AN INFLUENCE OF RAPE OIL ESTER CONTENT IN FUEL BLEND ON CARBON DIOXIDE EMISSION LEVELS

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INTRODUCTION

Man's natural environment is tremendously affected by toxic compounds present in fumes emitted by currently used vehicles. Carbon dioxide CO_2 is an especially harmful fumes element: although it is not toxic in itself, it causes the greenhouse effect having extremely bad consequences for the natural environment. The research problem is a consequence of the obligations concerning CO_2 emissions ratified by all the countries in the world as well as of a number of restrictions resulting from the introduction of the European standards. Reduction of the global fumes emission and especially a decreas of the toxic elements content concerns the whole society as it is a global world concept. It is important to involve in the issue not only vehicle producers (the construction and production stage) but also their users (exploitation stage). But the most efficient method of the reduction of toxic components emission in fumes of vehicles in the process of their exploitation is a decrease of emission levels by a proper choice of fuel. Hence great expectations are aroused by the prospect of substitution of conventional engine fuels with biofuels. The new agricultural policy aims at the use of an unconsumed agricultural production surplus, especially alcohols and plant oils, as biocomponents. Practically, three main sorts of fuels can be obtained from agricultural produce: alcohols (methyl and ethyl ones), plant oils esters and biogases. As to energetic value, rape oil (mainly in the form of ester) takes a medium position between petrol and engine oil, showing a much better value than alcohols.

In the process of photosynthesis carbon dioxide splits into oxygen and carbon and the latter one is assimilated in plants. Further on only part of it is stored in grains, and about 30% of that are hydrocarbons, which can be used as engine fuels. As a result of the whole process much less carbon dioxide is emitted to the atmosphere than has been assimilated from it by plants. Thus, a change from conventional to the so called renewable fuels seems to be by all means profitable [4].

As it is further presented in the paper , the emission level of carbon dioxide in the fumes of the engines fed with fuel blends consisting of different proportions of the mineral engine oil ON and rape oil ester RME does not differ from the emission level from the engines fed only with the mineral engine oil ON.

AIM AND RANGE OF RESEARCH

The paper aims at the statistical comparison of CO_2 emission level from the S-4002 engine fed with different fuel blends. The blends consisted of the mineral engine oil ON and rape oil ester RME mixed in 6 different proportions. Tests on the energetic and ecological parameters concerning the work indices and fumes of the S-4002 engine fed with RME and its blends with the engine oil ON were carried out at the Department of Vehicles and Engines, AR Lublin. The tests were carried out on the loading characteristics at the maximum moment speed $n_{Mo\max}$ (1600 rpm) and the maximum power speed $n_{Ne\max}$ (2000 rpm).

In the present research six kinds of RME and ON blends were used containing, respectively, 0%, 20%, 40%, 60%, 80%, 100% of RME and the measurements were taken for ten levels of an engine's loading (2-32kW).

An analysis of co-variance was used to statistically describe the obtained results of measurements. The indispensable calculations were made using the program EXCEL 2000.

THE USE OF A FEW MODELS OF A CO-VARIANCE ANALYSIS IN A SINGLE CLASSIFICATION

Let us notice that the level of CO_2 emission [%] depends on two variables: the developed power N_e [kW] and the percentage of RME in the mix of RME with ON. This statistical dependency of CO_2 on N_e and RME is presented in Figure 1 (and, respectively, Figure 2) by the points obtained from 60 measurements at the speed 1600 rpm (and 60 measurements at the respective speed of 2000 rpm). RME in the figures' key denotes the variable describing the percentage of rape oil ester in fuel.

In figures 1 and 2 differences can be observed in the emission levels of CO_2 from the S-4002 engine of an agricultural tractor between the two loading characteristics: at the speeds of the maximum moment $n_{Mo\max}$ (1600 rpm) and the maximum power $n_{Ne\max}$ (2000 rpm).

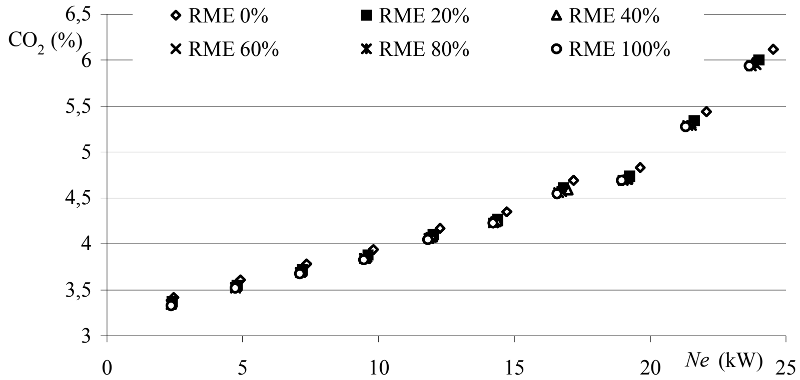

Fig. 1. Dependency of CO_2 emission level [%] on the power at 1600 rpm

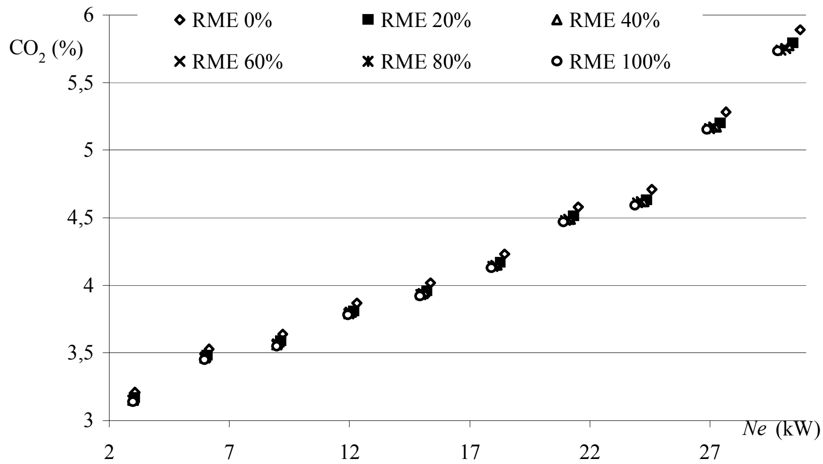

Fig. 2. Dependency of CO_2 emission level on the power [%] at 2000 rpm

An analysis of the Figures 1 and 2 shows a clear dependency between the CO_2 emission level in fumes and the effective power N_e, hence a large part of the CO_2 changeability is explained by the variable N_e. That is why the statistical method called a co-variance analysis was chosen to estimate the statistical influence of RME ester content in fuel on the emission levels of CO_2 in fumes. In this model the independent (grouping) variable is the percentage of RME in fuel, the dependent variable – CO_2 level, and the concurrent variable – the effective power N_e [1]. This analysis allows to remove the known source of changeability (N_e) so that the influence of RME factor on the dependent variable CO_2 is more apparent.

The preliminary statistical analysis showed that in a co-variance analysis a concurrent variable N_e needs to be taken into account together with its square N_e^2 and cube N_e^3.

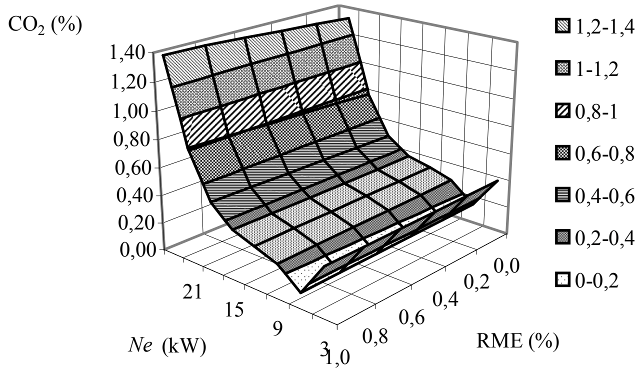

Fig. 3. The graph of differences between regression surfaces CO_2 (*Ne*, RME) for 1600 rpm and CO_2 (*Ne*, RME) for 2000 rpm

The structure of a correct co-variance analysis model in a single classification demands that for both the rotational speed 1600 rpm and 2000 rpm, separately, i.e. when $k = 1, 2$ in both models ($k = 1, 2$), considered in the first step:

$$\mathrm{CO}_{2ij}^{1k} = \alpha_i^{1k} + \beta_{i1}^{1k} N_{ekij} + \beta_{i2}^{1k} N_{ekij}^2 + \beta_{i3}^{1k} N_{ekij}^3 + e_{ij}^{1k} \tag{1}$$

for the group number i ($i = 1, 2, \ldots, 6$) apart from the effect …..there was also an individual regression of the form:

$$\beta_{i1}^{1k} N_{ekij} + \beta_{i2}^{1k} N_{ekij}^2 + \beta_{i3}^{1k} N_{ekij}^3 \tag{2}$$

For the sake of clarity we also present the way of indexation applied in the following models:

$$\mathrm{CO}_2{}_{i,j}^{s,k} = \mathrm{CO}_2{}_{Nr\%RME,NrObserwacji}^{NrModelu,Nr\,\mathrm{Pr}\,ędkości}$$

It was further assumed that $i = 1$ for 0% RME, $i = 2$ for 20% RME,…, $i = 6$ for 100% RME. For $k = 1, 2$, and in each group nr i ($i = 1, 2, \ldots, 6$) 10 measurements were taken for different levels of the effective power $N_{e\,kij}$ which means that we have got $j = 1, 2, \ldots, 10$.

Successively for $k = 1.2$ we assume the zero hypothesis that the regression coefficients $\beta_{i1}^{1k}, \beta_{i2}^{1k}, \beta_{i3}^{1k}$ are common for all the 6 groups (RME values) i.e.:

$$\mathrm{H}_0^1\colon \beta_{11}^{1k} = \ldots = \beta_{61}^{1k},\ \beta_{12}^{1k} = \ldots = \beta_{62}^{1k} \text{ i } \beta_{13}^{1k} = \ldots = \beta_{63}^{1k} \tag{3}$$

The hypothesis H_0^1 means the parallelism of the six regression lines (2) crossing the Y-axis in the points α_i^{1k}.

Separately for the rotational speed 1600 rpm and for the speed 2000 rpm, that is when $k = 1, 2$ the hypothesis was not rejected. Table 1 presents the results of the testing of this hypothesis at $n = 1600$ rpm and Table 2 at $n = 2000$ rpm.

Table 1. Results of tests on the parallelism of the 6 regression lines at the rotational speed 1600 rpm

	Totals of squares	Freedom steps	Mean squares	F	p
parallelism	0.0201	15	0.0013	0.3120	0.9907
error	0.1545	36	0.0043		

Table 2. Results of tests on the parallelism of the 6 regression lines at the rotational speed 2000 rpm

	Totals of squares	Freedom steps	Mean squares	F	p
parallelism	0.0109	15	0.0007	0.2030	0.9991
error	0.1294	36	0.0036		

Thus, separately for the rotational speed 1600 rpm and separately for the speed 2000 rpm (i.e. when $k = 1, 2$), in the models considered in the second step:

$$\mathrm{CO}_{2ij}^{2k} = \alpha_i^{2k} + \beta_1^{2k} N_{ekij} + \beta_2^{2k} N_{ekij}^2 + \beta_3^{2k} N_{ekij}^3 + e_{ij}^{2k} \tag{4}$$

for $i = 1, 2,\ldots, 6$ apart from an individual α_i^{2k} -an object effect of the group nr i, there is also an all group regression in the form:

$$\beta_1^{2k} N_{ekij} + \beta_2^{2k} N_{ekij}^2 + \beta_3^{2k} N_{ekij}^3 \tag{5}$$

Separately for k = 1, 2 we assume now the zero hypothesis that …effects are identical for all the 6 groups i.e.

$$\mathrm{H}_0^2\!: \alpha_1^{2k} = \alpha_2^{2k} \ldots = \alpha_6^{2k} \tag{6}$$

In the model (4) separately for the speed 1600 rpm and separately for the speed 2000 rpm , i.e. when $k = 1, 2$, the hypothesis was not rejected, as there are no statistical grounds for that in this case. Table 3 presents the results of the testing of this hypothesis at $n = 1600$ rpm and Table 4 at $n = 2000$ rpm.

Table 3. Results of tests on the hypothesis (6) in the model (4) (about the lack of any shift of the 6 regression lines in relation to each other) at the rotational speed 1600 rpm

	Totals of squares	Freedom steps	Mean squares	F	p
groups	0.0194	5	0.0039	0.9748	0.4421
error	0.2026	51	0.0040		

Table 4. Results of tests on the hypothesis (6) in the model (4) (about the lack of any shift of the 6 regression lines in relation to each other) at the rotational speed 2000 rpm

	Totals of squares	Freedom steps	Mean squares	F	p
groups	0.0167	5	0.0033	1.0174	0.4172
error	0.1677	51	0.0033		

The approval after H_0^1 as soon as in the second run of the hypothesis H_0^2 proves that the 6 regression lines are identical and leads to the third model in the common form for all the RME levels:

$$\mathrm{CO}_{2ij}^{3k} = \alpha_0^{3k} + \beta_1^{3k} N_{ekij} + \beta_2^{3k} N_{ekij}^2 + \beta_3^{3k} N_{ekij}^3 + e_{ij}^{3k} \tag{7}$$

separately for the considered rotational speeds, where $k = 1,2$. The estimators of the models (7) obtained by the method of the smallest squares are presented in Table 5.

Table 5. The estimated parameters of the model (7) for both the tested rotational speeds of an engine

Model	k =	α_0^{3k}	β_1^{3k}	β_2^{3k}	β_3^{3k}
1600 rpm	1	3.0223	0.1520	-0.0098	0.0004
2000 rpm	2	2.8198	0.1349	-0.0066	0.0002

Table 6. Test F for the model (7) at the rotational speed 1600 rpm

Elements	Totals of squares	Freedom steps	Mean squares	F	p
Regression	3	36.9957	12.3319	3111.5040	0.0000
Residual	56	0.2219	0.0040		
Total	59	37.2176			

Table 7. Test F for the model (7) at the rotational speed 2000 rpm

Elements	Totals of squares	Freedom steps	Mean squares	F	p
Regression	3	35.4997	11.8332	3593.3640	0.0000
Residual	56	0.1844	0.0033		
Total	59	35.6841			

The significance of the curves from the models (7) was verified by the test F (compare Tables 6 and 7).

RESULTS AND CONCLUSIONS

The derived models (7) with the parameters described in Table 5, where R=0,997, as well as Figure 3 lead to the conclusion that the changeability of carbon dioxide levels in fumes may be in 99% explained by the changeability of the power N_e[kW] developed by an engine. The higher N_e, the greater the differences between CO_2 levels at various speeds.

The analysis of the tests' results shows no significant effect of the RME blend's kind itself on the tested phenomenon.

Further intensive research is carried on concerning an effect of biofuels on pollution of the environment with the other toxic contents of fumes [2, 3, 4].

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SUMMARY

The article presents an analysis of CO_2 emission levels in the fumes of S-4002 engines fed with fuel blends composed of the mineral engine oil ON and rape oil ester RME in various proportions. It has been found out that the values of these emissions do not differ from the emission levels in the engines fed exclusively with the mineral engine oil ON.