

THE INFLUENCE OF REGULATION PARAMETERS CHANGE IN A FUEL INJECTION SYSTEM ON NO_x EMISSION LEVELS IN COMBUSTION GASES OF A TRACTOR ENGINE

Jacek Wasilewski

Department of Vehicles and Engines, Agricultural University of Lublin

Summary. The paper includes experimental research results on the level of nitrogen oxides emissions in fumes of a S-4003 engine in an agricultural tractor Ursus C-360 as well as theoretical dependencies determined by the method of the curve line regression analysis, at change of regulation parameters of an injection apparatus i.e. of the fuel pumping start angle and of the injectors opening pressure. The tests were carried out on the dynamometric stand in an 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 NO_x emissions in fumes was determined using a multigas absorption fume analyzer.

Key words: injection apparatus, regulation parameters, nitrogen oxides, tractor engine

INTRODUCTION

Toxic compounds emissions in combustion engines fumes of agricultural tractors and vehicles are one of the greatest threats for natural environment. Diesel engines, generally used as driving units in agricultural vehicles, emit into the atmosphere mainly particulate matter, the level of which often replaces that of fumes smokiness, but also nitrate oxides, carbon oxide and hydrocarbons.

Among different causes of the above-mentioned toxic elements emissions rise from diesel engines, a significant one is the technical state of fuel systems. Exploitation practice shows that over 50% faults in diesel engines are caused by faulty fuel systems, besides, defects of injection systems in agricultural tractors are often due to complex conditions of their exploitation and frequent inefficiency of technical staff [Krasowski 1990]. Defects and wear of an injection apparatus as well as incorrect regulation settings lead to worse indices of an engine's work and higher environment's pollution by toxic fumes contents. The influence of an injection apparatus wear on the contents and smokiness of an agricultural tractor's fumes was presented, among others, by the author in the paper [Wasilewski 1999].

DESCRIPTION OF RESEARCH STAND AND METHODS

The tests were 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 main element of the dynamometric stand is an electric brake of the type K1-136B-E (a.c. 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 NO5.

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 rotary piston chamber.

Contents of nitrate oxides 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 for two characteristic rotational speeds of the engine (the maximum engine torque – 1600 rpm and rated engine power – 2200 rpm), at alternating regulation settings of the fuel injection system.

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) was enlarged – a momentoscope was used;
- *of the injectors opening pressure* 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 [Janiszewski *et al.* 1987, Instr. napraw 1990].

RESULTS AND ANALYSIS

Changes in the emission levels of nitrate oxides (NO_x) in fumes 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. 1a and 3a – for the rotation speed of the engine 1600 rpm and in Fig. 1b and 3b – for the speed 2200 rpm.

Figures 2 and 4 present 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, the 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).

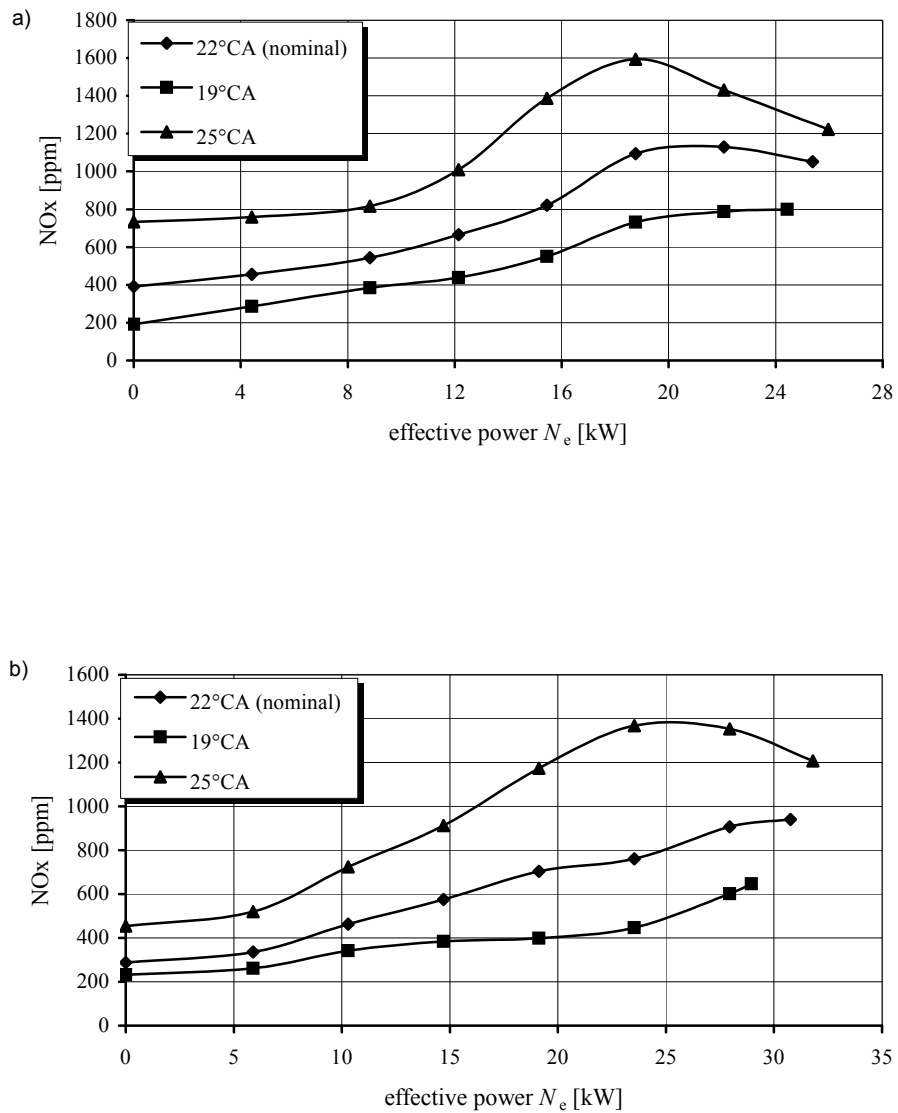
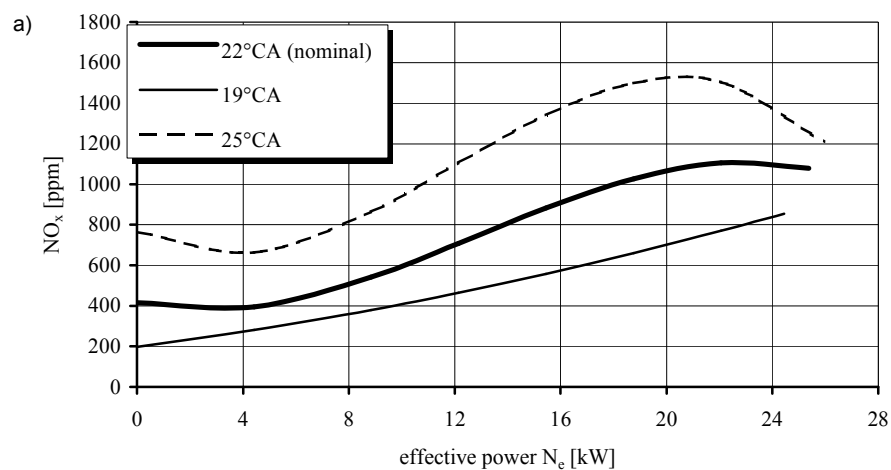


Fig. 1. Dependence of NO_x emission level in fumes on the effective power (N_e) of a S-4003 tractor engine, for different angles of the pumping start α_{ps} : a) 1600 rpm, b) 2200 rpm



$$y = -0,1708x^3 + 6,5629x^2 - 30,5x + 416,78 \quad R^2 = 0,975 \quad (22^\circ\text{CA})$$

$$y = (14,0085 + 0,6226x)^2 \quad R^2 = 0,9836 \quad (19^\circ\text{CA})$$

$$y = -0,3426x^3 + 12,271x^2 - 70,502x + 764,86 \quad R^2 = 0,9519 \quad (25^\circ\text{CA})$$

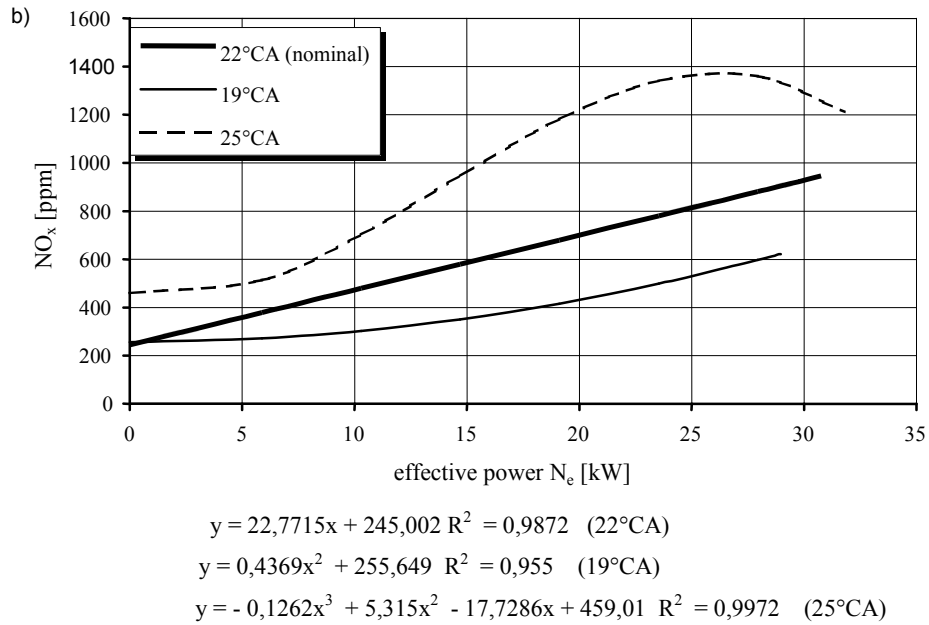
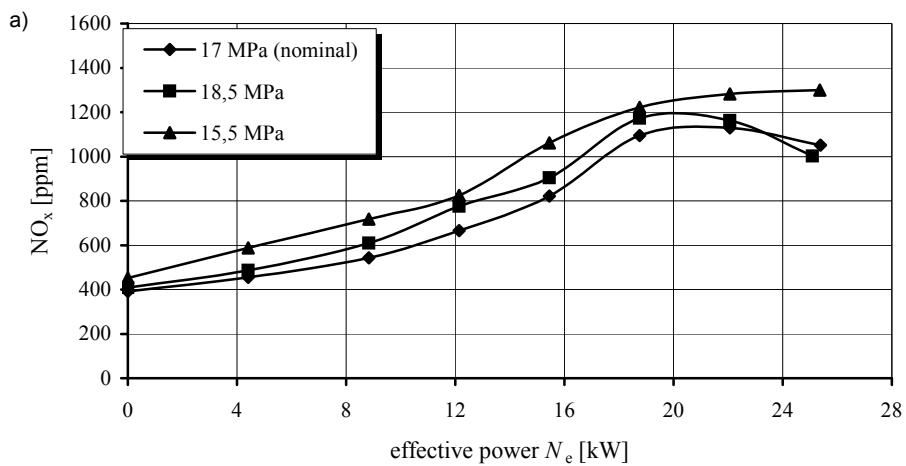


Fig. 2. Dependence of NO_x emission level in fumes on the effective power (N_e) of a S-4003 tractor engine, for different angles of the pumping start α_{ps} (regression analysis):
a) 1600 rpm, b) 2200 rpm



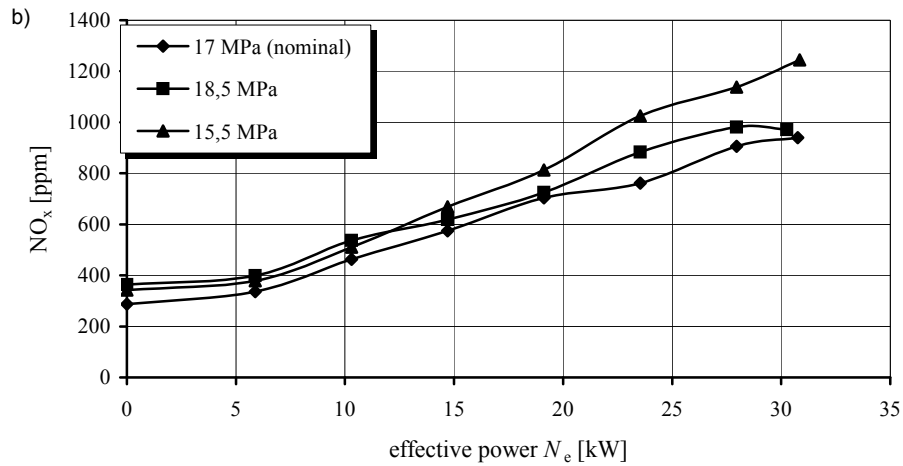
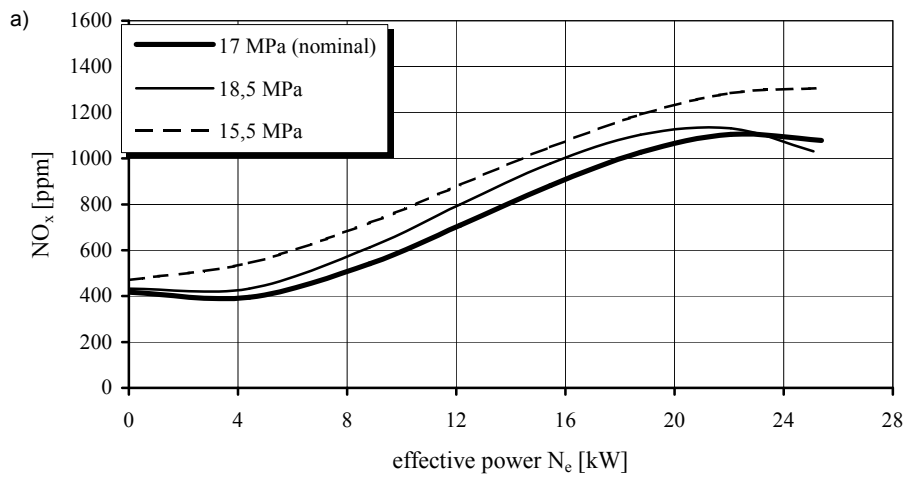


Fig. 3. Dependence of NO_x emission level in fumes on the effective power (N_e) of a S-4003 tractor engine, for different injectors opening pressures p_{io} : a) 1600 rpm, b) 2200 rpm



$$y = -0,1708x^3 + 6,5629x^2 - 30,5x + 416,78 \quad R^2 = 0,975 \quad (17 \text{ MPa})$$

$$y = -0,2115x^3 + 7,3851x^2 - 28,303x + 432,33 \quad R^2 = 0,9739 \quad (18,5 \text{ MPa})$$

$$y = -0,1111x^3 + 4,0841x^2 + 0,9303x + 469,42 \quad R^2 = 0,9909 \quad (15,5 \text{ MPa})$$

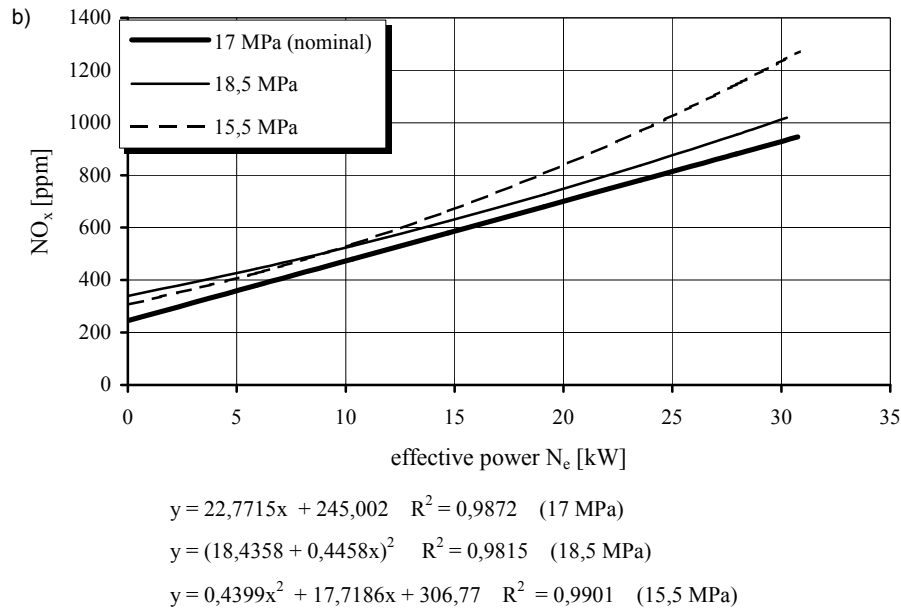


Fig. 4. Dependence of NO_x emission level in fumes on the effective power (N_e) of a S-4003 tractor engine, for different injectors opening pressures p_{io} (regression analysis):
a) 1600 rpm, b) 2200 rpm

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

1. Rise of nitrate oxides (NO_x) emission level in fumes in the whole engine loads range and at both the engine rotation speeds for the angle of the fuel pumping start $\alpha_{ps} = 25^\circ\text{CA}$ before TDC – on average by 51.7% at 1600 rpm and by 56.5% at 2200 rpm, compared to the nominal value ($\alpha_{ps} = 22^\circ\text{CA}$ before TDC).
2. Drop of NO_x content in fumes for a decreased $\alpha_{ps} = 19^\circ\text{CA}$ - on average by 34.1% at the rotation speed 1600 rpm and by 31.2% at 2200 rpm, compared to the nominal value $\alpha_{ps} = 22^\circ\text{CA}$, for the tested engine loads range.
3. An average for the tested engine loads range and at the used engine rotation speeds rise of NO_x content in fumes for a decreased injectors opening pressure $p_{ow} = 15.5 \text{ MPa}$) by 20.3% for 1600 rpm and by 23.9% for 2200 rpm and also for an increased $p_{ow} = 18.5 \text{ MPa}$ - by 8.4% at 1600 rpm and by 12.5% at 2200 rpm, compared to the nominal value ($p_{ow} = 17 \text{ MPa}$).
4. A good matching of the theoretical curves to the real function dependencies of NO_x 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 the carried out measurement conditions are contained in the range from 0.8773 to 0.9980.

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 NO_x emission

levels in the fumes of an agricultural tractor engine. Significant ecological benefits were noted for a decreased pumping start angle ($\alpha_{ps} = 19^\circ\text{CA}$), the delay of pumping, however, and consequently of the fuel injection, negatively affects the typical engine work indicators, which is supported by the drop in power by about 5%. Both an increase of the fuel pumping start angle and change in the injectors opening pressure compared to the nominal regulations caused an increase in nitrate oxides emission levels. The highest (more than 50%) increase of NO_x content in fumes was noted for $\alpha_{ps} = 25^\circ\text{CA}$, which resulted from temperature rise during combustion. The less evident influence of injectors opening pressure on NO_x content in fumes results from the contrasting factors counteraction, namely, e.g. in the case of $p_{ow} = 15.5 \text{ MPa}$, of the prior injection but worse fuel spraying.

REFERENCES

- Instrukcja napraw. Wydawnictwo przemysłowe WEMA, Warszawa 1990. Zrzeszenie Przemysłu Ciągnikowego URSUS. Zakłady Mechaniczne „Ursus”: Kołowe ciągniki rolnicze Ursus C-360, Ursus C-360-3P.
- Janiszewski T., Falkowski H., Sławski Cz. 1987: Krajowe silniki wysokoprężne. Obsługa i naprawa. WKiŁ, Warszawa.
- Krasowski E. 1990: Wpływ zużycia par precyzyjnych na parametry pracy silnika wysokoprężnego. Wydawnictwo Uczelniane Politechniki Lubelskiej, Lublin.
- Wasilewski J. 1999: Zużycie wybranych zespołów ciągnika rolniczego a jego parametry pracy w eksploatacji polowej. Rozprawa doktorska, AR w Lublinie, Lublin.