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EMISSIONS REDUCTION AT DIESEL ENGINES

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Abstract: The fuel injection system for modern Diesel engines has a rail that serves as a high pressure reservoir for the fuel delivered by the high pressure pump. By using piezoelectric injectors it is possible to preinject a small quantity of fuel, before the main injection. As a consequence, this will reduce emissions and soot in Diesel engines.

1. INTRODUCTION

Common rail injection systems are used in modern Diesel engines. The scheme for the common rail injection system is shown in fig.1.

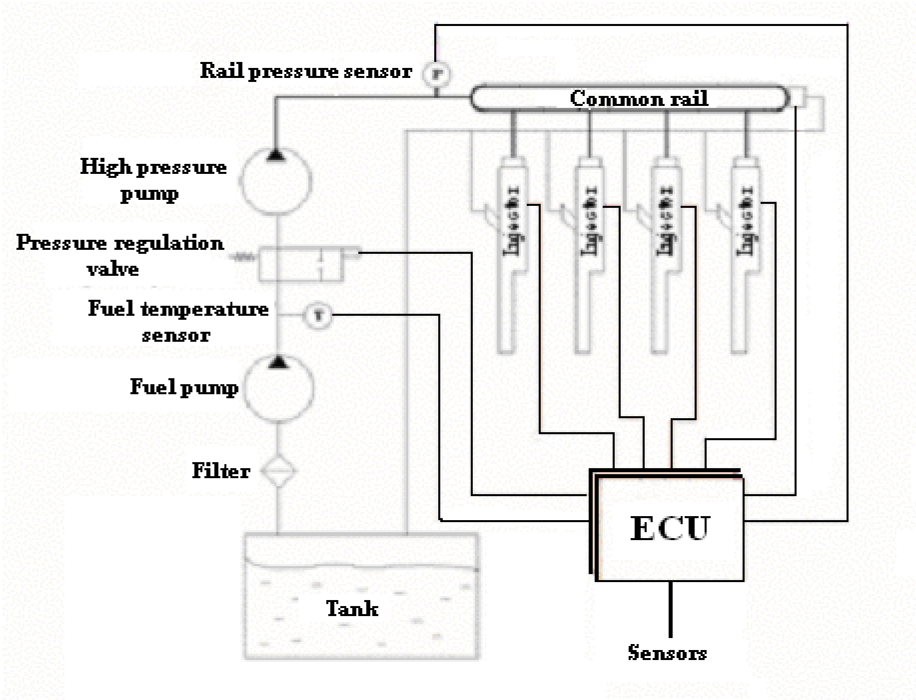

Fig.1 Common rail injection system

From the tank fuel is pumped to the high pressure pump. The high pressure pump can produce in the rail pressures up to 200 MPa. Pressure oscillations in the rail are controlled via a high pressure bypass. So pressure pulsation in the rail will be ±0,5 MPa.

The injectors are piezoelectric. The main part of the injector is a piezoactuator that allows relatively low electrical voltages. Opening and closing of the servo valve is done in less than 100 µs.

The nozzles have five holes and are sac-less.

The command of injection timing comes from the Electronic Command Unit (ECU) and it's based on the information coming from the sensors.

These sensors give informations regarding: engine speed, engine phase, speed, water temperature, air temperature, boost pressure, atmospherically pressure and air flow.

Actuators are for the EGR (exhaust gas recirculation) system and for the turbo unit.

2. EXHAUST EMISSIONS IN DIESEL ENGINES

Exhaust emissions in Diesel engines are:

1. Carbon dioxide (CO_2) emission can be lowered by reducing fuel specific consumption and enhancing consumption in partial load regime.
2. Carbon monoxide (CO) is formatting in Diesel engines because the inhomogeneity of mixture in areas where air-fuel ratio is less than one. Carbon oxide emissions are much lower in Diesel engines than in SI engines.
3. Hydrocarbons appear in exhaust gas from uncombusted and partially combusted fuel and from thermal cracking products. A reduction of hydrocarbons from 400 ppm to 100 ppm can be achieved by using zero blind hole nozzles.
4. Nitrogen oxides (NO_x) arise from the reaction between oxygen and nitrogen in air during combustion. NO formation takes place especially in the interval 2200-2400 K. At higher temperatures NO emission lowers. The trend is to reduce maximum temperature of engine cycle to 1700-1900 K.
5. Particles (soot) in Diesel engines are mostly hydrocarbon particles. The temperature interval for particle formation is 800-1400 K.]

3. THE MATHEMATICAL MODEL

In order to improve combustion and mixture homogeneity, a mathematical model was developed for the burning process and the formation of emissions and soot.

The mathematical model for the burning process was developed using AVL's FIRE Program.

By experiments it was proved that nitrogen oxides arise in time. Nitrogen oxides reaches a maximum concentration and afterwards it remains constant.

For the formation of nitrogen oxides it was used the Zeldovich mechanism. It is considered that NO_x arise as a result of chain reaction that includes the following elementary chemical reactions:

$O+N_2 \rightarrow NO+N$	(1)
$NO+N \rightarrow O+N_2$	(2)
$O_2+N \rightarrow NO+O$	(3)
$NO+O \rightarrow N+N_2$	(4)

Reactions 1 and 3 generate nitrogen oxides, but reaction 1 initiates the chain reaction. Reactions 2 and 4 decompose nitrogen. Reaction speed in these last two is small even at low temperatures so in expansion and exhaust processes the maximum nitrogen concentration achieved during the burning process is practical unchanged.

Based on the reaction speed for equations 1 and 3 it is possible to calculate the time in which maximum nitrogen oxides is achieved, that is 25-30 ^{0} of crankshaft rotation.

Soot in Diesel engine is of three types:

a. White smoke which appears when starting the engine. It is formed by fuel liquid particles with a diameter of around 1 μm.

b. Blue smoke appears at idle and at high loads and consists of unburned fuel particles with 0,5 μm diameter and oil.

c. Black smoke arise at low rotation speeds and in acceleration regime. It contains carbonate particles with 1 μm diameter.

It was proved that lower emissions can be reached by using pilot injection. The mathematical model was developed to calculate emissions in Diesel engines using pilot injection and further to determine the injection parameters to reduce at minimum emissions.

4. TEST BED DESCRIPTION

The test bed contains a Peugeot Diesel engine with a common rail injection system and a hydraulic brake (fig. 2) and vas used to validate the mathematical model.

Fig.2 The test bed

Emissions were measured with a smokemeter.

Tests were made at full and at partial loads on various rotational speeds.

5. COMPARISON BETWEEN CALCULATED AND MEASURED VALUES

The comparison was made for nitrogen oxides and soot at a 40% load and various starts of injection moments.

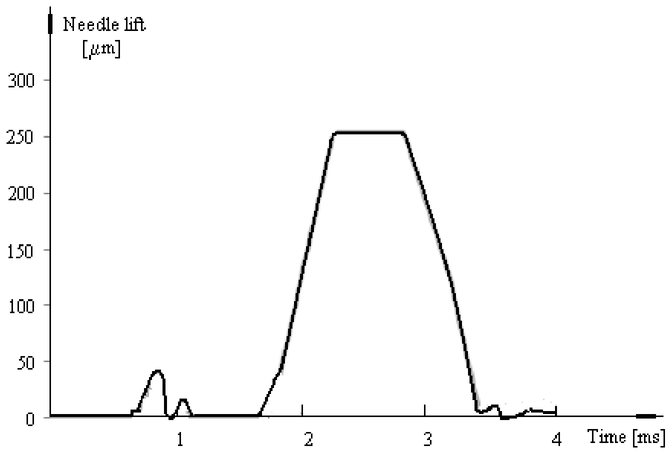

Fig. 3 Needle lift

The delay between the pilot injection and the main injection was of 1,5 ms and the quantity of fuel injected during the pilot injection was 1,7 mm^3 (fig. 3).

In fig. 4 is shown the difference between calculated and measured values for the nitrogen oxides emissions at starts of injection between -20 and 10 [^{0}CS].

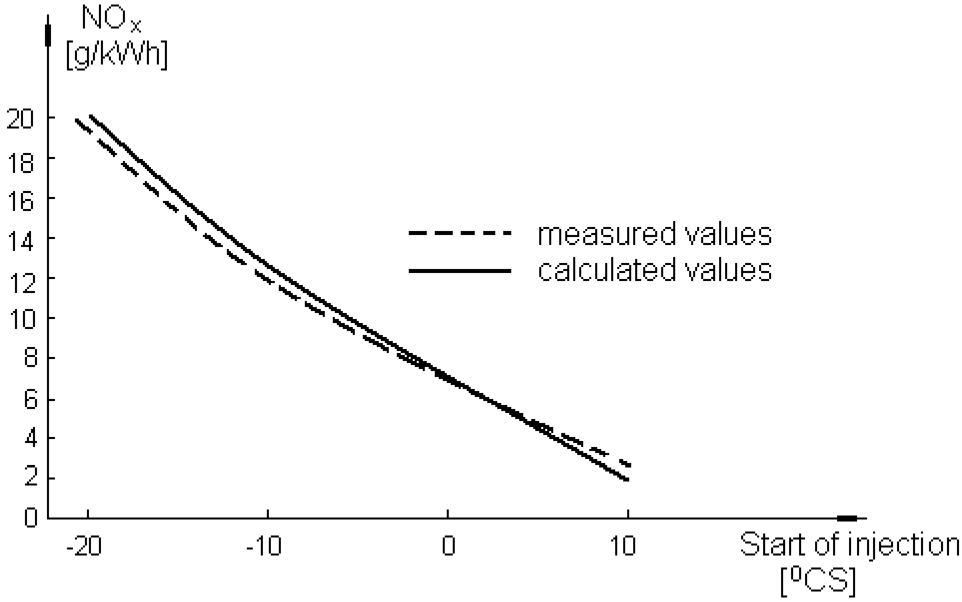

Fig.4 Comparison between measured and calculated values for nitrogen oxides

From fig. 4 one can see that the differences between measured and calculated values for nitrogen oxides are small (under 5%).

5. CONCLUSION

By using common rail injection systems and pump nozzle at Diesel engine it is possible to optimize fuel preparation. As a result a lower particle emission is achieved in exhaust gases.

The mathematical model developed by the authors for diesel engines with common rail injection systems offers the possibility to study the conflict between particle and nitrogen oxides emissions.

These emissions are influenced by some parameters such as: the start of injection, fuel injection pressure, nozzle shape, fuel injection quantity, preinjection, injection spacing, main injection and injection time.

From the calculated data best results regarding emissions were obtained with a start of injection between -12 and -6 ^{0}CS, with a 1,5 ms delay for the main injection and a pilot injection of 1,8 mm^{3}. The injection pressure was 170 MPa.

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