THE INFLUENCE OF REGULATION PARAMETERS CHANGES IN A FUEL INJECTION SYSTEM ON CO AND HC EMISSION LEVELS IN COMBUSTION GASES OF A TRACTOR ENGINE

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Pollution of natural environment due to combustion engines exploitation is now one of the basic research issues in the field of motorization. According to the available scientific papers motorization accounts for as much as 50% of toxic fumes emission [3]. Contamination of nature with motor fumes does not only concern big cities but is also found in rural areas. This is largely due to the exploitation of compression-ignition engines, generally used as driving units in agricultural vehicles.

A significant cause of toxicity rise in fumes emited by automatic ignition engines are faulty fuel systems. Exploitation practice shows that over 50% faults in A.I. engines are caused by faulty fuel systems [2]. Engines in agricultural tractors are especially liable to defects of injection system because of complex conditions of their exploitation and frequent inefficiency of their users. Defects and wear of an injection apparatus as well as incorrect regulation settings and frequent inadequacy of technical staff lead to worse indices of an engine's work and higher environment's pollution by harmful compounds in combustion gases or fuel and oil leaks. The influence of injection apparatus wear, especially precision pairs wear, on the toxicity of an agricultural tractor's fumes was presented by the author in the published papers [4, 5].

DESCRIPTION OF THE RESEARCH STAND AND METHODOLOGY

Research was done on a four-cylinder compression-ignition engine S-4003 of the tractor Ursus C-360 set on a dynamometric stand in the engine brake hall of The Department of Vehicles and Engines at the Agricultural University of Lublin. The draft of the research stand is presented in Fig. 1.

The basic element of the dynamometric stand is an electric brake of the type K1-136B-E (alternating current generator), which was also used for starting the tested engine. For the measurement of the rotating speed of the engine an inductive sensor was used cooperating with a digital gauge type N05.

The tested engine was equipped with a row type injection pump P24T8-3a which had the pumping elements FPE8-3a and pumping shutters DV83 as well as with injectors type WJ1S 78.7A having five-hole extended sprayers DSL150.A2. Its combustion system had a direct fuel injection to the toroidal chamber in the piston.

Contents of carbon oxide and hydrocarbons in the fumes of the tested tractor engine were determined by a multigas fume analyser type M-488 Multigas Plus. Measurements were taken for particular points of the load characteristics, at alternating regulation settings of the fuel injection system. Samples of combustion gases for an analysis of fume content were taken from behind the joint fume collector (Fig. 1).

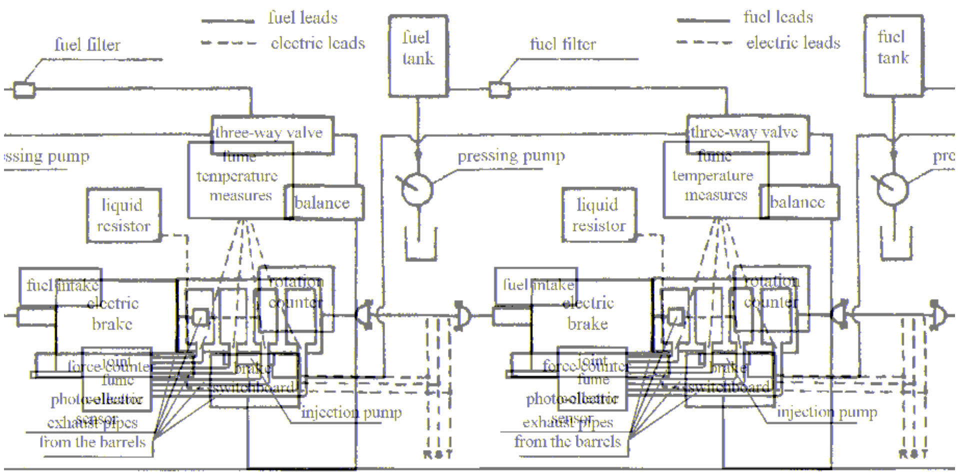


Fig. 1. Draft of the research stand

The following regulations of the fuel injection system were made:

– of the static fuel pumping start angle until the value: 19°CA (crankshaft angle), 22°CA (nominal angle), 25°CA before TDC. The regulations were made directly on the engine by the rotation of the injection pump round the axle of the camshaft (in the whole range for the tested engine); by moving the upper part of the pump nearer the engine, the angle of PS (pumping start) – α_{ps} was enlarged – a momentoscope was used.

– of the injectors opening pressure – p_{io} until the value: 15,5 MPa, 17 MPa (nominal pressure), 18,5 MPa – injectors sampler type PRW-3 was used. Tightness of the injectors and quality of fuel spray were also checked.

Control and regulations of the injecting pump and the injectors were performed according to [1, 6].

RESULTS AND ANALYSIS

Changes in the emission levels in fumes of carbon oxide (CO) in the function of the effective power (N_e) of a tractor engine S-4003 obtained in experimental tests depending on different regulation parameters of the injection system i.e. the pumping start angle and the injectors opening pressure are presented respectively in Fig.2a and 4a – for the rotation speed of the engine 1500 rpm and in Fig. 2b and 4b – for the speed 2000 rpm.

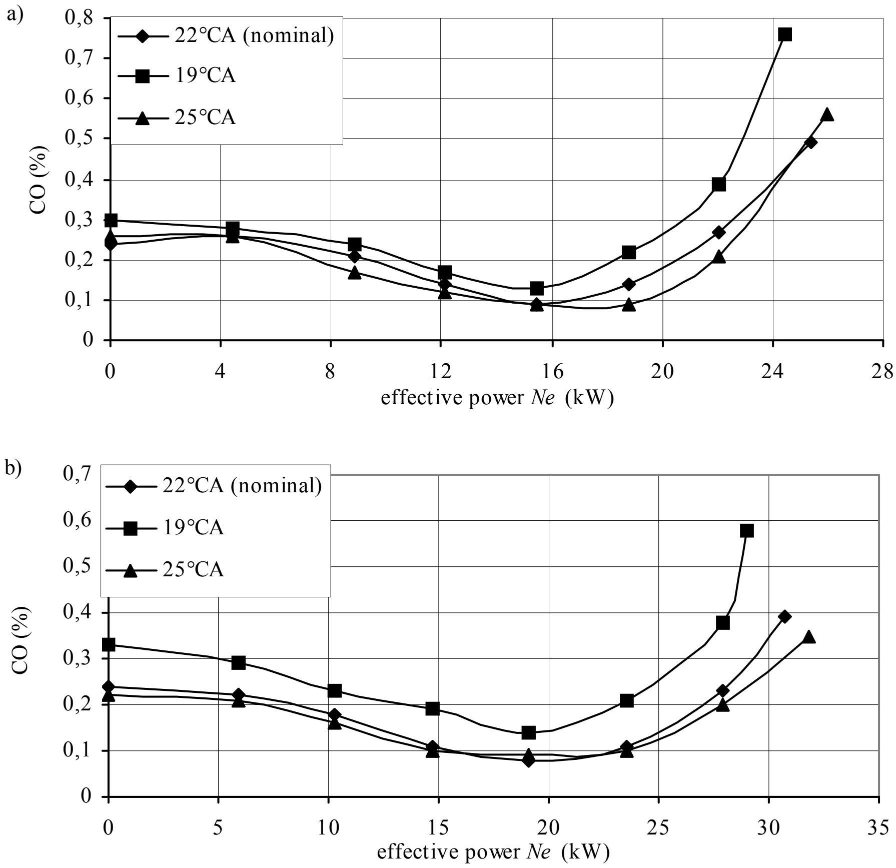
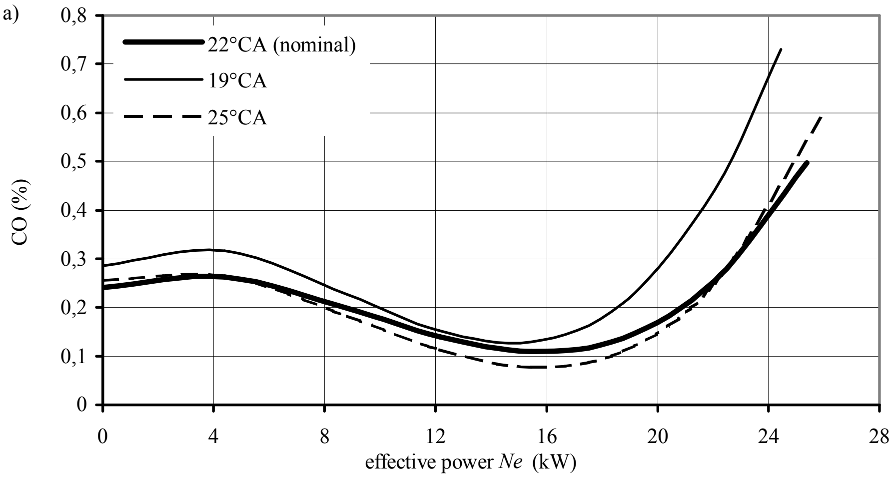


Fig. 2. Dependence of CO emission level in fumes on the effective power (Ne) of a S-4003 tractor engine, for different angles of the pumping start α_{ps}: a) 1500 rpm, b) 2000 rpm

Fig. 3, 5 and 7 represent theoretical dependencies corresponding to the above mentioned experimental curves. They were determined by means of of the curve analysis method. The proper regression equation was chosen on the basis of the values of determination coefficient R^2, values of the F-Snedecor test functions for testing a model's adequacy as well as of the significance levels of particular elements of the regression function (t-Student tests).

a)

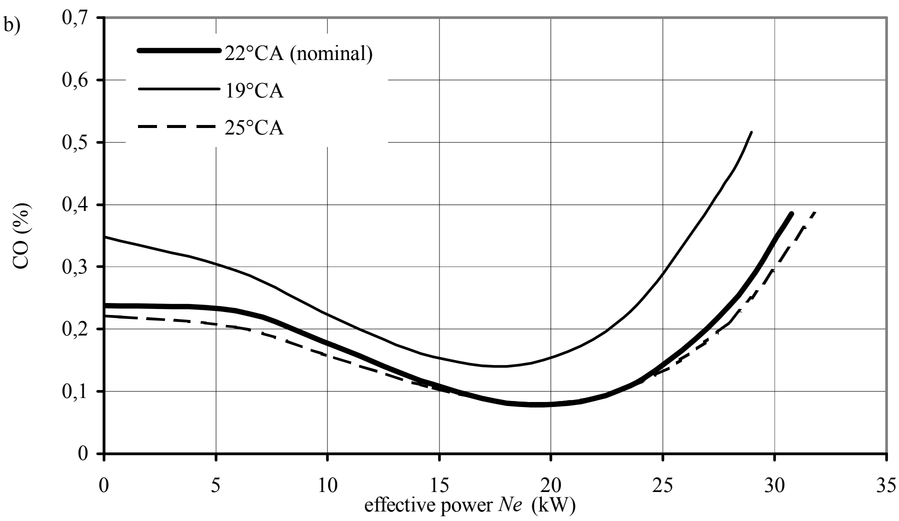


$y = 0{,}000148x^3 - 0{,}004149x^2 + 0{,}020341x + 0{,}240742$ $R^2 = 0{,}9927$ (22°CA)

$y = 0{,}000234x^3 - 0{,}006189x^2 + 0{,}029597x + 0{,}286068$ $R^2 = 0{,}9794$ (19°CA)

$y = 0{,}000165x^3 - 0{,}004485x^2 + 0{,}018369x + 0{,}256299$ $R^2 = 0{,}9942$ (25°CA)

b)



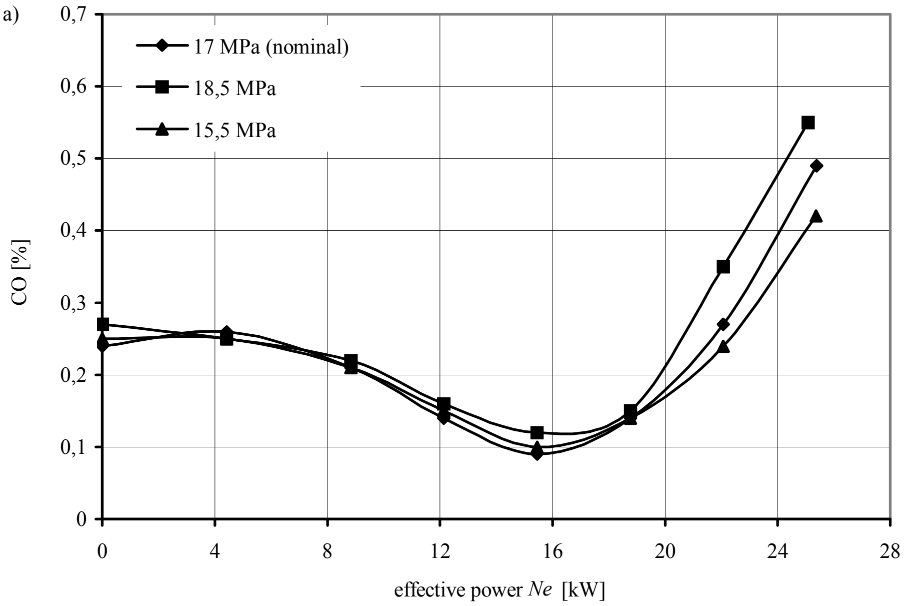
$y = 0.000066x^3 - 0.002179x^2 + 0.009109x + 0.237419$ $R^2 = 0.9968$

$y = 0.000077x^3 - 0.00202x^2 + 0.348436$ $R^2 = 0.9244$

$y = 0.000051x^3 - 0.001574x^2 + 0.004514x + 0.221991$ $R^2 = 0.9959$

Fig. 3. Dependence of CO emission level in fumes on the effective power (*Ne*) of a S-4003 tractor engine, for different angles of the pumping start α_{ps} (regression analysis): a) 1500 rpm, b) 2000 rpm

a)



b)

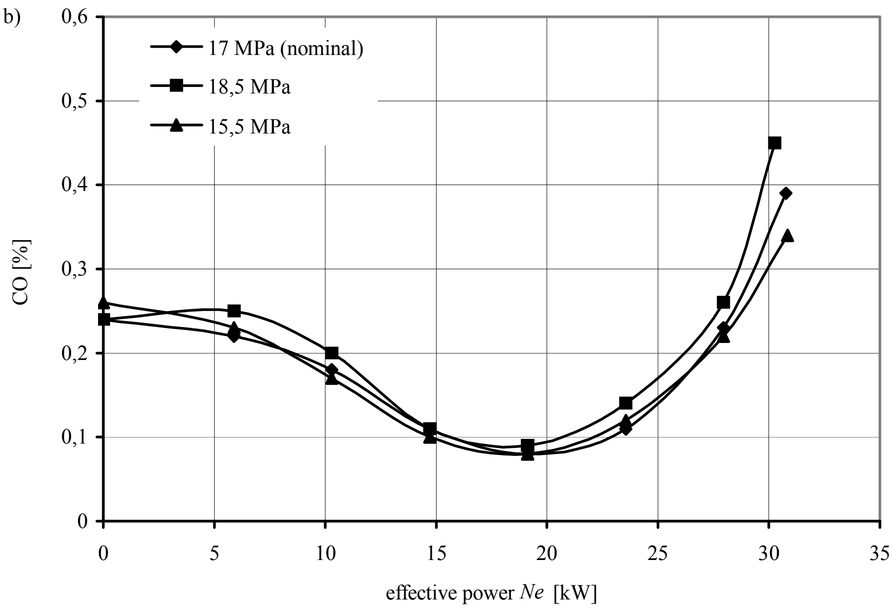
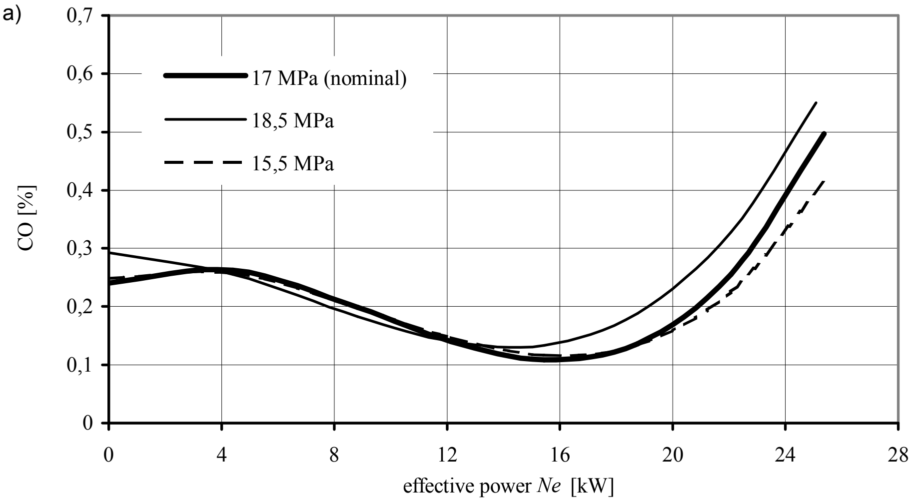


Fig. 4. Dependence of CO emission level in fumes on the effective power (*Ne*) of a S-4003 tractor engine, for different injectors opening pressures p_{io} : a) 1500 rpm, b) 2000 rpm

a)

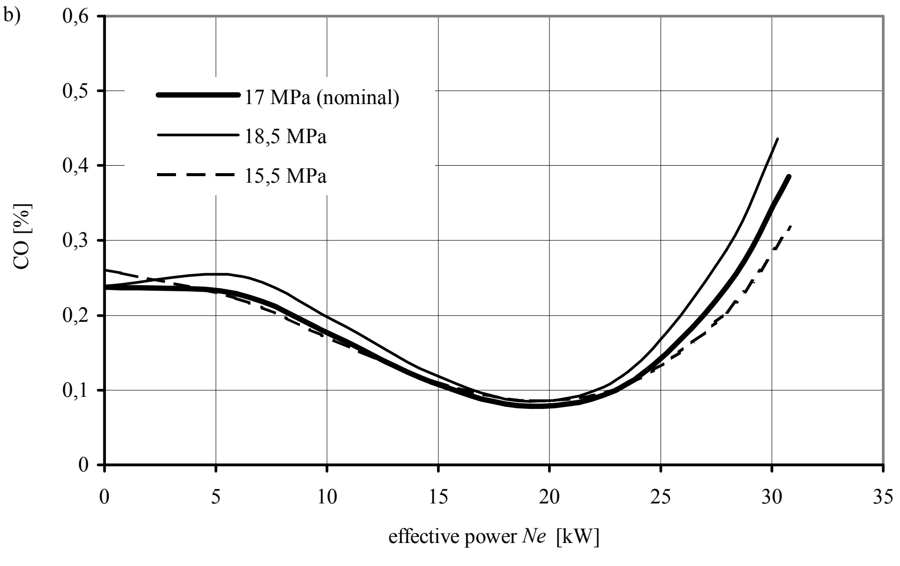


$y = 0{,}000148x^3 - 0{,}004149x^2 + 0{,}020341x + 0{,}240742$ $R^2 = 0{,}9927$ (17 MPa)

$y = 0{,}000111x^3 - 0{,}002388x^2 + 0{,}292379$ $R^2 = 0{,}9673$ (18,5 MPa)

$y = 0{,}000118x^3 - 0{,}003304x^2 + 0{,}014335x + 0{,}24855$ $R^2 = 0{,}9909$ (15,5 MPa)

b)



$y = 0{,}000066x^3 - 0{,}002179x^2 + 0{,}009109x + 0{,}237419$ $R^2 = 0{,}9968$ (17 MPa)

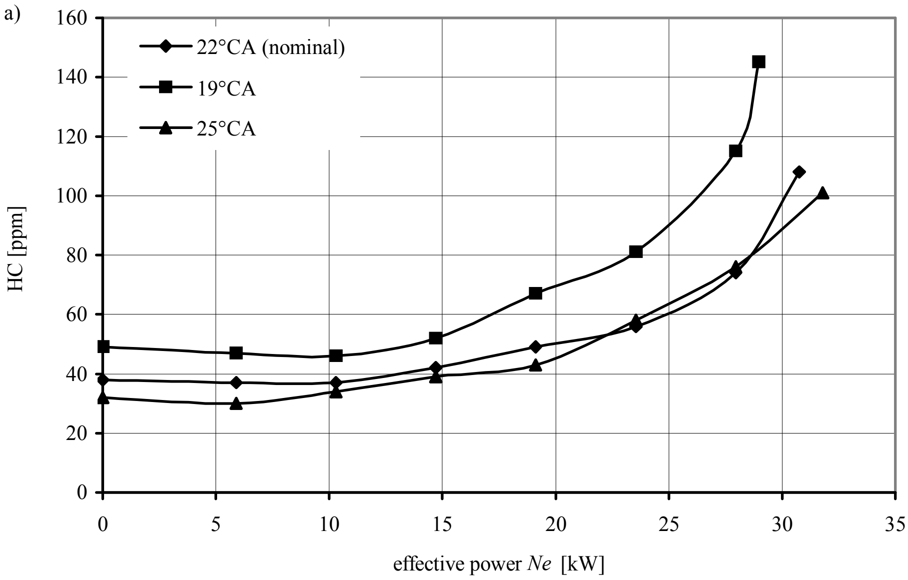
$y = 0{,}000086x^3 - 0{,}002937x^2 + 0{,}016632x + 0{,}239264$ $R^2 = 0{,}9847$ (18,5 MPa)

$y = 0{,}000046x^3 - 0{,}001354x^2 + 0{,}260781$ $R^2 = 0{,}9891$ (15,5 MPa)

Fig. 5. Dependence of CO emission level in fumes on the effective power (*Ne*) of a S-4003 tractor engine, for different injectors opening pressures p_{io} (regression analysis) : a) 1500 rpm, b) 2000 rpm

Changes in the hydrocarbons (HC) content in fumes in the function of the effective power (*N*e) on the load characteristics at the speed 2000 rpm, for alternating angles of the pumping start, were presented in Fig.6a, and for alternating injectors opening pressures, in Fig. 6b.

a)



b)

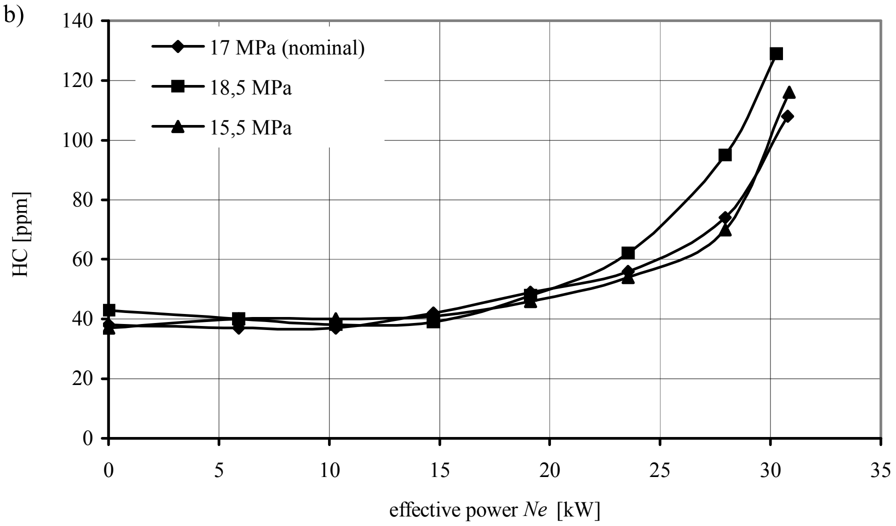
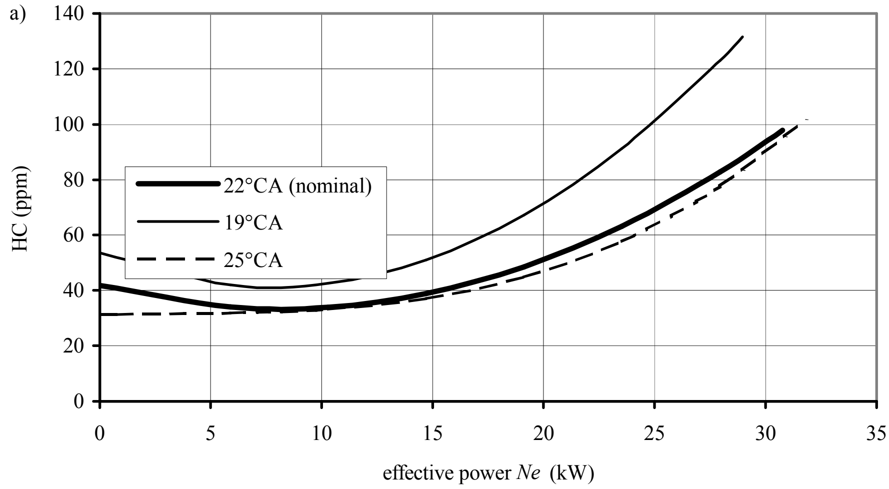


Fig. 6. Dependence of hydrocarbons emission levels (HC) on the effective power (Ne) of S-4003 tractor engine, at 2000 rpm, for different angles of the pumping start α_{ps} – fig. 6a and for different injectors opening pressures p_{io} – fig. 6b

a)

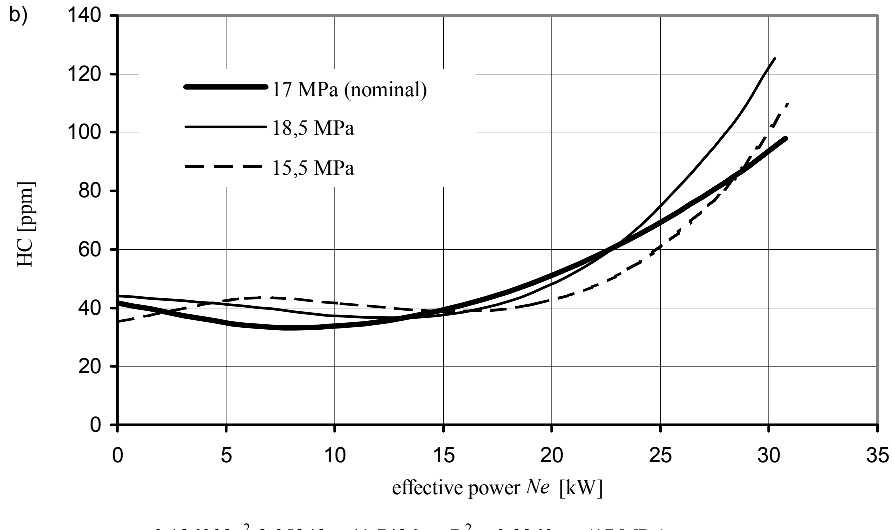


y = 0,126002x2-2,05249x+41,7426 R2 = 0,9360 (22oCA)

y = 0,20122x2-3,1322x+53,4717 R2 = 0,9565 (19oCA)

y = 0,002816x3-0,024576x2+0,143236x+31,3857 R2 = 0,9972 (25oCA)

b)



$y = 0{,}126002x^2 - 2{,}05249x + 41{,}7426$ $R^2 = 0{,}9360$ (17 MPa)

$y = 0{,}007688x^3 - 0{,}144134x^2 + 44{,}1555$ $R^2 = 0{,}9931$ (18,5 MPa)

$y = 0{,}01035x^3 - 0{,}337949x^2 + 2{,}97871x + 35{,}3591$ $R^2 = 0{,}9599$ (15,5 MPa)

Fig. 7. Dependence of hydrocarbons emission levels (HC) on the effective power (Ne) of S-4003 tractor engine, at 2000 rpm, for different angles of the pumping start α_{ps} – fig. 7a and for different injectors opening pressures p_{io} – fig. 7b (regression analysis)

The analysis of the above mentioned curves showed:

1. Rise of CO emission level in fumes in the whole engine loads range and at two engine rotation speeds for the angle of the fuel pumping start α_{ps} = 19^{o}CA before TDC – on average by 35.3% at 1500 rpm and by 50.6% at 2000 rpm, compared to the nominal value (α_{ps} = 22^{o}CA before TDC).

2. Drop of CO content in fumes for an increased α_{ps} = 25^{o}CA - on average by 6.3% at the rotation speed 1500 rpm and by 12.4% at 2000 rpm, compared to the nominal value α_{ps} = 22^{o}CA, in the tested engine loads range.

3. Rise of HC emission level in fumes for α_{ps} = 19^{o}CA – on average by 36.,5% and drop on average by 8.4% for α_{ps} = 25^{o}CA compared to the nominal value α_{ps} = 22^{o}CA, in the tested engine loads range and at the used engine rotation speed.

4. An average in the tested engine loads range and at the used engine rotation speeds rise of CO concentration in fumes for an increased injectors opening pressure p_{io} = 18.5 MPa – by 12.5% for 1500 rpm and by 11.5% for 2000 rpm and also drop of CO concentration for a decreased p_{io} = 15.5 MPa – by 5.4% at 1500 rpm and by 4.1% at 2000 rpm, compared to the nominal value (p_{io} = 17 MPa).

5. A slight (on average by 2.2%) drop of HC concentration in fumes for p_{io} = 15.5 MPa and a rise in its emission level on average by 12,1% for p_{io} = 18.5 MPa, compared to the nominal value p_{io} = 17 MPa, in the tested engine loads range.

6. The regression analysis showed a good matching of the theoretical curves to the actual function dependencies of CO and HC emission levels in the fumes of the tested engine, due to the high values of determination coefficients R^2 , which for alternating regulation parameters and in the realised measurement conditions are contained in the range from 0.9242 to 0.9972.

CONCLUSIONS

The research showed a significant influence of the change (compared to the nominal values) of the regulation parameters of a fuel injection system on CO and HC emission levels in the fumes of an agricultural tractor engine. The highest emission of toxic fume contents was recorded for a smaller pumping start angle (α_{ps} = 19^{o}CA before TDC), which proves the unfavourable character of the engine work parameters obtained at a delayed fuel injection (the engine power's value dropped by several per cent). The lowest CO and HC concentration in fumes was obtained for α_{ps} = 25^{o}CA, such conditions, however, are characterised by a remarkable dynamics of combustion and hard work of an engine. A rise of injectors opening pressure is connected with a delayed injection (despite a better fuel spray), hence, for the pressure 10% higher than the nominal one, an increased emission of toxic compounds was recorded. For the injectors opening pressure about 10% lower than the nominal one, the changes in CO and HC emission were found to be the smallest.

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SUMMARY

The article presents results of experimental tests on emission levels of carbon oxide and hydrocarbons in fumes of S-4003 engine of the agricultural tractor Ursus-360 as well as the theoretical dependencies found out by the method of curvilinear regression analysis at changing regulation parameters of a fuel injection system, i.e. at different fuel pumping start angles and injectors opening pressures. The tests were carried out on a dynamometric stand in an engine brake room, for two rotation speeds of the engine and for the full road range. CO and HC emission levels were determined by means of a multigas absorption fume analyser.