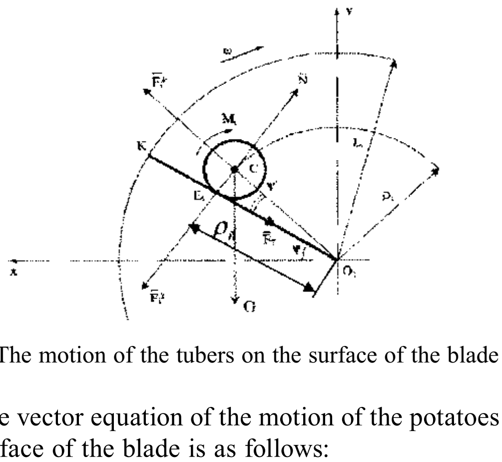

Fig. 5. The motion of the tubers on the surface of the blade

The vector equation of the motion of the potatoes at the surface of the blade is as follows:

$$\frac{dx}{dt} = A(t)x + G(t)\alpha + f(t), t \in [t_0, T], \tag{4}$$

where m is the mass of the potatoes in kg., $\bar{a}$ is the acceleration of the potatoes at the blade surface in m/s^2, $\bar{G}$ is the gravitational force on the potatoes in newtons, $\overline{N}$ is the normal reaction at the surface of the blade, in newtons, $\overline{F}_T$ is the force of friction exerted when the potatoes rub the blade in newtons, $\overline{F}_i^{в}$ is the centrifugal force of inertia of the potatoes with respect to the axis of rotation O1 in newtons, and $\overline{F}_i^{к}$ is the force of Koriolis inertia in newtons.

The equation for the motion of the potatoes on the blade projected unto the fixed coordinate system O_1XYZ is:

$$\left.\begin{aligned} m\ddot{x} &= -N\sin\psi - F_T\cos\psi + F_i^{кв}\sin\psi + F_i^{в}\cos(\overline{F}_i, x) \\ m\ddot{y} &= -G + N\cos\psi - F_0\sin\psi + F_i^{кв}\cos\psi + F_i^{в}\cos(\overline{F}_i, y) \end{aligned}\right\}, \tag{5}$$

where ψ is the angle of rubbing friction in degrees, and $\cos(\overline{F}_i^{в}, x)$ $\cos(\overline{F}_i^{в}, y)$ are the cosines of the angles of motion, where:

$$\cos(\overline{F}_i^{в}, x) = \cos\psi\frac{\sqrt{\rho_{cб}^2 - R^2}}{\rho_c} - \sin\psi\frac{R_б}{\rho_c} = \frac{1}{\rho_c}\left[\cos\psi\sqrt{\rho_c^2 - R_б^2} - \sin\psi R_б\right], \tag{6}$$

$$\cos(\overline{F}_i^{в}, y) = \sin\psi\frac{\sqrt{\rho_c^2 - R_б^2}}{\rho_c} + \cos\psi\frac{R_б}{\rho_c} = \frac{1}{\rho_c}\left[\sin\psi\sqrt{\rho_c^2 - R_б^2} + \cos\psi R_б\right], \tag{7}$$

where: Rб is the radius of the tuber in meters, mcode; cc is the radius in meters of the position of the center C of the potatoes with respect to the O_1 axis.

Solving (5), (6) and (7) we find that:

$$\left.\begin{aligned} m\ddot{x} &= -N\sin\psi - fN\cos\psi + 2m\omega V\sin\psi + m\omega^2(\cos\psi\sqrt{\rho_c^2 - R_б^2} - \sin\psi R_б) \\ m\ddot{y} &= -mg + N\cos\psi - fN\sin\psi - 2m\omega V\cos\psi + m\omega^2(\sin\psi\sqrt{\rho_c^2 - R_б^2}\cos\psi R_б) \end{aligned}\right\}. \tag{8}$$

As the potatoes perform constant motion the projected acceleration of point C will be $\ddot{X} = 0$, $\ddot{Y} = 0$. Calculating we find that:

$$\left.\begin{aligned} -N\sin\psi - fN\cos\psi + 2m\omega V\sin\psi + m\omega^2(\cos\psi\sqrt{\rho_c^2 - R_б^2} - \sin\psi R_б) = 0 \\ -mg + N\cos\psi - fN\sin\psi - 2m\omega V\cos\psi + m\omega^2(\sin\psi\sqrt{\rho_c^2 - R_б^2}\cos\psi R_б) = 0 \end{aligned}\right\}. \tag{9}$$

Reducing system (9) we find the value of the normal reaction at the surface of the blade:

$$N = \frac{mg}{\sin\psi(tg\psi + ctg\psi)} + 2m\omega V - m\omega^2 R_б. \tag{10}$$

The equation for the moments of rotation of the potatoes around its axis is:

$$I_б\ddot{\xi} = Mr - F_T R_б, \text{ or } \frac{2}{3}mR_б^2\ddot{\xi} = NR_б tgV - fNR_б, \tag{11}$$

where: I_b is the moment of inertia of the potatoes with respect to their center in kg-m; $\ddot{\xi}$ the angular acceleration of the rotational motion of the potatoes in rad/s^2, and Mr is the moment of rubbing friction of the potatoes in newton-m.

From equation (11) we determine that:

$$\ddot{\xi} = \frac{3}{2}(tgV - f)\left[\frac{g}{R_{б}\sin\psi(tg\psi + ctg\psi)} + \frac{2\omega V}{R_{б}} - \omega^2\right]. \quad (12)$$

Taking into account that $\psi = \psi_0 + \omega t$, and $V = R_{б}\dot{\xi}$, making the corresponding transformation we find that:

$$\frac{d^2\xi}{d\psi^2} - \frac{A_1}{\omega}\cdot\frac{d\xi}{d\psi} = \frac{A_2}{\omega^2}\cos\psi - \frac{A_3}{\omega^2}, \quad (13)$$

where $3\omega(tgV - f) = A_1$; $\frac{3}{2}(tgV - f)\frac{g}{R_{б}} = A_2$; $\frac{3}{2}(tgV - f)\omega^2 = A_3$.

The solution of equation (13) is performed by numerical methods, initially setting the condition for the initial entrance of the potatoes into the blade mechanism:

$$N = F_i^{кв} - G\cos\psi + F_i \sin\psi' > 0. \quad (14)$$

Taking into account that when the potatoes are first taken in, the normal for N=0, $\omega^2 R_{б} - g\cos\psi - 2m\omega V > 0, a\dot{\xi} = d\xi/dt$, the dependence of the angle of entrance of the potatoes when cut off by the blade can be written as the condition:

$$\psi > ar\cos(\frac{\omega^2 R_{б} - 2\omega\dot{\xi}R_{б}}{g}). \quad (15)$$

The solution of equation (13) then takes the form:

$$\xi = \frac{\omega t}{2} + \frac{3g(tg\upsilon - f)\cdot\sin\frac{\omega t}{2}}{2\omega^2 R_{б}}$$

$$\frac{\left[\sin(\frac{\omega t}{2}) - 3(tg\upsilon - f)\cdot\cos(\frac{\omega t}{2})\right]}{\left[9\cdot(tg\upsilon - f)^2 + 1\right]}. \quad (16)$$

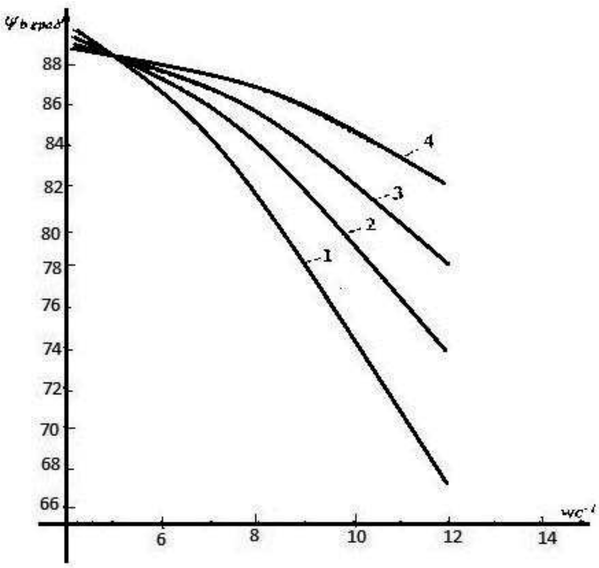

Fig. 6. The dependencies of the angle of introduction on angular velocity $\psi_{в}$, for the angular velocities ω:1, 2, 3, 4 corresponding to R_b = 0,06; 0,04; 0,25; 0,01 m.

Differentiating equation (13) with MathCadi for ξ, we obtain the following value for the angular velocity of the tubers:

$$\dot{\xi}(t) = \frac{\omega}{2}(1 + \frac{3\cdot g\cdot(tg\theta - t)}{g\omega^2 R_{б}\sqrt{9\cdot(tg\theta - f)^2 + 1}}\cdot$$
$$\cdot\sin\omega t + arctg(3(f - tg\theta))). \quad (17)$$

In Fig. 6 we see the dependencies of the angle of introduction on the angular velocity and the radius of the potatoes (going from the equality $\psi_{в} = \arccos(\omega^2 R_{б} - 2\omega\dot{\xi}R_{б})/g)$.

It was determined that with the radius for the potatoes R_b = 0.06 m, and the angular velocity of rotation of the blade ω = 9,….,11 rad/s, the potatoes are thrown out at an angle of $\psi_{в}$ = 70,…,75^0 [13, 14, 16, 17, 18].

CONCLUSIONS

1. Existing technologies for digging potatoes, using traditional means do not properly break up the potato bearing soil to its full extent, especially when the soil is moist (soil sticks to the moving parts, thus greatly reducing the efficiency of the separation process. The way to improve the efficiency of this process is use a ploughshare- rotor blade system.
2. Examining the motion of the soil/potatoes mixture on the surface of the ploughshare we determine its optimal form and parameters. The optimal angle for the set of the plough is $\alpha = 12^0$ with at machine speed of V_H = 0,4 m/s. Increasing the machine speed and the ploughshare angle α leads to a dangerous accumulation of soil in front of the surface of the plough.
3. By mathematically modelling the motion of the potato producing soil, we obtained the theoretical dependency of its motion as it is lifted up on the surface of the ploughshare.
4. We made a mathematical model that characterizes the relative, reciprocal motion of the processed mixture on the surface of the rotor blade. As a result of the analysis, we determined that the necessary distance for the thrown potatoes is between 0,8 and 1,1 m. and that the optimal values are obtained for an angular velocity for the blade of V_0 = 3 m/s and a blade length l_1 = 0,44 m.

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Treatment of potato tubers before planting in a magnetic field

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Abstract. The results of research on the impact parameters of treatment of potato tubers in a magnetic field to change their biopotential and yield are presented. The optimum regimes of treatment were determined.

Key words: magnetic field, magnetic treatment of potatoes, magnetic induction, speed of the conveyor, biopotential.

INTRODUCTION

Currently, potato yields in Ukraine are low - (120-140) kg / ha. To improve the growing efficiency, a growing effort in the application of energy-saving technologies has been visible, including one the most promising, i. e. magnetic treatment of potatoes.

Magnetic treatment of potatoes compared with other electro-physical methods is a highly energy efficient and safe for staff method.

The determination of the parameters of a potato in a magnetic field, examination of the field's impact on the change of electro-physical parameters and yield of potatoes, will make it possible to substantiate constructional parameters and develop the equipment for magnetic treatment of potatoes.

The purpose of research was to increase potato yields by direct action of a magnetic field on them before planting.

MATERIALS AND METHODS

Theoretical study of a magnetic field's influence on the change of potato biopotential was conducted based on the theory of collisions.

Experimental study of the changes of biopotential in magnetic potato treatment was performed on the specially designed laboratory installation with electromagnets. Gradient magnetic field was created by four inductors, switched-opposite parallel. Magnetic induction in air gap inductor regulated DC voltage changes applied to the coil inductors. The magnitude of the magnetic induction was measured by teslameter. The speed of potatoes transfer through a magnetic field, created by inductors, was being changed by the frequency converter Delta VFD004EL43A. Platinum measuring and auxiliary electrode was put into potatoes and measured redox potential of the potato before the magnetic treatment and after it by pH-meter-millivoltmeter.

In the study of the influence of magnetic induction on the change of potato biopotential, magnetic induction in air gap inductor changed within 0 - 50 mT at the speed of the potatoes through a magnetic field 1.0 m / s, which corresponds to the speed of conveyors in the production lines treatment of potatoes before planting.

The study of the conveyor belt speed's impact at the magnetic treatment of potatoes on the change of biopotential was performed using the method of experiment planning. During the study, orthogonal central-composite plan was applied (Table 1) [1].

On the basis of one-factor experiments, the change was observed in magnetic induction of 15 ... 45 mT, as well as the values of top, bottom and core-level factors, the change of the conveinig speed limit was 0.5 ... 1.5 m / sec.

Field studies of potato variety "Lugovska" carried out under the scheme: 1-and variant (control) – the potatoes were grown without treatment in a magnetic field; 2nd option – before planting, potatoes were treated by in a magnetic field with magnetic induction of 13 mT; 3rd option – with magnetic induction of 20 mT; 4th option – with magnetic induction of 30 mT, 5-th option - with the magnetic induction of 45 mT.

Experiments were performed in fourfold repetition. Research areas, an area of 20 m^2, were located by the usual repetitions. Effect of magnetic treatment on potatoes was assessed by biometric parameters control and yield of plants.

RESULTS AND DISCUSSION

In potato tubers various chemical and biochemical reactions occur that are inherently mainly oxidation-reduction. Stimulation of a potato is associated with an increase in its velocity due to changes in activation energy caused by the action of Lorentz force on ions [2].

Changing the activation energy and causing the change of velocity of chemical reaction causes a change in potato biopotential. Using the equation of Van't Hoff-Arrhenius and Nernst it was found out that the change in magnetic field processing of biopotential was proportional to change in activation energy [3]:

$$\Delta БП = 2{,}3^2\,\frac{\Delta E_a}{zF}, \tag{1}$$

where: E_a – activation energy; z – charge of ion; F – Faraday number.

According to the theory of collisions, chemical effects of collisions depend on the kinetic energy of relative motion along the line of centers [4]. The magnetic treatment of potatoes as a result of Lorentz force changes the normal component of ion velocity v_n, (Fig. 1):

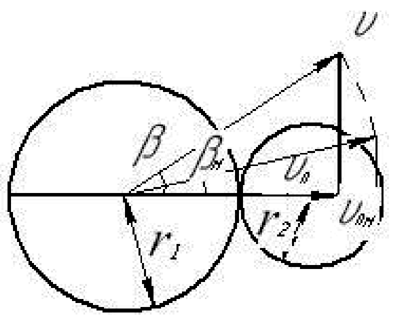

Fig. 1. Figure ion collisions

$$\Delta v_{nм} = v\cdot(\cos\beta\;\;-\cos\beta), \tag{2}$$

or

$$\Delta v_{nм} = r\cdot q\cdot B\cdot(\cos\beta\;\;-\cos\beta)\,/\,m, \tag{3}$$

where: r – radius of the circle on which the movement of the ion occurs; q – charge of ion, B – magnetic induction; m – mass of the ion, β_m and β – the angle between the velocity vector and the line connecting the centers of particles, respectively, with magnetic treatment and without magnetic treatment.

As follows from expression (3), changing the normal component of ion velocity depends on the magnetic induction, type of ions (their mass and charge) and number of the reverse (respectively angle β_m).

Due to changes in the normal component of the velocity of ions, changes occur in the kinetic energy of relative motion of particles along the line of centers:

$$\Delta E_{n\,м} = \frac{\mu\cdot\Delta v_{nм}^2}{2} + \mu\cdot v_n\cdot\Delta v_n\ , \tag{4}$$

where: μ – reduced mass of particles.

Subject to (3) the expression (4) will be rewritten as:

$$\Delta E_n = \frac{\mu\cdot K^2 B^2}{2} + K\cdot\mu\cdot v_n\cdot B, \tag{5}$$

where: K – coefficient, which depends on the type of ions and number of the reverse:

$$K = r\cdot q\cdot B\cdot(\cos\beta_м - \cos\beta)\,/\,m. \tag{6}$$

Then the biopotential change:

$$\Delta БП = \frac{2{,}3^2 K\mu}{zF}\left(\frac{KB^2}{2} + v_n B\right). \tag{7}$$

Studies have shown that it is possible to estimate change of activation energy and determine the effect of magnetic treatment appropriate for the change of biopotential. To do this, measure the redox potential of the potato before the magnetic treatment and after it, and compare their difference with the value of the expanded measurement uncertainty, which is 2 mV.

Dependence of biopotential change on magnetic induction in the magnetic treatment of potato at the speed of the conveyor 1 m/s is shown in Fig. 2. When changing magnetic induction from 0 to 30 mT, potato biopotential grows, and with further increase of magnetic induction – it falls. The dependence of potato biopotential on magnetic induction is described by the equation:

$$\Delta БП = -0{,}0272B^2 + 2{,}1362B. \tag{8}$$

Curves 2 and 3 (Fig. 2) show changes in potato biopotential, measured in two weeks and a month after magnetic treatment. As follows from the presented dependences, potato biopotential practically does not change within one month after treatment.

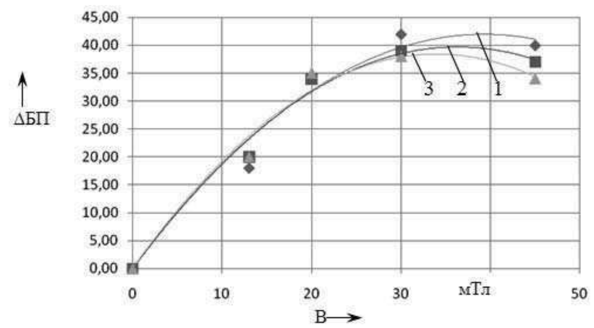

Fig. 2. Dependence of changes in biopotential caused by magnetic induction in the magnetic treatment of potatoes:
1 – first day of treatment, 2 – two weeks after treatment, 3 – one month after treatment

Table 1. Investigation of changes in potato biopotential after magnetic treatment

Number point	X_0	X_1	X_2	$X_1^/ = X_1^2 - a$	$X_2^/ = X_2^2 - a$	$X_1 X_2$	Energy dose, J • s/kg	$\Delta Б П$, mV
1	+	-	-	1/3	1/3	+	0,115	35
2	+	+	-	1/3	1/3	-	1,035	36
3	+	-	+	1/3	1/3	-	0,037	23
4	+	+	+	1/3	1/3	+	0,345	41
5	+	-	0	1/3	-2/3	0	0,058	26
6	+	+	0	1/3	-2/3	0	0,518	40
7	+	0	-	-2/3	1/3	0	0,46	39
8	+	0	+	-2/3	1/3	0	0,152	38
9	+	0	0	-2/3	-2/3	0	0,23	42

The measurement of conveying speed impact and energy dose needed in magnetic treatment of potatoes to change their biopotential was the planned method of the experiment (Table 1). Based on multifactorial experiment, regression equation was obtained for biopotential change, that for the 5% significance level has the form:

$$\Delta Б П = 24,12 + 1,44B - 19,66v + 0,57Bv - 0,027B^2, \quad (9)$$

where: v – velocity of the conveyor belt.

Dependence of changes in potato biopotential on magnetic induction and the speed of conveyor belt at the magnetic treatment is shown in Fig. 3.

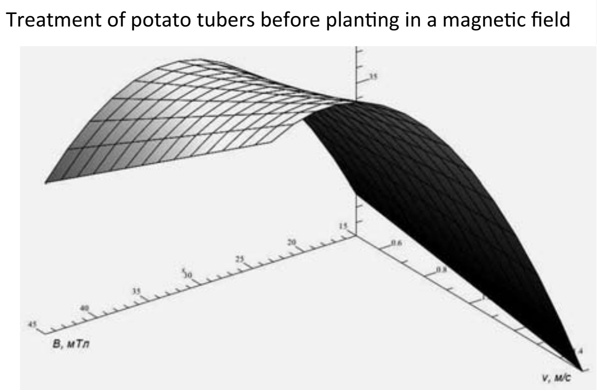

Fig. 3. Dependence of changes in potato biopotential on magnetic induction and the speed of conveyor belt at the magnetic treatment

The conducted multifactorial experiment made it possible to establish the dependence of potato biopotential on energy dose during treatment, which was determined by the formula:

$$D = \int \frac{B^2}{2\mu\mu_0 \rho v} dl = \frac{B_m^2 l}{6\mu\mu_0 \rho v}, \quad (10)$$

where: B_m – value of magnetic induction in the plane of the installation of magnets, l – the path that potatoes go in a magnetic field in the treatment, ρ – density of potatoes.

Dependence of potato biopotential change on energy dose during treatment is presented in Fig.4. As follows from the dependence, the biggest change in potato biopotential is observed at energy dose of 0.23 J • s/kg, which corresponds to the magnetic induction of 30 mT and the conveying speed of 1 m/s.

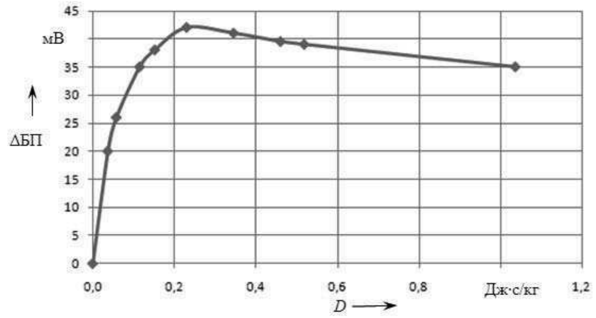

Fig. 4. Dependence of changes in potato biopotential on energy dose during treatment

The prescribed mode of magnetic treatment of potatoes causing change in their biopotential was tested by examining yield and biometric indices of potato plants after magnetic treatment in accordance with the known methods of field experiments [5].

As a result of field studies it was found out that the best biometric performance and yield of potatoes were obtained at the magnetic induction of 30 mT and speed of conveyor belt 1 m/s (dose of treatment 0.23 J • s/kg). When increasing or decreasing the dose of treatment, biometric parameters and yield of potatoes decreased, but remained higher compared to potatoes untreated in a magnetic field (Fig. 5).

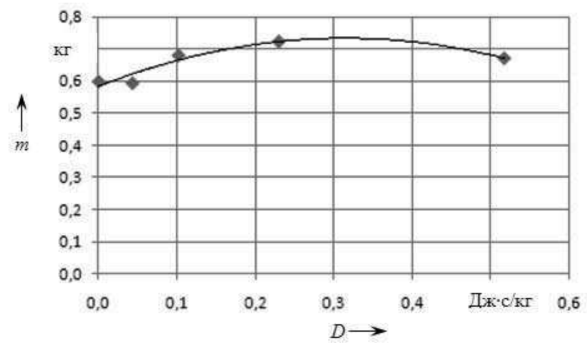

Fig. 5. Dependence of the average yield of potatoes bush from energy dose of treatment

On the basis of studies, electro-technological facility for magnetic treatment of potatoes was established, which includes conveyor and device for magnetic treatment of potatoes (Fig. 6). Device for magnetic treatment of potatoes consists of 4 pairs of permanent magnets based on NdFeB, laid parallel above and below the belt conveyor with variable polarity. Magnets are glued to steel plates, and the intervals between them are filled with textolite.

The transporter frame in the area of placement of device for magnetic treatment is made of stainless steel. Its drive is carried out by three-phase asynchronous electric motor via step-down reducer.

CONCLUSIONS

On the basis of the studies it was found out that the most appropriate mode of magnetic treatment of potatoes before planting is the magnetic induction at 30 mT at the fourfold repetition and the speed of conveyor belt 1 m/s. Yield of potatoes at magnetic treatment before planting increases by 17…21 %, quantity of commodity tubers increases by 15 %, the starch, vitamin C, dry matter content in potato tubers treated in a magnetic field increase by 3…4 %, and the concentration of nitrates is reduced by 6 %.

Treatment of potato tubers before planting in a magnetic field

Fig. 6. Electro-technological facility for magnetic treatment of potatoes

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Application of biomass-powered stirling engines in cogenerative systems

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Abstract. Due to the properties of different kinds of renewable energy as sources of energy for small farms in Podkarpackie province, cogenerative biomass technologies have proved the most suitable for its supplying. Special solutions based on direct combustion boiler coupled with biomass-powered Stirling engine are the most interesting. The characteristics and examples of use of cogenerative system based on Stirling engine are presented.

Key words: biomass use, CHP, cogenerative system, Stirling engine

INTRODUCTION

Limited resources of energy, risks connected with emission of pollutants and greenhouse gas and low efficiency systems of thermal energy transmission lines require exploration of other methods of generation, transmission and consumption of electric and thermal energy. One of the solutions of this problem is the idea of generating electric and thermal energy directly in a house. A special system of combined heat and power for the home (CHPH) is utilized in a single-family home [1, 2]. Application of CHPH improves the degree of thermal energy utilization and eliminates transmission loss of thermal and electric energy. In spite of lower efficiency of electric energy generation, the total efficiency of CHPH is higher than large electrical power systems. Combined heat and power for the home systems raise power engineering safety, reduce power demand and facilitate energy usage from renewable resources. As a source of primary energy a natural gas, liquefied gas, oil derivatives, biogas and biomass may be utilized.

Considering effectiveness of application of renewable energy sources in agricultural tourism farm several assumptions should be made [3, 4]. From the point of view of possibility of RES utilization, the most interesting is the case resulting from location, or ecological assumptions and also the lack of access to traditional direct energy carrier, network energy in particular. It can lead to the necessity of assurance of energy self-sufficiency in respect of electric and thermal energy delivery.

Combined Heat and Power (CHP) is the sequential or simultaneous generation of multiple forms of useful energy (usually mechanical and thermal) in a single, integrated system. Cogenerative systems enable production of thermal and electric energy in association with gas engine, Rankine engine, mictoturbine, Stirling engine and fuel cell. Rankine engine allows for utilization of discard energy with temperature above 100°C and offers power in range from 10kW to a few MW [5]. Cogeneration allows for an increase of total efficiency of system up to 85% in relation to primary energy. Furthermore, this ensures about 35% fuel energy economy in comparison with separable generation of energetic carrier [6]. The additional advantages are minimization of transmission loss in cooperation with distribution network and low emission of greenhouse gases. The reduction of CO_2 decreases by up to 0,5 kg per kWh produced energy. Modular installations enabling to utilize discard energy include, besides Rankine and Stirling engines, steam engine and helical steam engine. Systems utilizing chemical energy of biofuels and biogases for associated production of thermal and electric energy like gas engine, Elsbett engine, Ericsson engine allow for a considerable reduction of the cost of enterprise energy balance and greenhouse gases emmission.

The fundamental issue in using any energy source is its accessibility. In case of some biomass technologies, the natural sources and industrial wastes can be utilized. However, not all technologies tolerate each form of the biomass. Not too much efficiency of photosynthesis in comparison with other technologies of solar radiation processing cause the necessity to establish special plantations of energetic plants.

STIRLING ENGINE

Stirling engine processes heat into mechanical energy without explosive combustion process. The heat is supplied to working medium through the heating of the external wall of a heater. As a result of external heat provision, it is possible to supply the engine's primary energy practically from any source: wood, coal, biomass, oil derivatives. Stirling engine is composed of two cold and warm pistons, regenerative heat exchange and heat exchangers between working medium and external sources (Fig. 1).

The external combustion facilitates monitoring of combustion process and causes that the process is pure and more efficient. The essential part working in circulation is the regenerator that transfers heat from working medium flowed between the heating and cooling space.

The characteristic feature of Stirling engine is utilization of heat for heating up of working gas in the cylinder. The heat regeneration occurs under conditions of constant gas volume inside closed working space of the engine. Recovered heat in heat exchanger is used for heating running water and habitats in household. The theoretical cycle of Stirling engine operations is composed of a few thermodynamic processes (Fig. 2). During the Stirling process, the thermodynamic medium being ideal, the gas is subjected to four thermodynamic processes in turn. Stirling cycle is composed by constant volume heating process, isothermal expansion process, constant volume cooling process and isothermal compression process. As a heat source, mainly combustion gases derived from combustion process of fuels are utilized. Cycle efficiency depends on temperature difference between sources (T_H – T_L). Cogenerative systems with using of the Stirling engine are characterized by high electric and thermal

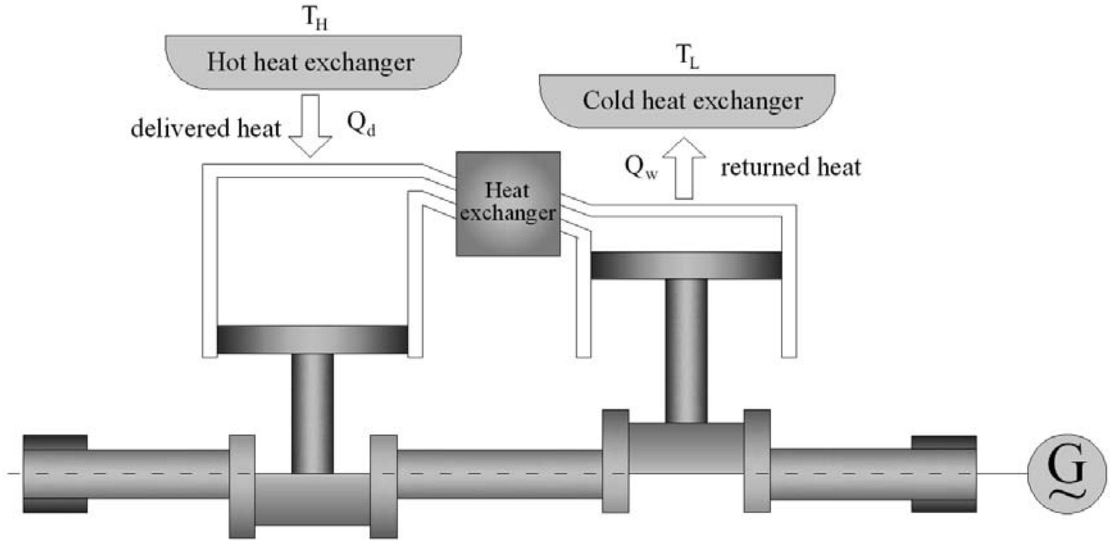

Fig. 1. Scheme of α-type Stirling engine [7]

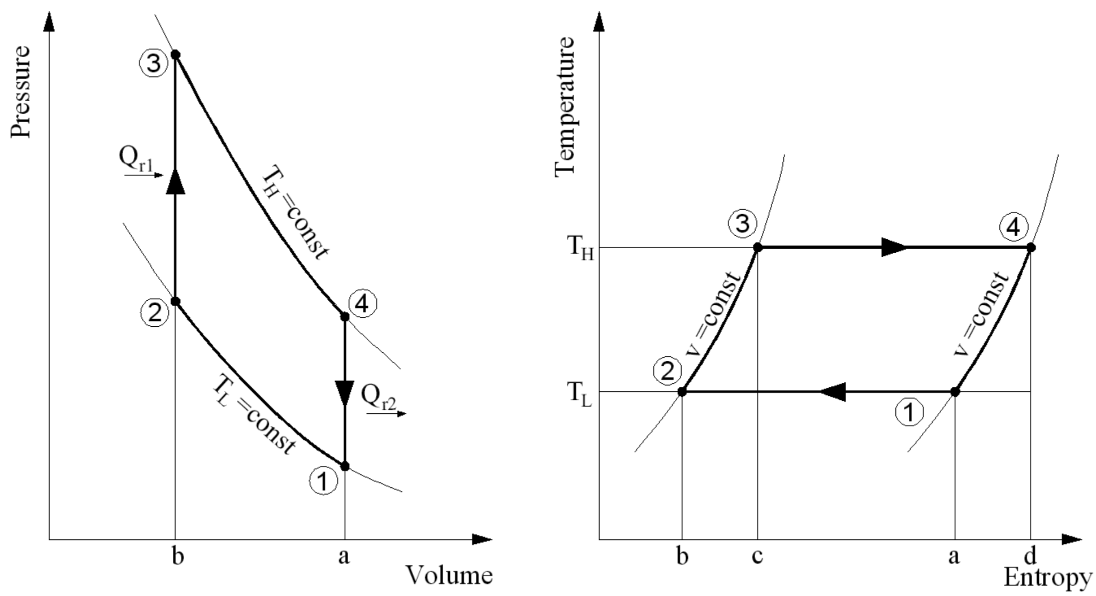

Fig. 2. The theoretical cycle of Stirling engine on pressure-volume (a) and temperature-entropy (b) coordinates

efficiency, adequately about 30% and 70% [8]. Their total efficiency reaches about 90%.

In the ideal cycle, heat is rejected and work is done on the working fluid during the isothermal compression process 1-2. For a fixed mass of working fluid, the amount of total work required for this process is represented by the area 1-2-b-a on the pressure-volume *(p-v)* diagram (Fig. 2a) and the amount of heat transferred from the working fluid, by area 1-2-b-a on the temperature-entropy *(T- s)* diagram (Fig. 2b). During process 2–3, heating at constant volume occurs, where the temperature is raised from T_L to T_H and the pressure increases. Area 2-3-c-b (Fig. 2b) represents heat addition. Next, the constant-temperature expansion process is done 3-4 where work is done by the working medium as heat is added. Area b-3-4-a (Fig. 2a) represents work and area c-3-4-d (Fig 2b) represents heat addition. The last process 4-1 represents constant-volume heat rejection process where no work is done and the rejected heat is represented by area a-1-4-d (Fig. 2b). Because more work is done by expanding gas at high temperature than it is required to compress the same amount of gas at a low temperature, the Stirling cycle produces a net amount of work. The net work is represented by area 1-2-3-4 (Fig. 2a). By the first law of thermodynamics, this is also the net amount of heat that must be added to the cycle to produce this work. This net amount of heat is represented by the area 1-2-3-4 (Fig. 2b).

During isochoric process heat delivered Q_{r1} and heat returned Q_{r2} are equal. Thanks to this, a constructional possibility exists to alternate delivering and returning the same quantity of heat from gas without using external heat sources. This task is realized by using regenerator, that accumulates heat during process 1-4. During the process 2-3 the same quantity of the heat is transferred back to gas.

Types, design, principles of work and state-of-the-art of Stirling engines are described in greater detail in literature [2, 9].

APPLICATION OF STIRLING ENGINE

Actually, Stirling engines are not very popular although they have a dominant position in the renewable energy technology. They are used as a power unit in solar dish collectors and convert solar energy with efficiency higher then photovoltaic. The most innovative Stirling engines at solar power technology are line β-type engines with no rotating parts, line generator, no bearings and lubrication system and very long maintenance-free time [10].

Other typical but still not very popular application of Stirling engine is CHP biomass combustion plant (Fig. 3). In Stirling engine over internal combustion engines the

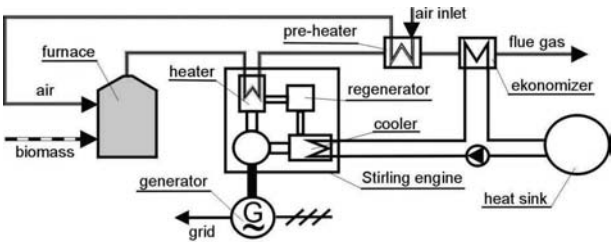

Fig. 3. CHP biomass combustion plant with Stirling engine

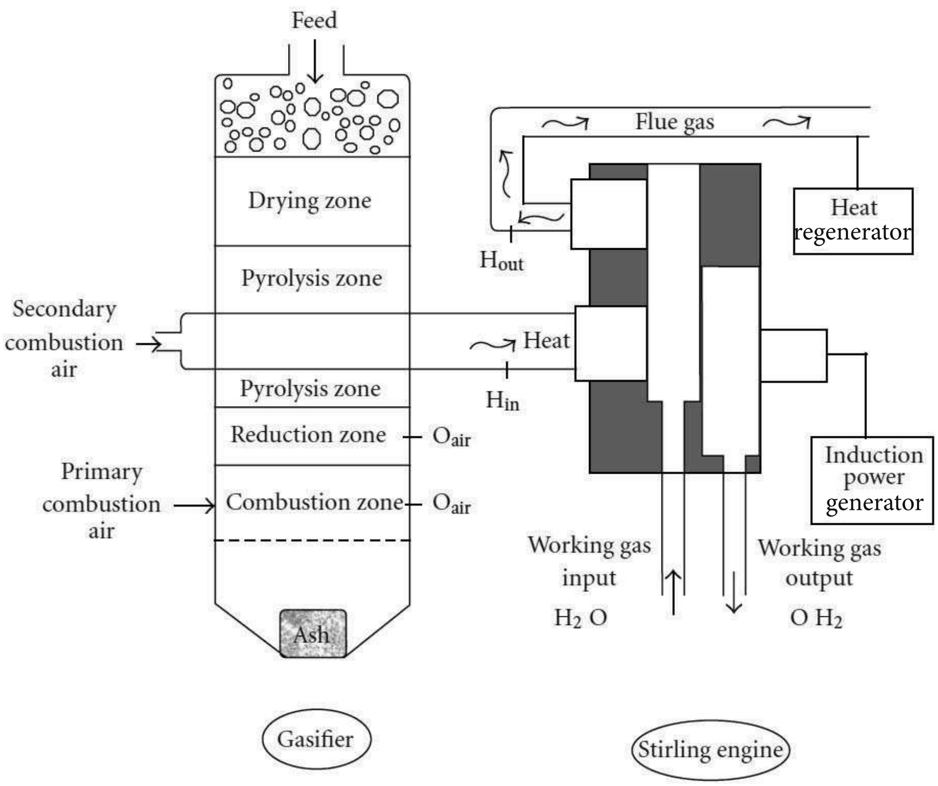

Fig. 4. Direct coupling of the updraft gasifier with a Stirling engine [12]

heat is not supplied to the cycle by combustion of the fuel inside the cylinder, but transferred from the outside through a heat exchanger. Consequently, the combustion system for a Stirling engine can be based on proven furnace technology, thus reducing combustion related problems typical of solid biomass fuels. The heat input from fuel combustion is transferred to the working gas through a hot heat exchanger at a high temperature typically between 680 °C and 780 °C [6, 11]. The temperature of the cooling water in a cold heat exchanger is (25–75) °C.

The more competitive than a large stand-alone plant are the small- scale direct integration of updraft gasifier with Stirling engine combustion system (Fig. 4). The flue gas produced by the synthetic gas combustion is piped directly to the heater head. The engine then will extract and convert the heat contained in the flue gas into electricity automatically. The heat input is proportional to the flow rate and temperature of the flue gas. The proposed technology allows for the use of solid biomass and generation of electric power of 25 kW.

CONCLUSIONS

A biomass-fuelled Stirling plant is an installation which converts biomass, in solid, gaseous or liquid form, into carbon neutral power and heat. The biomass-fuelled Stirling plant has many advantages. The modern cogenerative systems with Stirling engines are fully automated. The use of external combustion causes that the CHP systems engine plants are able to use a variety of low-value fuels, such as wood chips, low-methane biogas or sewage gas. A one-engine plant has a nominal capacity of 1 - 35 kW and 140 kW in multi-engine plant and up to four engines can be combined in individual unit [11]. For every ten units of energy presented in the fuel source, two units are converted into electricity and seven units are converted into heat. This enables close to 90% energy utilization, equal to primary energy savings of over 40% relative to using a heat-only boiler and power from the grid.

Especially interesting for undertakings connected with biomass processing are solutions based on the direct combustion furnace with the Stirling engine supplied with pellets or wood chips. So the implementation of the Stirling machine has been proposed in order to meet the demand of energy small farms. This task demands making specialized investigations of technical solutions applied in the Stirling engine and equipments for production and processing of the biomass.

Endorsement of the presented solution of biomass utilization in order to satisfy energetic needs of a small farm demands doing special research on the technical solutions applied in machines for production and transformation of wood-biomass. Technical solutions of machines for biomass processing were worked out and patented in Rzeszow University of Technology, and they are to be widely tested together with the biomass CHP system with the Stirling engine in cooperation with Lvov State Agricultural University within the framework of „The Program of the Transborder Cooperation Poland - Byelorussia - Ukraine 2007 - 2013" in the project entitled „Bioenergetics". For several years the Rzeszow University of Technology has presented constructional solutions of the machines for cultivation, production and processing of the biomass and technologies of utilization of municipal waste deposits as manure in established plantations.

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ECONTECHMOD. AN INTERNATIONAL QUARTERLY JOURNAL – 2012, Vol. 01, No. 2, 57–62

Influence of exhaust gas recirculation on the ignition delay in supercharged compression ignition test engine

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Abstract. The results of analysis of thermal cycle of the test engine are presented in the paper. The study focused on determining the ignition delay in compression ignition engine. The correlations available in literature, Hardenberg and Hase, Wolfer and Watson and Assanis were used to determine ignition delay. With the increase of the EGR the ignition delay has increased. It turned out that very often it is necessary to determine own ignition delay correlation.

Key words: ignition delay, combustion, modeling, engine

INTRODUCTION

Ignition delay is one of the most important parameters of diesel engines which will directly affect the performance, emissions and combustion. A number of investigations have been conducted to study the ignition delay of diesel fuel. The results showed that the ignition delay depends on fuel parameters and pressure, temperature and excess air fuel ratio.

Rodríguez and all [3, 2, 9] in their work the results of engine tests of biodiesels obtained by transesterification of palm oil and rapeseed oil and with fossil diesel fuel as a reference have presented. Palm oil and rapeseed oil biodiesel gave shorter ignition delay than fossil diesel fuel due to the higher cetane number for the biodiesels. The ignition delay data were correlated as a function of the equivalence ratio, the mean cylinder pressure and mean temperature over the ignition delay interval. A comparison was made with other available correlations [3]. In their study the correlation for predicting the ignition delay of two biodiesels in a direct injection diesel engine was developed. The start of combustion was estimated using the pressure rise curves. At each condition, ignition delay was determined as the difference between start of injection and start of combustion. The new proposed correlations for biodiesels have been compared against the Watson and Assanis correlations. The comparison of results showed that the new correlations predict ignition delay for biofuels better than the available correlations for diesel fuel. It is therefore concluded that the new correlations significantly improve the ignition delay predictiveness for biodiesels in a wide range of parameters such as the cylinder pressures and temperatures at injection, the equivalence ratio, and the engine load and speed conditions [3]. Alkhulaifi and Hamdalla [4] in they work results of studies of ignition delay are presented. Watson, Assanis, Hardenberg and Hase correlations have been developed based on experimental data of diesel engines. However, they showed limited predictive ability of ignition delay when compared to experimental results. The objective of the study was to investigate the dependency of ignition delay time on engine brake power. An experimental investigation of the effect of automotive diesel and water diesel emulsion fuels on ignition delay under steady state conditions of a direct injection diesel engine was conducted [4, 12]. The ignition delay experimental data were compared with predictions of Assanis and Watson ignition delay correlations. The results of the experimental investigation were then used to develop a new ignition delay correlation. The newly developed ignition delay correlation has shown a better agreement with the experimental data than Assanis and Watson when using automotive diesel and water diesel emulsion fuels especially at low to medium engine speeds at both loads. In addition, the second derivative of cylinder pressure which was the most widely used method in determining the start of combustion was investigated [4, 16, 17]. Zou and all in their work the ignition delay of a dual fuel engine operating with methanol ignited by pilot diesel have investigated. The experimental results showed that the polytrophic index of compression process of the dual fuel engine decreases linearly while the ignition delay increases with the increase in methanol mass fraction. Compared with the conventional diesel engine, the ignition delay increment of the dual fuel engine was about 1.5° at a methanol mass fraction of 62%, an engine speed of 1600 r/min, and full engine load [11]. With the elevation of the intake charge temperature from 20°C to 40°C and then to 60°C, the ignition delay of the dual fuel engine decreases and was more obvious at high temperature. Moreover, with the increase in engine speed, the ignition delay of the dual fuel engine by time scale (ms) decreased clearly under all engine operating conditions. However, the ignition delay of the dual fuel engine increased remarkably by advancing the delivery timing of pilot diesel, especially at light engine loads [11, 24, 26]. Liu and Karim [13] changes in the physical and chemical processes during the ignition delay period of a gas-fueled diesel engine (dual-fuel engine) due to the increased admission of the gaseous fuels and diluents has examined. The extension to the chemical aspects of the ignition delay with the added gaseous fuels and the diluents into the cylinder charge was evaluated using detailed reaction kinetics for the oxidation of dual-fuel mixtures at an adiabatic constant volume process while employing n-heptane as a representative of the main components of the diesel fuel. The extension to the chemical process of the ignition delay, which results from the chemical interactions between the diesel and gaseous fuels, was the main rate-controlling process during the delay period of the dual-fuel engine. The extent of the extension to the ignition delay period depends strongly on the type of the gaseous fuel used and its concentration in the cylinder charge [13]. In spark ignition engines, under defined conditions, a self-ignition of the air-fuel mixture can occur, too [15, 18]. This phenomenon is known as knock combustion [19, 22].

Many researches around the world are involved in the modeling of the process of combustion in compression ignition engines [23, 28, 14, 18]. It is advanced computer programs that are used for this purpose, which serve for solving flows in combustion engine chambers of any geometry by numerical methods. These are programs belonging to the fluid mechanics field, where numerical methods are employed for solving CFD (Computational Fluids Dynamics) problems. One of them is AVL Fire.

THEORETICAL APPROACH

The ignition delay is the time between the start of injection and the start of combustion. It is widely accepted that the ignition delay has a physical and a chemical delay. The physical delay is the time required for fuel atomization, vaporization and mixing with the air, whereas the chemical delay is the pre-combustion reaction of fuel with air [1]. Ignition delay in diesel engines has a direct effect on engine efficiency, noise and exhaust emissions. A number of parameters directly affect the ignition delay period, among them cylinder pressure and temperature, swirl ratio and misfire. In addition to these effects the recent trend of changing fuel quality and types has a great effect on ignition delay. Experimentally, the start of ignition is mainly determined by the first appearance of visible flame on a high speed video recording [5], or sudden rise in cylinder pressure or temperature caused by the combustion [6, 25, 27].

In the literature there are many correlations for predicting ignition delay. They exist as a function of engine and charge parameters. This correlation can be written of the form:

$$\tau_{id} = Ap^{-n}\exp\left(\frac{E_A}{RT}\right) \tag{1}$$

where: E_A – apparent activation energy for the fuel auto ignition process, R – universal gas constant, A and n – constants dependent on the fuel.

The ignition delay is defined as the time between the start of fuel injection and the start of detectable heat release [1]. The ignition delay is a function of mixture pressure, temperature, excess air ratio. In an engine, pressure and temperature change during the delay period due to the compression resulting from piston motion. To account for the effect of changing conditions on the delay the following empirical integral relation is usually used [1]:

$$\int_{t_{si}}^{t_{si}+\tau_{id}}\left(\frac{1}{\tau}\right)dt = 1, \tag{2}$$

where: t_{si} – the time of start of injection, τ_{id} – the ignition delay period, τ - the ignition delay at the conditions pertaining at time t.

Well-known correlation describing the ignition delay is formula developed by Hardenberg and Hase for the duration of the ignition delay period in DI engines [2]:

$$\tau_{id} = \left(0,36+0,22c_m\right)\exp\left[E_A\left(\frac{1}{RT}-\frac{1}{17190}\right)\left(\frac{21,2}{p-12,4}\right)^{0,63}\right], \tag{3}$$

where: τ_{id} – ignition delay in crank angle degrees (CA), T – temperature in K, p – pressure in bars. E_A – the apparent energy activation, c_m – the mean piston speed (m/s), R – the universal gas constant (8.3143 J/molK).

The activation energy is given by:

$$E_A = \frac{618840}{CN+25}, \tag{4}$$

where: CN – the fuel cetane number,

Another correlation proposed Wolfer [9], Watson [10]:

$$\tau_{id} = 3,45\frac{\exp\left(\frac{2100}{T}\right)}{p^{1,02}}, \tag{5}$$

where: p – pressure, T – temperature.

The correlation proposed by Assanis [7] is a function of equivalence ratio, with a pre-exponential factor of 2.4

that considers the equivalence ratio variations (from 2.6 to 3.8 for the combined pre-exponential factor) as opposed to the Watson correlation where it is fixed at 3.45. This constant value used by Watson would translate into =0.116:

$$\tau_{id} = 2,4\frac{\exp\left(\frac{2100}{T}\right)}{p^{1,02}\varphi^{0,2}}. \tag{6}$$

In AVL Fire the ignition delay is calculated on the basis of correlation [8]:

$$\tau_{id} = 4,804\cdot 10^{-8}\left(N_{O_2}^{u,M}\Big|_{u,M}\right)^{-0,53}\left(N_{Fu}^{u,M}\Big|_{u,M}\right)^{0,05}\left(\overline{\rho}^{u}\right)^{0,13} e^{\frac{5914}{T^u}}$$

where: mole fraction of species (O_2, fuel) is in mol/m^3, temperature in K, density $\overline{\rho}^u$ in kg/m^3

THE OBJECT OF INVESTIGATION

Modeling of the thermal cycle of an auto-ignition internal combustion engine in the AVL FIRE program was carried out within the study. The object of investigation was a 6CT107 turbocharged auto-ignition internal combustion engines fed with diesel oil, installed on an ANDORIA-MOT 100 kVA/ 80kW power generating set in a portable version.

Engine specification:

- CI 6-cylinder engine, supercharged,
- displacement 6.54 dm^3,
- rotational speed 1500 rpm,
- crank throw 60.325 mm,
- cylinder bore 107.19 mm,
- connecting-rod length 245 mm,
- compression ratio 16.5.

The computational grids used in modeling is presented in figure 1. Computations were conducted for the angle range from -180° CA before TDC to 180° CA after TDC.

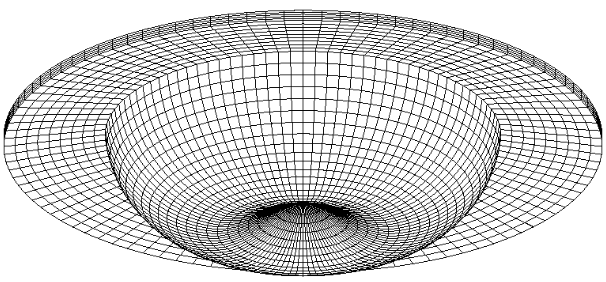

Fig. 1. The computational grid for combustion chamber modeling in TDC

The grid of the modeled combustion chamber of the 6CT107 test engine consisted of nearly 36000 computation cells. Two-layered wall boundary layer was considered.

Table 1. Modeling parameters

Engine rotational speeds	-	1500 rpm
Cylinder bore	-	107.19 mm
Crank throw	-	60.325 mm
Connecting-rod length	-	245 mm
Initial pressure for 180° CRA before TDC	-	0.16 MPa
Initial temperature for 180° CRA before TDC	-	310 K
Injection angle	-	-9° CA before TDC
Injected fuel mass	-	0.0735 g/cycle
Injection duration angle	-	20° CA
Fuel temperature	-	330 K
FIRE program's sub-models		
Turbulence model	-	k-zeta-f
Combustion model	-	Coherent Flame ECFM-3Z Model

The ECFM (Extended Coherent Flame Model) model [8] was developed specially for modeling the combustion process in a compression ignition engine. The CFM has been successfully used for modeling the process of combustion in spark ignition engines. The ECFM-3Z model belongs to a group of advanced models of the combustion process in a compression ignition engine. For several years it has been successfully used, constantly modified and improved by many researchers. Together with turbulence process sub-models (e.g. the k-zeta-f), exhaust gas component formation, and other sub-models, they constitute a useful tool for modeling and analysis of the thermal cycle of the compression ignition internal combustion engine. This model is based on the concept of laminar flame propagation with flame velocity and flame front thickness as the average flame front values. It is also assumed that the reactions occur in a relatively thin layer separating unburned gases from the completely burned gases [8]. The combustion model for the self-ignition engine has been complemented with the unburned product zone. The exhaust gas contains unburned fuel and O_2, N_2, CO_2, H_2O, H_2, NO, CO. The fuel oxidation occurs in two stages: the first oxidation stage leads to the formation of large amounts of CO and CO_2 in the exhaust gas of the mixture zone, at the second stage in the mixture zone exhaust gas, the previously formed CO is oxidized to CO_2 [20, 21].

RESULTS AND DISCUSSION

The paper presents results of 3D modeling of engine thermal cycle operating at a constant rotational speed.

The work investigates the influence of EGR on engine operating parameters, on heat release rate and ignition delay. The study was conducted for constant injection timing and load. Research engine is supercharged engine. After the validation process of the model were started modeling. Highly compatible modeling and experimentally obtained results (Fig. 2) was received. Calculated engine efficiency is the gross efficiency, the modeling does not include charge exchange loop.

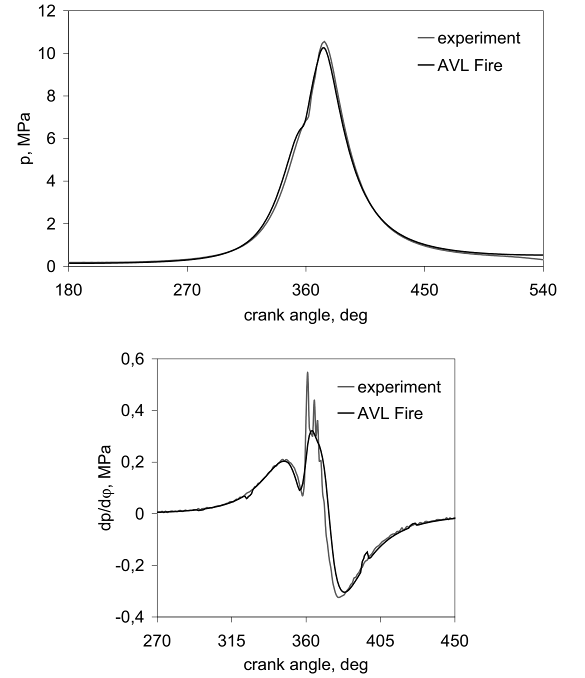

Fig 2. Result of model validation, traces of pressure and dp/dφ.

Figure 2 shows the comparison of engine cylinder pressure obtained through the real engine indication and modeling. Satisfactory agreement of these curves (p and dp/dφ.) at this point of engine work was achieved.

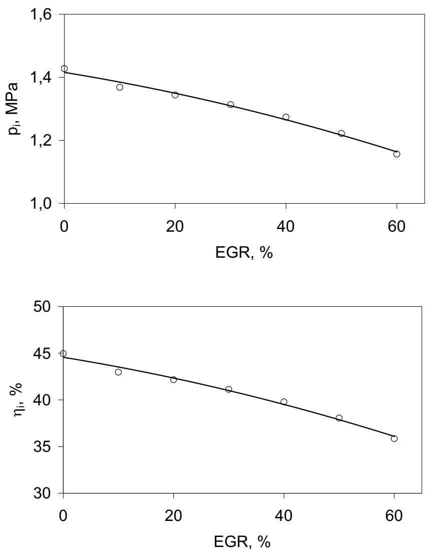

Fig. 3. Mean indicated pressure and indicated efficiency

Figure 3 shows the influence of EGR on the mean indicated pressure and indicated efficiency of the test engine. At the time of increase the participation of the EGR mass fraction of fuel injected into the cylinder was constant. At 60% share of the EGR the biggest drop in efficiency was received, and it reached a value of 36%. Similarly, the value of indicated pressure was decrease to value equal 1.16 MPa. There has not been optimization of the thermal cycle of the test engine.

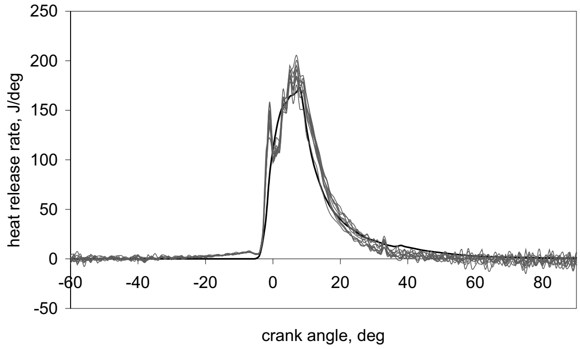

Fig. 4. Comparison of traces of heat release rate taken from real engine (set of red traces) and modeling (black)

Figure 4 shows a comparison of the rate of heat release curves. One line represents heat release rate of modeled engine and the others traces were obtained on the basis of experimental studies. The curves of heat release rate were used to determine the ignition delay. The algorithm for determining the ignition delay was presented in the literature review.

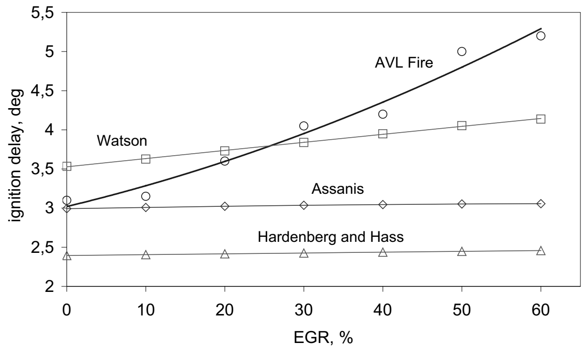

Fig. 5. Ignition delay lines calculated on the basis of correlations and determined on the basis of modeling results

Figure 4 shows the lines for ignition delay calculated using Hardenberg and Hase, Watson and Assanis correlations and determined on the basis of modeling results. In conditions without EGR, the closest value of ignition delay was obtained by using of the Assanis correlation. With the increasing of the recirculated exhaust gas participation, the ignition delay increased, which is consistent with results obtained by other authors. The results obtained with the use of Hardenberg and Hase and Assanis correlation did not give satisfactory results.

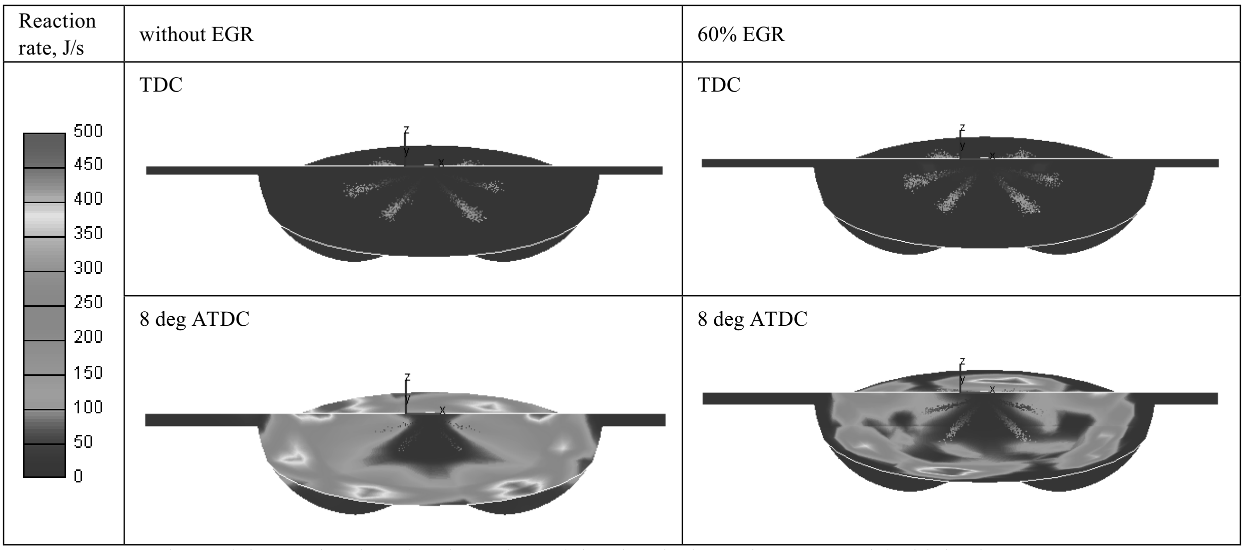

Fig 6. Cross sections of the combustion chamber. View of the chemical reactions rate and fuel injection process

With the increase of the EGR to 60% the ignition delay value has increased from 3.1 to 5.2 deg.

Figure 6 shows the cross sections, in two planes, of the combustion chamber. The reaction rates of combustion in the modeled combustion chamber are presented. It is clear that in the case with EGR the space covered by combustion process in the combustion chamber is smaller than in the case without recirculation. This is due, inter alia, by the ignition delay.

CONCLUSIONS

The results of analysis of thermal cycle of the test engine are presented in the paper. The study focused on determining the ignition delay in compression ignition engine. Ignition delay is one of the most important parameters of diesel engines which will directly affect the performance and emissions. In order to determine this parameter, the correlations available in literature were used. The ignition delay on the basis of modeling results was determined, too. It turned out that, in this case, these correlations did not give satisfactory results. With the increase of the EGR to 60%, the ignition delay value increased from 3.1 to 5.2 deg, in the model test engine.

Based on the literature study it can be said that other authors also stated that these universal correlations usually do not give the expected results. Often it is necessary to determine the correlation by defining ignition delay.

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Use of GIS systems in the construction of hydraulic model of networks

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Abstract. This article presents the use of GIS system for the construction of a hydraulic model in the network enterprise. The model has been built on the basis of data associated with the objects existing in the network and with their spatial relations. The data describing the network objects are usually transferred from existing technical documentation. The local stocktaking of networks is carried out in case of any doubts regarding data update status. The preparation of properly processed data, as well as verification of their correctness while entering them into a database is the most difficult and labour consuming phase of network modelling. A properly configured network model should incorporate at least the following features: the possibility to perform comprehensive analyses of the existing system functioning as well as analyses of the system modernization and extension variants in order to optimize technical solutions.

Key words: GIS, hydraulic model, bit map, vector map.

INTRODUCTION

Since the launch of the first GIS systems (Geographic Information Systems) in early 1960s in Canada up to the present time, the number of their users increased dramatically. Their popularization was possible mainly as a result of the development in the scope of information technology and public Internet access. The methods have been created together with technical progress in order to enable the access to bit maps by means of websites, data transfer in network and finally the creation of and the access to vector maps.

GIS system is defined as an organized set consisting of hardware, software, spatially referred data and its users. The tasks of the system are as follows: acquisition, retrieval, processing, analysis and visualization of all geographical data.

The multilayer structure of graphical data is the basic feature of GIS technology. The data collected in GIS system can be illustrated in the form of editable thematic layers (Fig. 1). This solution makes it possible to assign a set of attributes to determined layer and to display only those selected by the user.

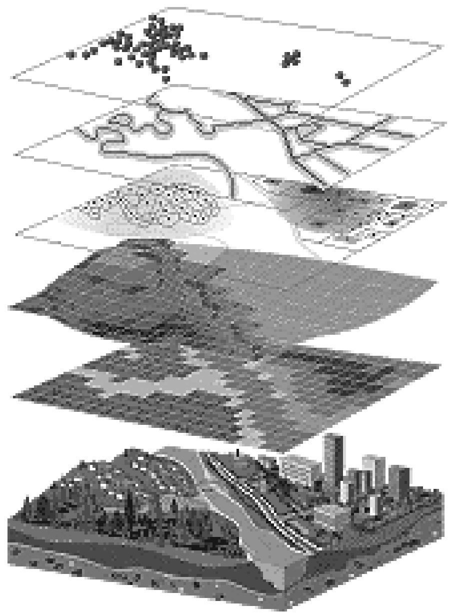

Fig. 1. Diagram illustrating an area subdivision by means of editable layers [19]

The specialized Geographic Information Systems (GIS) find a wide range of applications facilitating the decision making processes, reducing the period of time required to perform a task, performance of routine tasks associated with network inventory in network enterprises without necessity to spend several hours in the company archive of technical documentation [8, 12, 14]. The research in the scope of time saving indicated the savings in individual fields of the enterprise activity achieved as a result of the use of GIS systems, as illustrated in Table 1.

Tab. 1. Work time required for the conducting of activity in individual areas in Yokosuka City Waterworks Bureau enterprise [13]

The scope of enterprises activity	*Annual number of hours before GIS introduction*	*Annual number of hours after GIS introduction*	*Time saving [hours] [(%)]*
Water recipients service as a result of complaints	2200	600	1600 (73%)
Designing of networks	2500	700	1800 (72%)
Works associated with water supply shortage	2500	700	1800 (72%)
Granting of permits for the use of water supply systems	1800	550	1250 (69%)

A continuous improvement of the Geographic Information Systems is associated with the use of advanced mathematical possibilities supported by specialized databases. One of the most important tasks to be performed by network enterprises is to ensure the management of the whole network operation in a rational manner. However this task is not easy due to the size and extensiveness of the network as well as the spectrum of materials used for its construction and diversification of working parameters of individual fragments of this network.

ACQUISITION AND PROCESSING OF DATA REQUIRED FOR MODELLING

The network enterprises perform many tasks, among others associated with the operation, overhauling and extension of the network as well as with its inventory. GIS systems are an excellent tool designed for execution of various analyses represented in the form demanded by the user and for the disclosure of potential problems before they progress to serious symptoms disturbing correct operation of the network. In course of the creation of GIS database, only the latest information describing the factual state of the network is entered. The local stocktaking of networks is carried out in case of any doubts. The age of the documentation collected in the enterprise archive is diversified and its technical condition is sometimes unsatisfactory. It happens that the technical condition of the network illustrated in the technical documentation significantly deviates from its factual condition. The network inventory systems are provided in order to make it possible to quickly process and analyze the recorded data spatially associated with map as well as to make the decision in a manner adequate to existing situation [3, 9, 10].

The software available on the domestic and global market is sufficient to support the operation processes, to enable the measuring data support and the integration with AM/FM (Automated Mapping/Facilities Management) and SCADA (Supervisory Control And Data Acquisition) systems. Therefore it is possible to use the digital or vector maps only with background bitmap for the visualization of the network layout as well as the integration of 3D data and descriptive network objects, network operation status and the works in progress [15, 18].

The majority of GIS systems is equipped with the functions enabling the execution of economic – spatial analyses in order to compare the costs of various variants of network extension and to evaluate the impact of intended construction of the network on hydraulic and reliability characteristics of the whole system. The purpose of the creation and implementation of the system is [5, 9]:

- to collect the data in single point in order to expedite decision making process;
- to increase the efficiency of business processes, exploitation works as well as to identify the locations of failures and their elimination;
- to increase the efficiency of engineering department and emergency service operation;
- to improve the supervision over the time of works carried out in the field;
- to furnish a complete and updated database for network operations parameters in order to create the modelling system based on that database.

The construction of a complete GIS system needed for mathematical model can be subdivided into several phases [1, 9]:

- preparation and elaboration of updated documentation required for the creation of database;
- digitalization of principal maps with S and U patch in the network presence location;
- data entry, verification and updating by the personnel employed in an enterprise, most frequently by employees of engineering departments (local stocktaking of networks is carried out in case of any doubts);
- ordering, analysis and elaboration on the basis of entered data and information from technical documentation, preparation of data for modelling by means of properly simplified methods used to describe individual objects.

As early as 15 year ago, the designers commenced the creation of electronic engineering drawings by means of computer software e.g. AutoCad or similar type. The preparation of the technical documentation in hardcopy format and in electronic version is mandatory in major part of enterprises. The laws of Poland contain the technical (geodetic) manuals determining how to create the maps and information recorded therein. The principles in this scope have been established in order to eliminate the problems associated with maps preparation at an

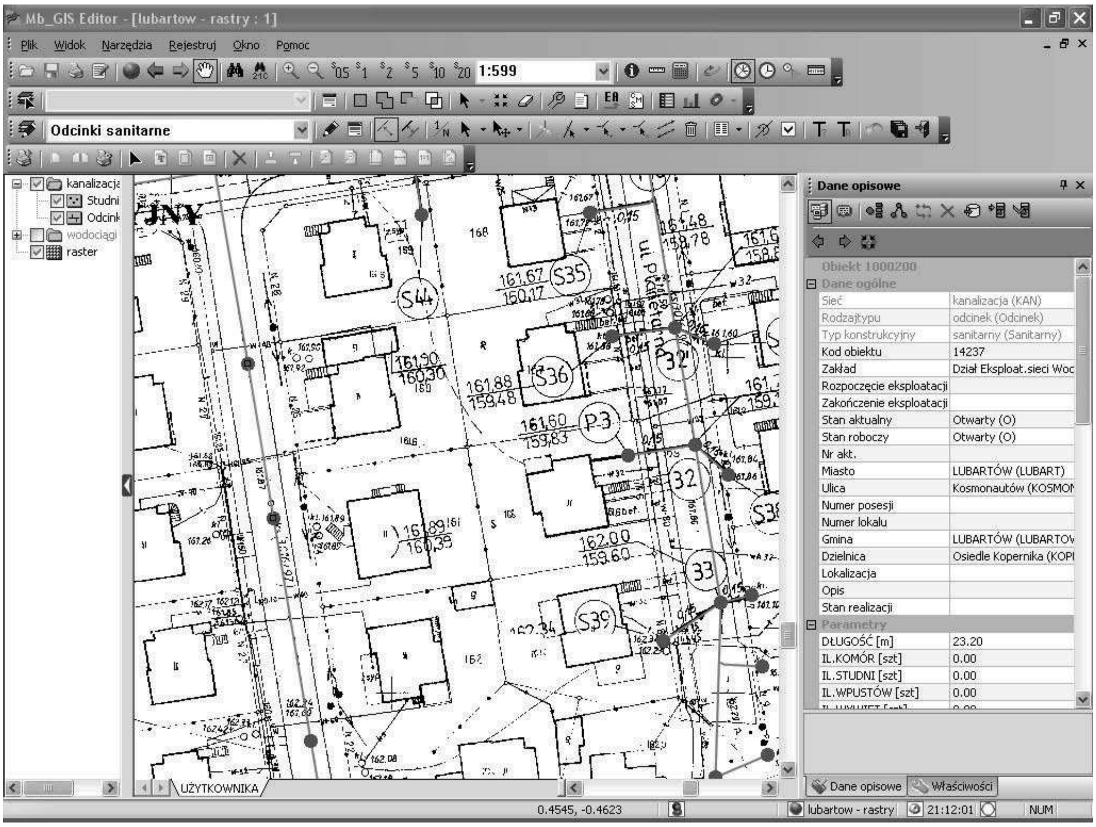

Fig. 2. The layout of network in the connection of oriented graph of the network (3D data) with descriptive data in Mb_GIS Edytor program using a bit map [16]

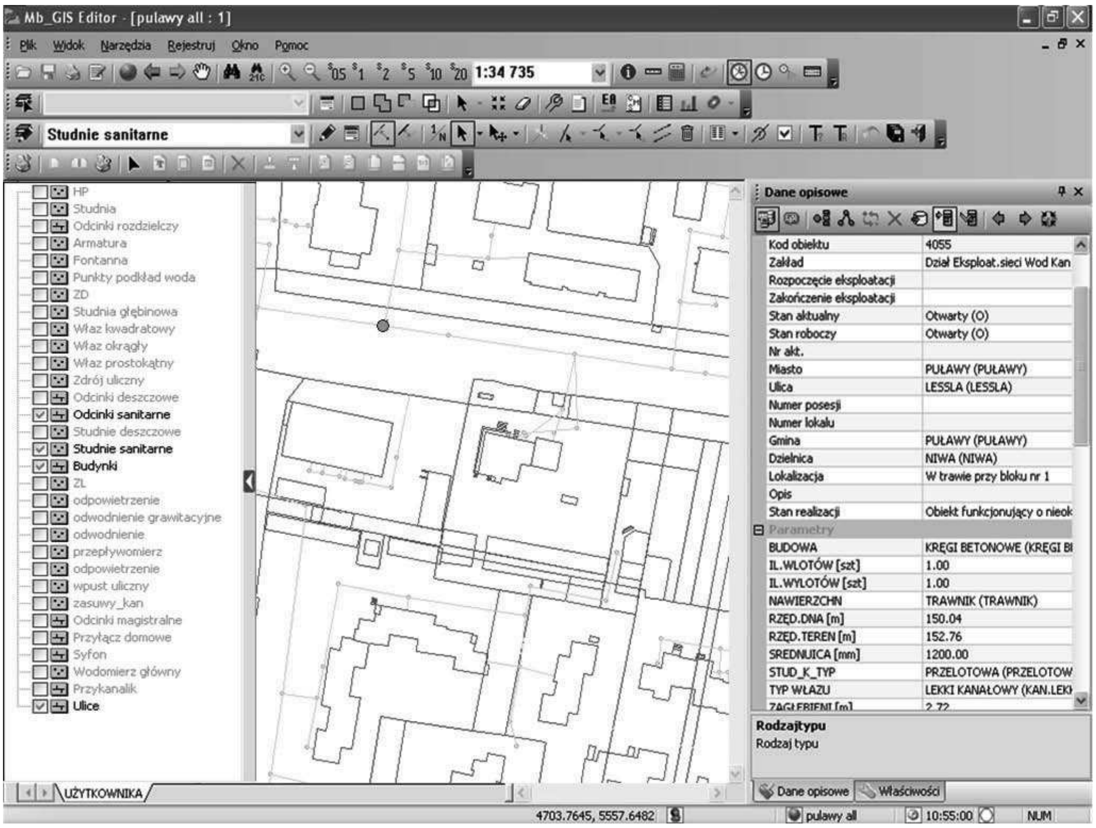

Fig. 3. The layout of network in the connection of oriented graph of the network (3D data) with descriptive data in Mb_GIS Edytor program using a vector map [2]

individual discretion or with the use of symbols conforming with regional habits. However, despite the use of GIS system in various disciplines, there are still no uniform standards and guidelines describing an unified approach to the creation of electronic versions of technical documentation [6, 17]. Most commonly encountered problems associated with the creation of electronic versions of technical documentation are:

– creation of the whole drawing in one layer only (usually "0") and diversification of individual elements by means of various thickness of line;
– lack of colour concept for drawings presented in geodetic manuals for the creation of principal maps;
– individual drawings are drawn in various scales, instead of 1:1;
– use of various styles and sizes of fonts;
– use of diversified nomenclature and symbols;
– drawing of networks in a manner not always conforming with media flow direction.

NETWORK MODEL BASED ON GIS SYSTEM

A system enabling the use of digital maps in connection with database by several users simultaneously is essential for a network enterprise. The use of vector maps and the display of network geometry shall be possible in an automatic mode, with possibility of the selection of a background bitmap (Fig. 2), a vector map (Fig. 3) or an orthophotomap [4] by the user in accordance with actual needs.

The network objects database contains detailed information about descriptive data, for individual network objects and their spatial relations. The Geographic Information System created in an appropriate manner makes it possible to collect the information about the networks at the same place and its proper presentation. Thanks to the introduction of insignificant corrections and simplifications in the description of some network objects, GIS system can be used as data source for the execution of computer simulations of the network operation.

The computer analyses in case of sewage network can be carried out [7, 11]:

– to determine the correctness of network structure described in the system,
– to simulate the runoffs,
– to determine the throughput of severs,
– to determine the level of severs filling.

The scope of analyses in case of water supply networks is similar to the scope of analyses in case of sewage networks (with consideration of changed medium transported by the network):

– to determine the correctness of network structure described in the system;
– to determine the sections of the network with insufficient values of flow rate;
– to determine the areas to be modernized in order to eliminate water stagnation;
– to determine the areas to be provided with closures in order to achieve an insignificant change of flow direction.

CONCLUSIONS

The creation of an oriented graph using the network objects parameters described with appropriate accuracy is the most labour consuming and the most difficult phase of the mapping of a real network system. Any erroneously entered data from GIS database make any accurate representation of the network operation impossible and contribute to the falsification of parameters.

The simulations of the network operation by means of properly created mathematical models are carried out to support the problems solution and to facilitate the efficient functioning of network enterprises. The basic condition to be met by the mathematical models used for this purpose is to represent really existing network features validated through the previous verification of GIS system data and their confrontation with reality.

Considering the measuring system and monitoring (existing in an enterprise) in the computer analyses of network operation, the tasks of individual units in this enterprise can be performed in a more efficient manner in the following scope:

– modernization and extension of networks – assessment of the impact of intended structures and their diameters (in design phase) on operation of the whole network;
– network operation – checking for possibility of additional loading of the network without necessity of its extension; the assessment of failure consequences associated with a sever out of service, the assessment of network utilization degree – on the basis of a network (e.g. sewage network);
– recording – control of the correctness of network data entries.

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Mathematical modelling of nonstationary electromechanical processes in Coaxial-Linear Engine

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Abstract. The mathematical model of the electromagnetic and mechanical processes is developed in a coaxial-linear engine with massive magnetic conductors.

Key words: linear engine, massive magnetic conductor, electromagnetic and mechanical change.

INTRODUCTION

Application of electromechanical impulse systems in the different machine and device processes involves the use of alternating motion. For its realization the coaxial-inductive engines can be used. Due to constructive characteristics they displaced engines based on progressive rotation with digital systems of executive mechanisms.

During design of electro-technical devices it is necessary to look over quite a large quantity of variants for choosing necessary construction, which as a rule takes a lot of time, material and power resources. Therefore, there is a need to work out the mathematical models which will adequately display the processes within the examined devices and also create calculating algorithms and program modules based on them. This approach will make the projecting visibly quicker and cheaper [6, 7].

Nowadays, the most widely applied methods for the calculation of electromagnetic fields are: method of final differences (MFD), method of final elements (MFE), methods based on integral equations or on the theory of chains, and combined methods as well, because they involve the advantages of different methods and are free from defects [1, 8]. Choosing the numerical method the characteristics of research object (in our case the characteristics of electromagnetic system of linear engine) must be considered.

In comparison with CLE, the use of MFD and MFE for modeling connected electromagnetic and mechanical processes cannot be defined as rational because they possess a row of disadvantages (artificial limitation of calculated range, sampling of circumjacent space etc.). Therefore, during the analysis of electromagnetic processes in CLE the most suitable is the method of integral equations for the magnetic field sources: eddy current and linked current of magnetization on the border between steel and air [2, 3, 5, 8].

In the work [9] the mathematical model of electromechanical process in CLE was suggested, where the magnetic circuit was supposed to be constructed of separate bars. This allowed for representing of electromagnetic force in square form with respect to instantaneous counts of currents in puttees and it made modeling significantly easer. But fabricating of magnetic circuit for the similar devices presents a difficult technological problem. A variant for its solving is the fabrication of massive magnetic circuit that requires consideration of eddy current influence on the electromechanical process in the electro drive.

The goal of the work is to work out the mathematical model of the

nonstationary electromechanical process in CLE with the massive magnetic circuit and to propose the algorithm for its numerical realization. The analysis of the influence of material characteristics of CLE constructive elements was performed. Also, the law was analyzed of the influence of voltage changing on the stator relatively to the force-characteristic of engine.

STATEMENT OF THE PROBLEM

In Figure 1.1 *a*, a simplified scheme of CLE is shown which consists of co-axially arranged circular reels and toroidal steel bodies. Each puttee consists of identical reel which connected with next one in such a way that their field is active. We will designate the quantity of reels which stator and inductor puttee consists of as N_{W_1}, N_{W_2}, respectively. We will designate the quantity of winds in each reel of stator and inductor as w_1, w_2. Puttee of the inductor feeds from the source of constant voltage $u_1 = const$, and puttee of the stator feeds from the frequency transformer with voltage $u_2 = u_2(t)$.

One should take that geometrical parameters and also electrical and magnetic characteristics of materials are known: γ_1, γ_2 - conductivity of inductor and stator materials; μ – total magnetic penetration of inductor and stator materials, $\mu = const$; k – coefficient of springs stiffness; m – mass of inductor.

The principle of CLE working is the following: When alternative voltage $u_2(t)$ is given on the stator puttee, the pulsatory magnetic field arises which during interaction processes with current fields of inductor puttee, eddy currents in massive conductors and magnetized currents on the division of magnetic circuits leads to the oscillation of inductor with amplitude $\Delta x_{\max}$.

The modeling of electromechanical process in CLE is a difficult task which is based on united solving of Maxwell's equations in the unlimited range which contains geometrically complicated ferromagnetic massive conductors and equations of inductor motions. Therefore, the problem is divided into several stages: 1) electromagnetic task is to calculate the characteristics of electromagnetic field in CLE when speed of inductor motion is adjusted; 2) mechanical task is to calculate the characteristics of mechanical process when value of electromagnetic force which affects the inductor is adjusted.

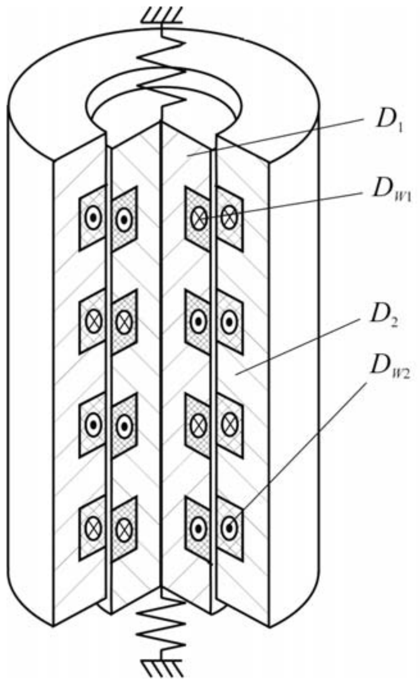
MODELING OF ELECTROMAGNETIC PROCESS IN A COAXIALLY-LINEAR ENGINE

In the works [2, 4] based on the integral equations the method of calculating of magnetic field in devices which consist of co-axially arranged circular reels and toroidal steel bodies is examined. When an independent magnetic penetration of material of ferromagnetic body from tensity of magnetic field is admitted, the density of simple layer of currents on their division correspond to the next integral equation [8]:

$$\sigma(Q,t)+\frac{\chi}{\pi}\oint_{l}\sigma(M,t)P(Q,M)dl_M +$$
$$+\frac{\mu}{\mu_0}\frac{\chi}{\pi}\oint_{D}\delta(M,t)P(Q,M)ds_M =$$
$$=-\frac{\chi}{\pi}\oint_{D_W}\delta_W(M,t)P(Q,M)ds_M, Q\in l=l_1\cup l_2, \qquad (1)$$

where: $\sigma(Q,t)$ - is a instantaneous density of simple layer of currents in the point Q on the division of magnetic circuits $D = D_1 \cup D_2$; $\sigma(M,t)$ - is analogically in the point M; $\chi = (\mu - \mu_0)/(\mu+\mu_0)$; μ - is total magnetic penetration of material of magnetic circuits; $\mu_0 = 4\pi\cdot 10^{-7}$ H/m – magnetic constant;

$$P(Q,M)=\vec{e}_\alpha\cdot\left[\vec{n}_Q\times\vec{b}(Q,M)\right]=$$
$$=n_z(Q)b_r(Q,M)-n_r(Q)b_z(Q,M).$$



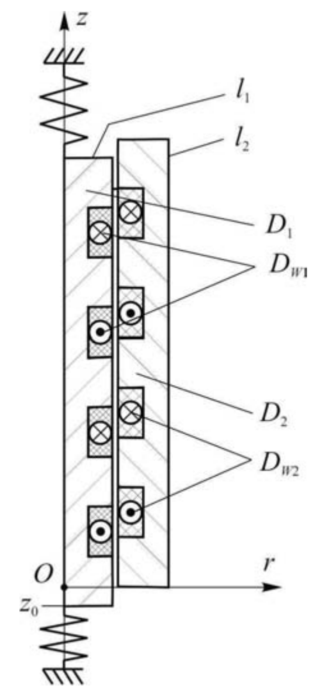


Fig. 1. Simplified electromagnetic scheme of the coaxial-linear engine (a), cut by meridian flat (b): D_1 - magnetic circuit of the inductor, D_{W_1} - puttee of the inductor, D_2 - magnetic circuit of the stator, D_{W_2} - puttee of the stator

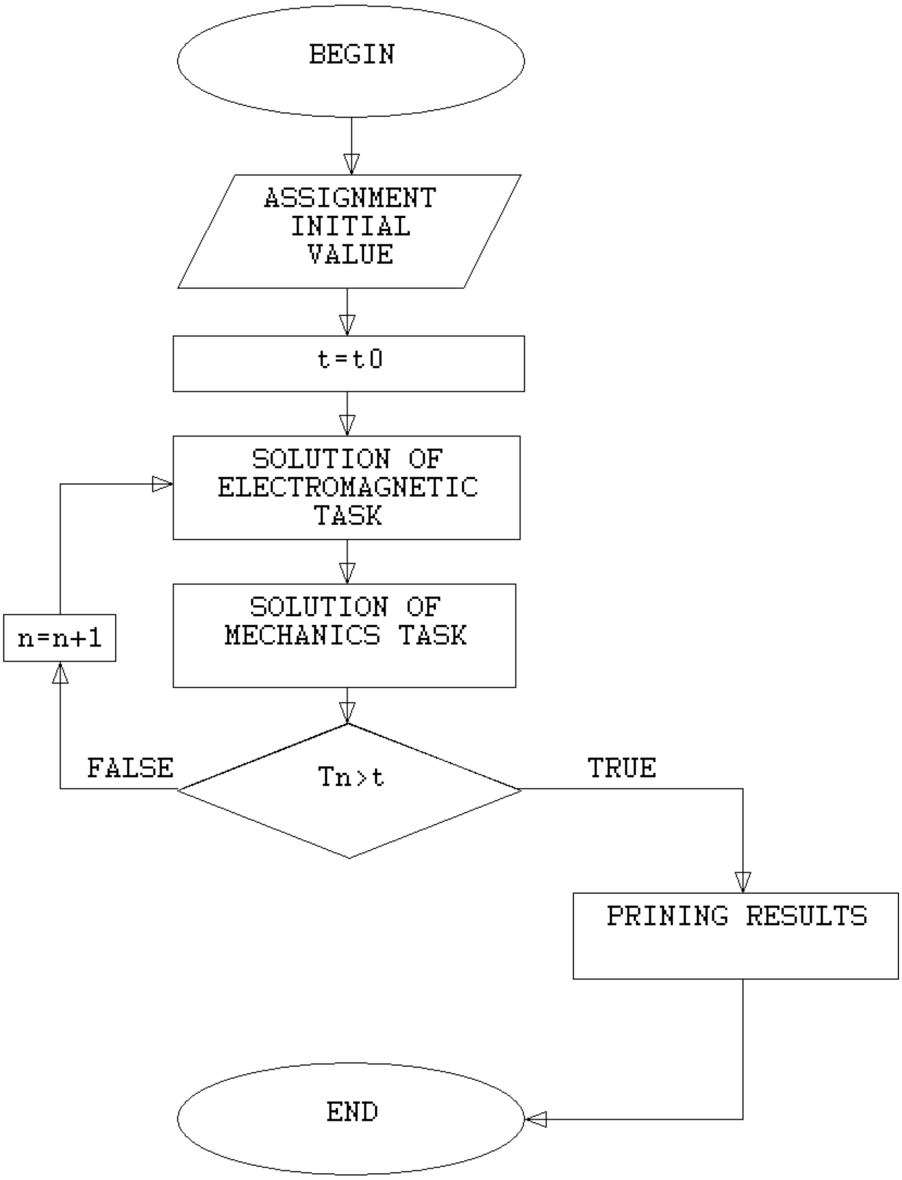


Fig. 2. Integrated bloc-scheme of nonstationary electromechanical process modeling

Here $\vec{n}_Q = n_r(Q)\vec{e}_r + n_z(Q)\vec{e}_z$ - is directed towards the division of magnetic circuits in the point Q; $\vec{e}_r\ \vec{e}_\alpha\ \vec{e}_z$ unit vectors of cylindrical system of axes;

$$b_r(Q,M) = \frac{z_Q - z_M}{r_Q\sqrt{(r_Q + r_M)^2 + (z_Q - z_M)^2}} \left[-K(k) + \frac{r_Q^2 + r_M^2 + (z_Q - z_M)^2}{(r_M - r_Q)^2 + (z_Q - z_M)^2}\right], \tag{2}$$

$$b_z(Q,M) = \frac{1}{r_Q\sqrt{(r_Q + r_M)^2 + (z_Q - z_M)^2}} \left[K(k) + \frac{r_M^2 - r_Q^2 + (z_Q - z_M)^2}{(r_M - r_Q)^2 + (z_Q - z_M)^2}\right], \tag{3}$$

$$\vec{b}(Q,M) = \vec{e}_r b_r(Q,M) + \vec{e}_z b_z(Q,M). \tag{4}$$

If inductor moves progressively along axes Oz with speed $\vec{V}(t) = \vec{e}_z V_z(t)$, integral-differential equations for calculation of eddy currents density in cuts of massive conductors will be next [8]:

$$\frac{\partial}{\partial t}\oint_l \sigma(M,t) T(Q,M)\, dl_M + \frac{\delta_1(Q,t)}{\gamma_1 \lambda} + \frac{\mu}{\mu_0}\frac{\partial}{\partial t}\oint_D \delta(M,t) T(Q,M)\, ds_M = -\frac{\partial}{\partial t}\oint_{D_w} \delta_w(M,t) T(Q,M)\, ds_M + \Phi(Q,t),\ Q \in D_1 \tag{5}$$

$$\frac{\partial}{\partial t}\oint_{l}\sigma(M,t)T(Q,M)\,dl_M +$$

$$+\frac{\mu}{\mu_0}\frac{\partial}{\partial t}\oint_{D}\delta(M,t)T(Q,M)\,ds_M =$$

$$=-\frac{\partial}{\partial t}\oint_{D_w}\delta_w(M,t)T(Q,M)\,ds_M,\; Q\in D_2, \tag{6}$$

where: $\lambda=\mu_0/(2\pi)$; $\Phi(Q,t)=\frac{1}{\lambda}\left(\vec{e}_\alpha\cdot\left[\vec{V}(t)\times\vec{B}(Q,t)\right]\right)=$ $=\frac{1}{\lambda}V_z(t)B_r(Q,t)$.

The induction of the magnetic field can be found in the following way:

$$\vec{B}(Q,t)=\frac{\mu}{2\pi}\int_D\delta(M,t)\vec{b}(Q,M)ds_M +$$

$$+\frac{\mu_0}{2\pi}\int_D\delta_w(M,t)\vec{b}(Q,M)ds_M +$$

$$+\frac{\mu_0}{2\pi}\int_D\sigma(M,t)\vec{b}(Q,M)ds_M,$$

where: $\vec{b}(Q,M)$ is defined using equation.

In equations (1), (5), (6) current densities in cuts of stator and inductor puttees remain unknown because it is accepted that voltage on their tips is known. Therefore, the system of equations must be completed with equations that determine the connection between puttee voltages and total current distribution in electromagnetic system. Based on the second Kirhgof's law for the chains of puttee of stator and inductor:

$$u_1=i_1(t)R_1+\frac{d\psi_1(t)}{dt},\quad u_2(t)=i_2(t)R_2+\frac{d\psi_2(t)}{dt}, \tag{7}$$

where: u_1, $u_2(t)$ - voltage on the stator and inductor puttees; $i_1(t)$, $i_2(t)$ - currents on the puttees of the inductor and stator; $\psi_1(t)$, $\psi_2(t)$ - total linkage with inductor and stator puttees respectively, which can be found by the next way [9]:

$$\psi_1(\mathrm{t})=\sum_{q=1}^{N_{W_1}}\sum_{i=1}^{w_1}2\pi r_{qi}A(Q_{qi},t),$$

$$\psi_2(\mathrm{t})=\sum_{q=1}^{N_{W_2}}\sum_{i=1}^{w_2}2\pi r_{qi}A(Q_{qi},t), \tag{8}$$

where: r_{qi} - is the centre radius of the i-loop and of q-reel of inductor and stator puttees for the first and second equations respectively; $A(Q_{qi},t)$ - instantaneous value of the vector potential in the centre of the i-loop and of q-reel. Integrating the equation (7) by the time we got the Volter's equations:

$$u_1(t-t_0)=R_1\int_{t_0}^{t}i_1(t)dt+\psi_1(t)-\psi_1(t_0), \tag{9}$$

$$\int_{t_0}^{t}u_2(t)dt=R_2\int_{t_0}^{t}i_2(t)dt+\psi_2(t)-\psi_2(t_0).$$

The vector potential of the magnetic field which belongs to the equations, can be found using the relation:

$$A(Q,t)=\frac{\mu_0}{2\pi}\int_{D_W}\delta_W(M,t)T(Q,M)ds_M +$$

$$+\frac{\mu}{2\pi}\int_D\delta(M,t)T(Q,M)ds_M +$$

$$+\frac{\mu_0}{2\pi}\oint_l\sigma(M,t)T(Q,M)dl_M. \tag{10}$$

If current densities in puttees of inductor and stator are known, the eddy current densities of massive conductors and density of current of magnetization on the magnetic circuit divisions, instantaneous electrodynamical force which affects the inductor can be found:

$$\vec{F}(t)=\int_{D_1}\vec{\delta}_1(Q,t)\times\vec{B}_2(Q,t)ds_Q +$$

$$+\int_{D_{W_1}}\vec{\delta}_{W_1}(Q,t)\times\vec{B}_2(Q,t)ds_Q +$$

$$+\int_{l_1}\vec{\sigma}(Q,t)\times\vec{B}_2(Q,t)dl_Q, \tag{11}$$

where: $\vec{B}_2(Q,t)$ instantaneous magnetic induction, which is caused by currents in the stator puttee, eddy currents in magnetic circuit of the stator and by the currents of magnetization on its division.

THE MODELLING OF THE MECHANICAL PROCESS IN COAXIAL-LINEAR ENGINE

For the defining of position and speed of inductor in the field of electromagnetic force according to the second Newton's law the Koshy's problem is entered:

$$m\frac{d^2z}{dt^2}=-2kz-mg+F_z(t), \tag{12}$$

$$v=\frac{dz}{dt}, \tag{13}$$

$$z(0)=z^{(0)},\quad v(0)=v^{(0)}, \tag{14}$$

where: m – mass of inductor; $z=z(t)$ - coordinate of inductor position as function of time t; k – coefficient of springs stiffness; $g=9{,}8$ m/s^2 - acceleration of gravity; $F_z(t)$

- instantaneous value of Z-projection of electromagnetic force (11); $v = v(t)$ - instantaneous speed of inductor motion; $z^{(0)}$, $v^{(0)}$ - initial position of the inductor and its initial speed.

The equations (12), (13) were integrated and integral-differential equation were obtained:

$$m\left(v(t)-v(t_0)\right) = -2k\int_{t_0}^{t} z(t)\,dt - mg\left(t-t_0\right) + \int_{t_0}^{t} F_z(t)\,dt, \quad (15)$$

$$z(t)-z(t_0) = \int_{t_0}^{t} v\,dt. \quad (16)$$

Knowing the initial position of the inductor, its speed on the initial moment, the law of changing of Z-projection of electromagnetic force, which can be found from solution of electromagnetic problem by the way of solving system of equations (15), (16) we can find the inductor position in any moment of time.

For numerical solution of integral-differential equation systems for finding the functions the piecewise-constant approximation can be used. First, they can be approximated by the dimensional variables with using the method of complete averaging. Then, for approximation by the time equations (5), (6) which contain fluxions by time, they can be reduced to the Volter's equations and after that integrals by time can be replaced with cubature formulas with coefficients; equation (15) is approximated analogically. After that the iterative process of solution of linked electromagnetic and mechanical problems can be organized (Fig. 2).

CONCLUSIONS

The mathematical model of linked no stationary electromagnetic and mechanical processes in coaxial-linear drive with massive magnetic circuit was worked out. The solution of electromagnetic problem was determined as a system of integral-differential equations for the density of eddy currents in the cuts of massive conductors and for currents of magnetization on the divisions of magnetic circuits with considering of inductor motion. The last one was completed with equations for chains of inductor and stator using the second Kirhgof's law. The solution of the problem of inductor motion in the field of electromagnetic force was determined as an integral-differential equation using the second Newton's law. Using the worked out mathematical model the program was made based on *FORTRAN* language and using this model an analysis of influence of material characteristics of CLE constructional elements, law of voltage changing on the draught characteristic of the engine was carried out.

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Effect of temperature on the volume of gas emissions

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Summary. In the full mould process, the polystyrene pattern which fills the mould cavity is subjected to pouring of this mould with liquid metal to the effect of high temperature (1600 ^{0}C) and passes from the solid state into liquid and gas. During this process some solid and gaseous products of the thermal destruction of the pattern are created. The kinetics of this process depends on the temperature of evaporation and, though to a smaller extent, on the pattern density, which, combined with the mould parameters, parameters of a ceramic coating, i.e. its thickness, permeability, and resistance to the effect of high temperatures, parameters of a granular material filling the mould and parameters of a technological process, including the technique of pouring and design. The mould cavity is filled with a pattern made of foamed polystyrene which on pouring of mould with liquid metal undergoes total destruction.

Key words: Evaporative pattern technology, casting, pattern, pattern made of foamed polystyrene, ferrous alloys

INTRODUCTION

The studies focused on determining the volume of gases emitted from the plastic models and the assumed density. The gasification temperature was the variable parameter. The effect of temperature on the gasification of the material model: the results concerning the volume of emitted gases are presented in graphs [1, 3, 5, 6].

In the full form of the plastic models (polystyrene, copolymer, x models), the model which fills a cavity forms in the course of its filling by the liquid metal and is subjected to the influence of high temperature It passes from the solid through the liquid to the gaseous state. Solid and gaseous products of thermal decomposition of polystyrene patterns are emitted. The kinetics of this process is significantly influenced by the gasification temperature, density and mass of the polystyrene patterns. One of the basic parameters is the amount and rate of gasses from the model polystyrene during its thermal decomposition. To ensure optimal conditions for obtaining a cast of the assumed shape and quality, the main characteristic parameters of the processing need to be worked out, especially the chemical composition and density of the model [8, 10, 11, 13, 14, 15].

TOOL MATERIAL PATTERN

The following materials were selected for the study:

Polistyren (PS) (- [CH2CH (C6H5)] produced by the polymerization of styrene, usually derived from petroleum refining. The models obtained by the thermal expansion of polystyrene in the form of granules in the matrix metal.

DFO studies used models with the density of 20 - 28 kg/m^3

Kopolimer - the type of polymer chains in which there are two or more types of units.

Effect of the density of polystyrene pattern and of evaporation temperature on the kinetics of gas evolution in the full mould process was studied [2, 4, 7, 9, 12, 16, 18].

THE STUDY OF THE KINETICS OF VOLUME OF THE GAS EMITTED FROM THE PLASTIC MODEL

Gases are a regular feature occurring during melting and casting metal into the mould. Their impact on the structure and properties of the cast are dependent on the gas volume in the model, the physicochemical properties of form as well as the amount and form of its occurrence in the metal. If the gases are emitted in metals in amounts exceeding their natural solubility under given conditions (often at lower temperatures), they reduce the quality of the casting, and often contribute to the formation of defects such as gas bubbles, puncture. The formation of these defects is determined not only by quantity but also the kinetics of release of gases (eg, core pattern). Metal is in contact with the gases at all stages of the technological process (gassed feed material, the atmosphere in the process of melting and pouring metal into contact with the form and the core model) [17, 19, 20, 22, 24].

In this research studies focused on the determination of the volume of gases emitted from a selected plastic form.

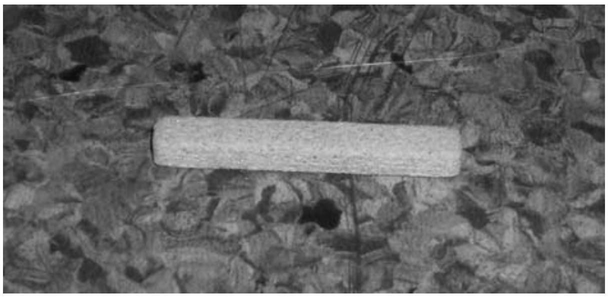

Fig. 1. Research pattern

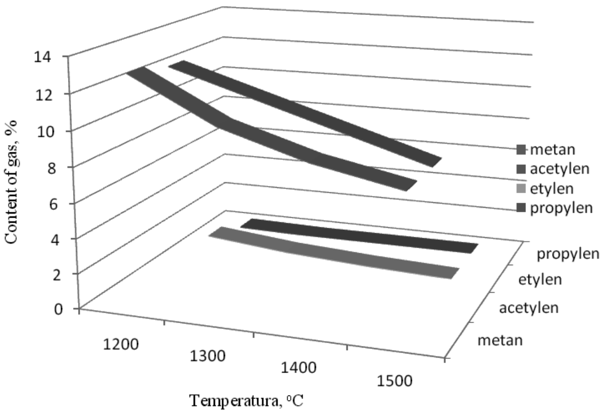

Fig. 2. The contents of selected gases in the polystyrene form in the temperature range 1200 to 1500°C, measured by the chromatograph

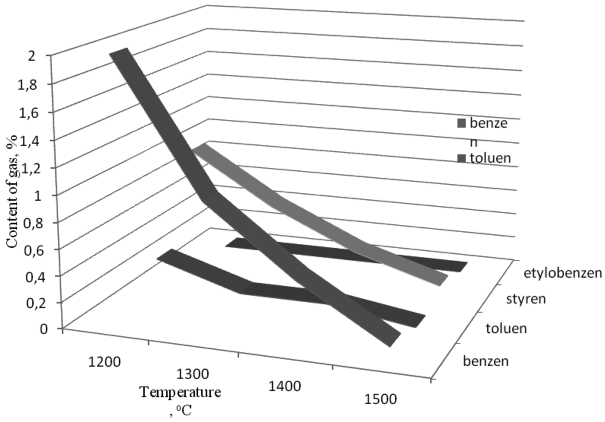

Fig. 3. The contents of selected gases in of the polystyrene pattern in the temperature range 1200 to 1500°C, measured by the chromatograph

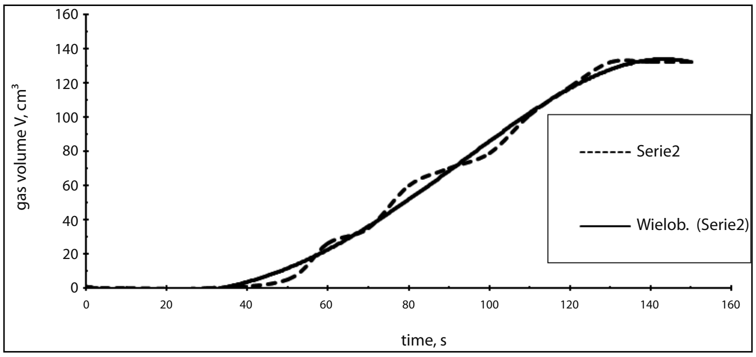

Fig. 4. Gas volume emitted from 1 g of the polystyrene pattern of 28 kg/m³ density at the temperature of 600°C in function of time

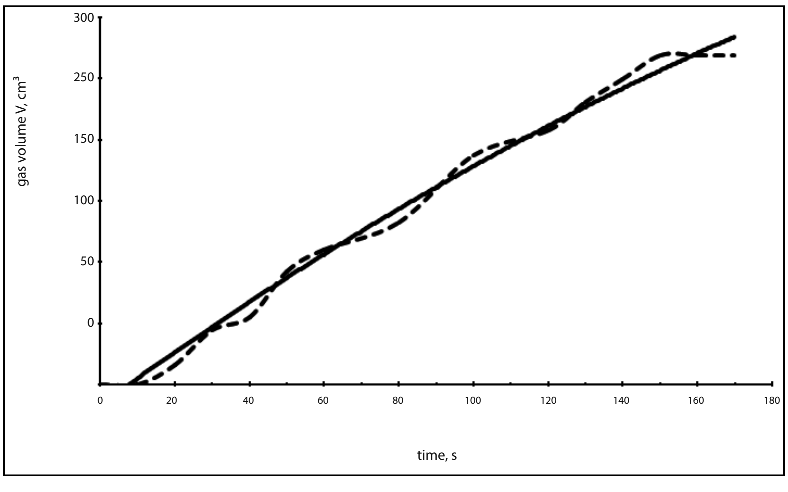

Fig. 5. Gas volume emitted from 1 g of the X pattern at the temperature of 700°C in function of time

RESULTS AND DISCUSSION

After examination of the volume of gas emitted from of the tested materials it was found out that the temperature of 600 °C occurs uniformly at the gasification process. And it ends when the model PS 120s and 70s are in the model X [21, 23, 25, 26].

Increased volume of gas spun from polystyrene model was found: the research has shown the volume of separated gases is greater than the volume of gas separated from the model X.

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Table of contents

ECONTECHMOD – GIDE FOR AUTHORS

The quarterly "ECONTECHMOD" publishes the original research papers in English. The papers should not exceed 10 pages including tables and figures. Acceptance of papers for publication is based on two independent reviews commissioned by Editor.

Text pages be of the A4 size, double line spacing, left and right margin of 2,5 cm, 12 point Times New Roman font. Manuscript should be organized in the following order (without subtitles):

Title, of the article,
Name and surname of the author(s),
Affiliations,
Full postal addresses,
e-mail,
Abstract (up to 200 words),
Key words (up to 5 words),
Introduction,
Materials (methods, techniques, theory),
Results, Discussion, Conclusions,
References.

References quoted in the text should be given in parentheses and include the author's surname and the publication year e.g. [1, 3]. The references list should be given at the article end, arranged alphabetically by surnames of the first authors.

List of the Reviewers

Basic Activities of Foundry Research Institute

- foundry research and development, consulting activities in metallurgy and technology of castings made from different materials (grey, alloyed, spheroidal and vermicular graphite cast irons, cast steel, alloys of aluminium, copper, magnesium, zinc, tin, indium, titanium, nickel, cobalt, and metal matrix composite materials);
- development of various casting processes: sand moulding, permanent mould or gravity die casting process, pressure die casting, squeeze casting, investment casting process using wax patterns, evaporative pattern casting (EPC), and other advanced processes;
- testing of mechanical, physico-chemical and technological properties of cast materials, structure examinations of the primary and auxiliary foundry materials, examination and identification of defects in cast products, simulation and optimising of foundry processes;
- development and implementation of reclamation systems with effective utilisation of foundry waste;
- foundry process and casting design using computer systems for the simulation of mould filling, and casting feeding and solidification;
- pattern making by various rapid prototyping techniques: Z-Corp, FDM-Titan, Solidscape, LOM, and manufacture of prototype castings (Vacuum Pressure Casting) by the investment casting process (MK Technology device);
- statistical analysis of casting production, of cost components, and of current world trends in foundry practice;
- processing and dissemination of information on foundry science, technique, economy (INFOCAST database), and standardisation;
- scientific and technical cooperation with similar research and development centres abroad, organisation of training workshops, conferences and seminars;
- certification of foundry products and auxiliary materials for foundry industry, of machines and equipment, and of control and measuring instruments for foundry (Office for Product Certification and Standardisation);
- assistance in development and implementation of quality systems, environmental management, and occupational safety and health management.

Mission of Foundry Research Institute

The leading intention of the Foundry Research Institute is to effectively face the needs of foundry science and practice both at home and abroad.
Therefore, in our activities, we focus attention on the execution and coordination of scientific and R&D works, on the analytical and exploratory studies, and on the development of innovative solutions in the field of technique, technology, organisation, and economy.
Of particular importance is effective dissemination of the study outcomes and implementation of the obtained results in industry to achieve full satisfaction of our Partners and Customers.

We aim at being perceived as a modern, efficiently managed and effectively operating, fully mobile, research and development centre. Our work should be creative and at the same time help our staff in development and self-realisation, with fair payments and satisfaction, offered especially to those who are responsible, full of invention, and active.

To protect cultural heritage as well as the knowledge and experience collected throughout the years, we strive to make the Foundry Research Institute a leading, competent, opinion-creating and training-information centre with ambitions to shape the national policy regarding functioning and development of the whole foundry sector in Poland, ensuring its important position in the European and global research and development area, technique, legislation and organisation.

Director
Prof. Jerzy J. Sobczak, DSc. PhD. Eng.

MACHINE FOR CUTTING SILICON SINGLE CRYSTALS TO THE PLATES

Technical novelty of the machine lies in the fact that the circle width of its cutting instrument, diamond cutting wheel with inner cutting edge, is smaller than the diameter of the cut of single crystal, it is able to pass through the crystal with all its effective area and to make a cut of unrestricted depth. The given way of cutting “on exit” allows to obtain plates with big diameters at relatively small dimensions of the cutting wheel.

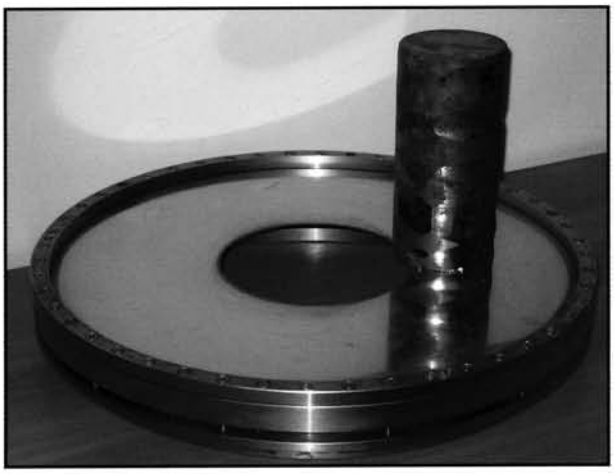
The presented machine has the following advantages:

- no restrictions on the diameter of the cut of single crystals;
- higher quality of the cut plates;
- lower cost price;
- higher productivity together with reduction of operating costs.

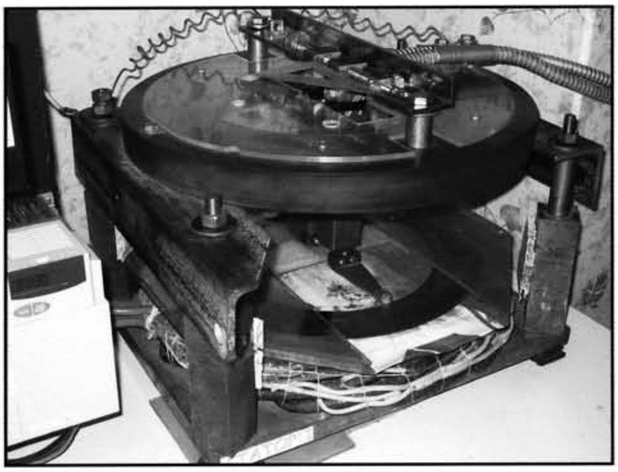
Principal technical characteristics of the machine:

Ingot size	OD: 300mm, L: 500mm
Speed of cutting feed (per X)	Up to 60 mm/min
BLADE SIDE	OD:520; ID:410, Tip thickness :0,38mm
Machine dimensions	800mm $\times$800mm$\times$1200mm
Frequency of instrument rotation	Up to 5500 min^{-1}
WEIGHT	Up to 500 Kg

Main working body of a traditional machine-tool



Experimental plant with dynamometer



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THE TECHNOLOGIES FOR PRODUCTION OF PARTS BY POWDER METALLURGY TECHNIQUES

Technologies of powder metallurgy allow to save the materials, electric power, produce dimensionally precise parts or close to finished parts with given chemical composition and necessary physico-mechanical and service properties.

The technologies for production of complex-shaped details without mechanical treatment, also, from nanostructural materials. The main technological operations: pressing, sintering and additional operations.

Structural details for transport machine-building from wear-proof powder materials

Density 100%, HRC 58-60, ultimate stress 580-930 MPa, high wear resistance.

Structural parts from low-carbon powder steels

Density 7.7-7.8 g/cm^3, ultimate stress 320-440 MPa, relative elongation 3-10%, good weldability.

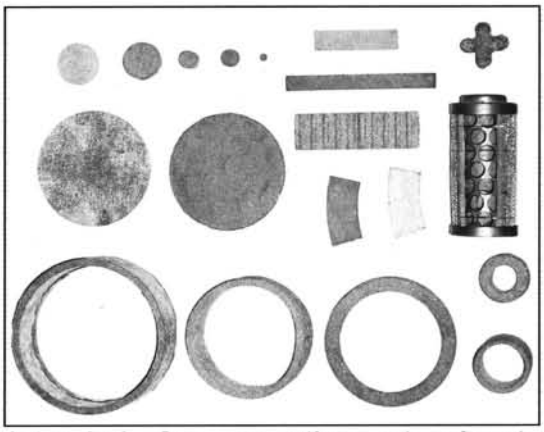
Structural details from copper and bronze

Density 100%, ultimate stress 220-300 MPa, Relative elongation 6-30%

Antifriction details from copper-based and iron-based materials

Assigned for operation at dry friction and high speed conditions
Porosity 3-20%, hardness HB 40-120, friction coefficient 0.01-0.03

The details of filtering elements and catalysts



Intended for operation at elevated temperatures in the aggressive media.
Porosity 55-70%, high filtration effectiveness and possibility of regeneration.

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