

## AN ANALYSIS OF SMOKE EMISSIONS FROM A RAPE BIOFUEL FED TRACTOR ENGINE

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**Summary.** The paper contains research results after testing experimentally the level of fumes smokiness in a S-4003 engine of an agricultural tractor Ursus C-360 as well as theoretical dependencies determined by the method of the curve line regression analysis, for an engine fed with ester fuel RME, diesel oil ON and the mixtures of both. The tests were carried out on the dynamometric stand in the engine brake hall at two rotational speeds of an engine (the maximum torque and the rated power) for the full loadings range. The level of smokiness was determined by the filter method using the smoke counter D-400.

**Key words:** ester fuel RME, fumes smokiness level, tractor engine

### INTRODUCTION

Pollution of natural environment with toxic contents of fumes due to combustion engines emissions is now one of the basic research issues in the field of motorization. Researches have proved that contamination of nature with motor fumes does not only concern big cities but is also found in rural areas. It is largely due to the exploitation of diesel engines, generally used as driving units in agricultural vehicles. This refers especially to the problem of particulate matter emissions, the level of which often replaces that of fumes smokiness. Particulate matter consists mainly of soot, causing the characteristic black colour of fumes (smoke), with the superficially absorbed organic compounds, i.e. toxic hydrocarbon compounds (coming from fuel and engine lubricant) as well as inorganic compounds such as sulfates, nitrates, water, salts, fuel and oil particles. Moreover particulate matter contains other substances, e.g. metals, coming from engine parts friction or fuel and oil pollution [Bocheński 1990, Chłopek 2002].

At the moment a priority in combustion engines development is the lowest possible emission of toxic fumes contents at an economic fuel consumption ( $\text{CO}_2$  emission), with the optimum engine dynamics and durability preserved. Adaptation of engine construction to the requirements of environmental protection promotes the use of replacement fuels, including plant fuels and their esters, for engine feeding. In our climactic conditions, an alternative for diesel engines feeding with diesel oil is rape-based fuel, particu-

larly methyl esters of rape oil fatty acids, RME (rape methyl ester), called biodiesel in western literature. Experience of many countries has shown that the use of both pure ester oil and its mixtures with engine oil is technically possible, but its production in the so called transestrification process results in a significant fuel price rise, which undoubtedly speaks for the use of diesel oil. However, research has shown that diesel engines feeding with rape biofuel is not only ecologically beneficial but also has other advantages, like: good biodegradability, participation in the greenhouse effect reduction ( $\text{CO}_2$  emitted from an engine is absorbed by plants from which biofuels are obtained), or the use of home raw materials for plant fuels production [Lotko 2000, Szlachta 2002].

Ester fuel plays a particular role in agriculture, with which it is involved from the very start, i.e. rape growing, its processing, biofuel production and its exploitation for diesel engines feeding in agricultural tractors and other vehicles. There is a possibility of providing new jobs as well as of exploitation of non-arable or chemically contaminated areas.

### THE DESCRIPTION OF RESEARCH STAND AND METHODS

The research was carried out on a four-cylinder diesel engine S-4003 of the C-360 Ursus tractor fixed on a dynamometric stand in the engine brake hall of the Department of Vehicles and Engines of the Agricultural University of Lublin. The tested engine has got the combustion unit with the direct fuel injection to the toroidal chamber in the piston. The diagram of the test stand is presented in Figure 1.

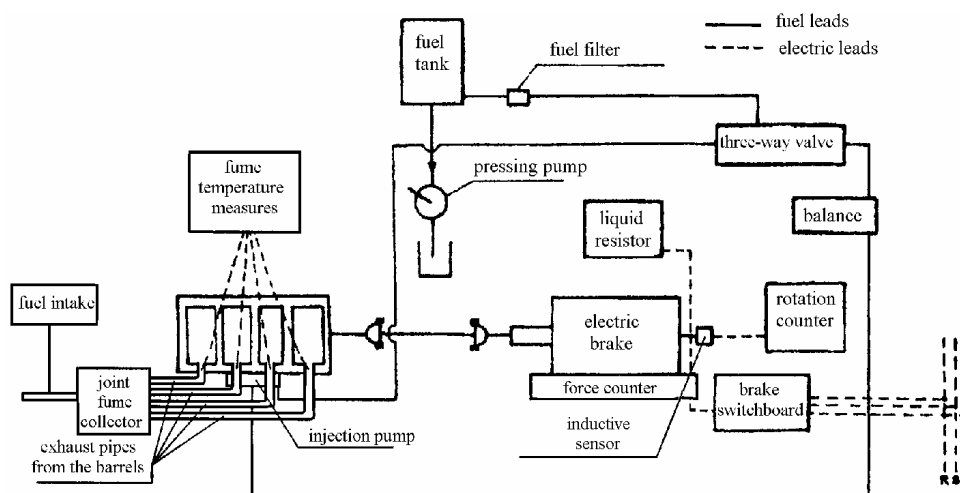


Fig. 1. The diagram of the test stand

The main element of the dynamometric stand is an electric brake of the type K1-136B-E (alternating current generator), which also served for the starting of the tested engine. The rotational speed of the engine was measured by means of an inductive sensor cooperating with a digital counter of the type NO<sub>5</sub>.

The level of fumes smokiness was determined by the filter method using a smoke counter of the type D-400. The measurements were taken for particular points of the

loading characteristics at two rotational speeds of the engine ( the maximum engine torque – 1600 rpm and rated engine power – 2200 rpm). The engine was fed with pure fuels: the ester of RME and engine oil (ON) as well as mixtures of RME and ON. Fume samples for the smokiness analysis were taken from behind the joint fume collector (Fig. 1). The selected properties of the tested fuels were presented in Table 1.

Table 1. Density and relative viscosity of the tested fuels at 20°C

Fuel	Density [g/cm <sup>3</sup> ]	Viscosity [°E]
100% ON	0.829	1.275
5% RME-95% ON	0.833	1.280
10% RME-90% ON	0.837	1.291
100% RME	0.875	1.676

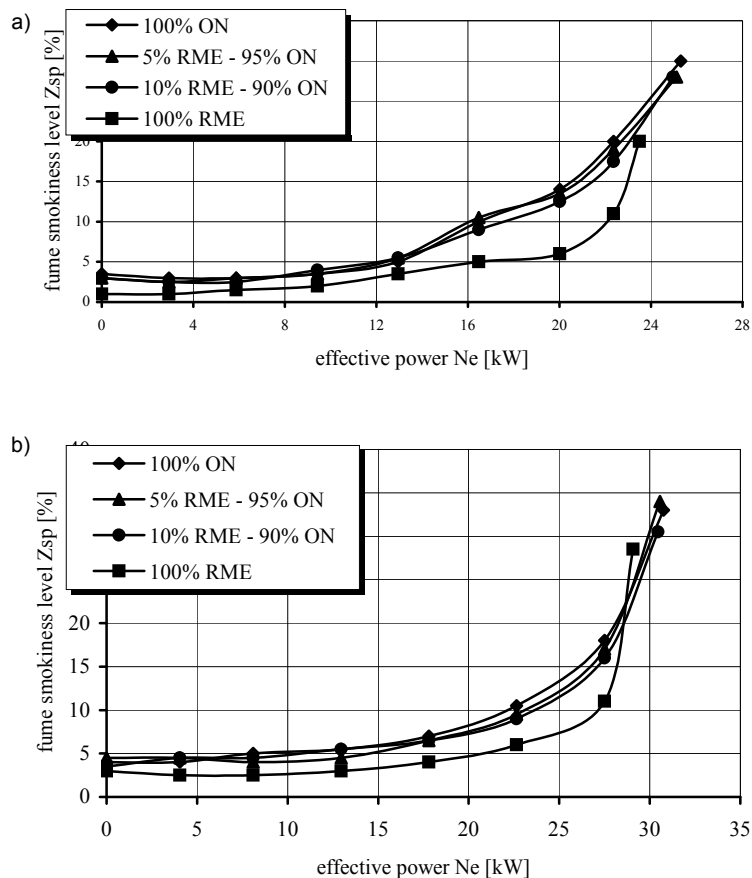


Fig. 2. The dependence of fume smokiness level on the effective engine power ( $N_e$ ) of a tractor engine S-4003 fed with pure fuels: ester (RME) and diesel oil (ON) as well as with mixtures of RME and ON: a) 1600 rpm b) 2200 rpm

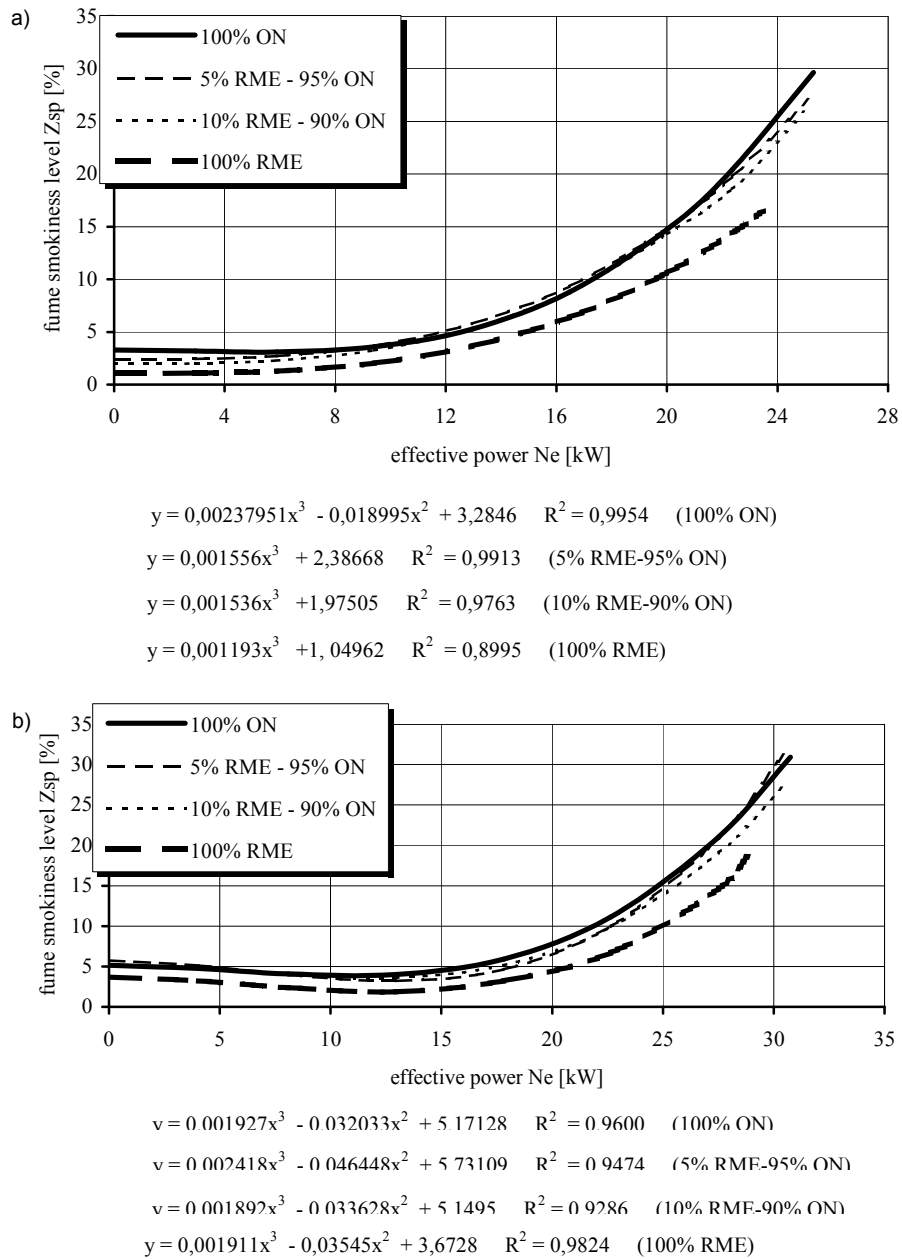


Fig. 3. The dependence of fume smokiness level on the effective engine power ( $N_e$ ) of a tractor engine S-4003 fed with pure fuels: ester (RME) and diesel oil (ON) as well as with mixtures of RME and ON (regression analysis): a) 1600 rpm b) 2200 rpm

## RESULTS AND ANALYSIS

The experimentally obtained changes in fumes smokiness ( $Z_{sp}$ ) emitted by a tractor engine S-4003 in the function of the effective power ( $N_e$ ), the engine being fed with ester oil RME and conventional diesel oil ON as well as mixtures of RME and ON, are presented in Figure 2a – for the rotational speed of the engine 1600 rpm and in Figure 2b – for the rotational speed 2200 rpm.

Figure 3 presents the theoretical dependencies, for the above-mentioned experimental runs respectively, determined by the method of the curve line regression analysis. The valid regression equation was selected on the basis of the determination coefficient  $R^2$  values, magnitudes of the F-Snedecor test functions for the testing of the model's validity as well as on the significance levels of the particular regression function elements (t-Student tests).

The analysis of the above-mentioned runs has shown the following:

1. Drop in fumes smokiness  $Z_{sp}$  for the whole loads range and at both the rotational speeds of an engine fed with pure ester fuel, by 53.8% on average at the rotational speed 1600 rpm and by 39.6 % at 2200 rpm, compared to feeding with diesel oil.
2. Drop of  $Z_{sp}$  in an engine fed with mixtures of RME and ON, by 6.2 on average at 1600 rpm and by 5.1% at 2200 rpm for the mixture of 10% RME – 90% ON as well as by 3.4% at 1600 rpm and by 3.7 % by 2200 rpm for the mixture 5% RME – 95% ON, compared to a diesel oil fed engine.
3. Drop in effective power  $N_e$  apparent at the full engine loading, by 7.1% at the rotational speed 1600 rpm and by 5.4% at 2200 rpm, for an engine fed with pure RME.
4. Good adjustability of the theoretical curves to real functional dependencies of the fumes smokiness level in the tested engine due to high determination coefficients  $R^2$ , which are included in the range from 0.8995 to 0.9954, for the tested fuels and the actual measurement conditions.

## CONCLUSIONS

The research has shown that using rape oil methyl esters (RME) for a tractor engine feeding results in a significant smokiness drop. After the analysis of tests results it can be said that fumes smokiness level in an engine fed with pure ester oil has dropped by over 45% on average in the full loadings range and for both the characteristic rotational speeds of the engine, compared to an engine fed with diesel oil. This is mainly due to a high oxygen content in plant oil which is reflected in the drop of particulate matter emissions and, consequently, in fumes smokiness. Similarly when an engine is fed with diesel oil to which methyl esters of rape oil were added, a drop in fumes smokiness was recorded, on average by about 3% (at 5% addition of RME) and about 5% (at 10% addition of RME), compared to an engine fed with diesel oil only. However, the drop in fumes smokiness in an engine fed with fuel based on rape oil methyl esters results in a simultaneous drop in engine power, on average by 6% for RME fuel, which is mainly due to its poorer burning value.

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