EMISSION CHARACTERISTICS OF A DIESEL ENGINE USING BIODIESEL PRODUCED FROM RAPESEED

Breda Kegl, Stanislav Pehan, Marko Kegl

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INTRODUCTION

To reduce harmful diesel engine emissions many experimental and numerical investigations related to the control of the injection and combustion processes have been done. To fulfill strongest emissions regulations many kinds of alternative fuels have been investigated.

The most frequently investigated parameters are related to the injection rate, injection timing, injection duration, injection pressure, start of combustion, in-cylinder gas pressure and temperature, and heat release rate. NOX emissions are significantly affected by injection timing and injection pressure [1]. Advanced injection timing and higher injection pressure result in higher in-cylinder gas temperatures. Soot emissions reduce as the injection pressure is increased and the minimum values are reached in case of advanced injection timing which improves the soot oxidation [1]. A strong relationship of the air/fuel ratio and in-cylinder gas temperature with NOX and soot emissions is reported [2]. To improve combustion and reduce harmful emissions of diesel engines, various oxygenates may be added to mineral diesel. The ignition delay influences the combustion process strongly [3, 4].

Biofuels may offer an opportunity to reduce some of the harmful emissions without expensive engine modifications. Biodiesel is a very promising fuel because it is a sulfur-free, non-toxic, oxygenated, renewable, and more than 90% biodiesel can be biodegradable within 3 weeks. Biodiesel has higher cetane number than mineral diesel, no aromatics, almost no sulfur, and contains more oxygen by weight.

Biodiesel distinguish higher density, viscosity, surface tension, sound velocity, and bulk modulus of elasticity. This affects the fuelling, injection timing, and fuel spray and consequently the emission characteristics [5]. The advantages of the biodiesel are shorter ignition delay due to a higher cetane number and an enhanced combustion process caused by oxygen in the biodiesel. On the other hand, the disadvantages of the biodiesel are higher kinematic viscosity and surface tension.

Biodiesel has lower heating value than mineral diesel and causes some loss of power. Therefore, it is necessary to increase the fuel amount to be injected into the combustion chamber. This will cause longer injection duration due to change in the injection timing. Higher cetane number corresponds to shorter ignition delay and advances the combustion timing [4].

In this paper the influence of biodiesel from rapeseed oil on combustion characteristics of bus diesel engine with M injection system is considered. Some important engine characteristics are determined by experiment and by numerical simulation. The objective is to identify as much as possible the dependences among fuel properties, the most important injection and combustion characteristics, harmful engine emissions, and other engine performances. Special attention is devoted to dependences among injection timing, in-cylinder gas temperature and NOX emission.

EXPERIMENTAL WORK AND NUMERICAL COMPARISON

The schematic diagram of the engine test bed is presented in **Fig.** Error! Reference source not found.. The test bed consists of an engine and electro-dynamometer Zöllner A-350AC, 300kW, air flow rate meter RMG, fuel consumption dynamic measuring system AVL, UHC analyser Ratfisch, NO_x chemoluminiscent analyzer Thermoelectron, O_2 analyzer Programmelectronic, CO analyzer Maihak, and smoke meter AVL. Using a data acquisition system the instantaneous injection pressure and needle lift, the instantaneous in-cylinder gas pressure, the temperatures of fuel, ambient air, intake air, cooling water at inflow and outflow of the engine, oil pressure and temperature, and the temperature exhaust gases are measured also.

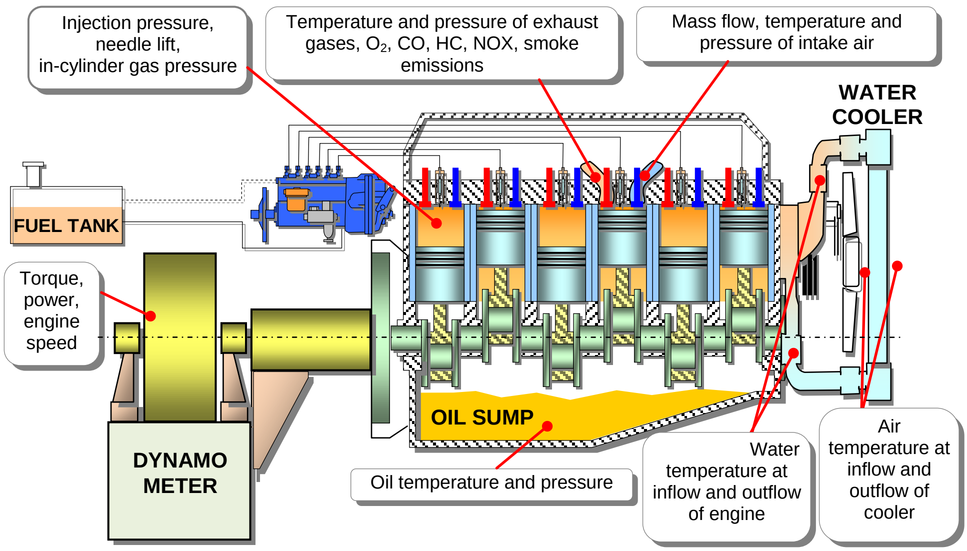

Figure 1 The engine test bed scheme.

The tested engine is a bus diesel engine MAN D 2566 MUM with a mechanically controlled fuel injection system. The engine has completed 500 000 km and has undergone general renovation. The direct injection M system is a kind of an injection combustion system. The M system does not distribute the fuel in the air initially, but sprays it with a single-hole nozzle onto the wall of a spherical combustion chamber, where it spreads to form a thin film. The fuel is injected in the direction of a high-speed air swirl. LabVIEW software platform is used to build the computer applications for data acquisition, data analyses and control algorithms. These applications are used to control the operation of the multifunction card and for data logging and post-processing.

The measurements and computations of engine characteristics are performed at various engine operating regimes. The comparison is done for all tested fuels at several operating regimes at full load, especially at the peak torque and rated conditions.

To check the accuracy of the numerical simulation used for our engine model, presented in **Fig.** Error! Reference source not found., the in-cylinder gas pressure, the engine power and the effective specific fuel consumption are measured at various engine operating regimes.

Accurate and efficient numerical analysis is a key factor for successful determination of combustion characteristics and their improvements. For the steady state performance prediction of diesel engines, there are several commercial packages that are widely accepted, rigorously tested, and verified. Efficient use of such software requires fine tuning of parameters and proper choice of available options. For the experiment approval in the presented case the AVL BOOST v2009.1 and the sub-models are used.

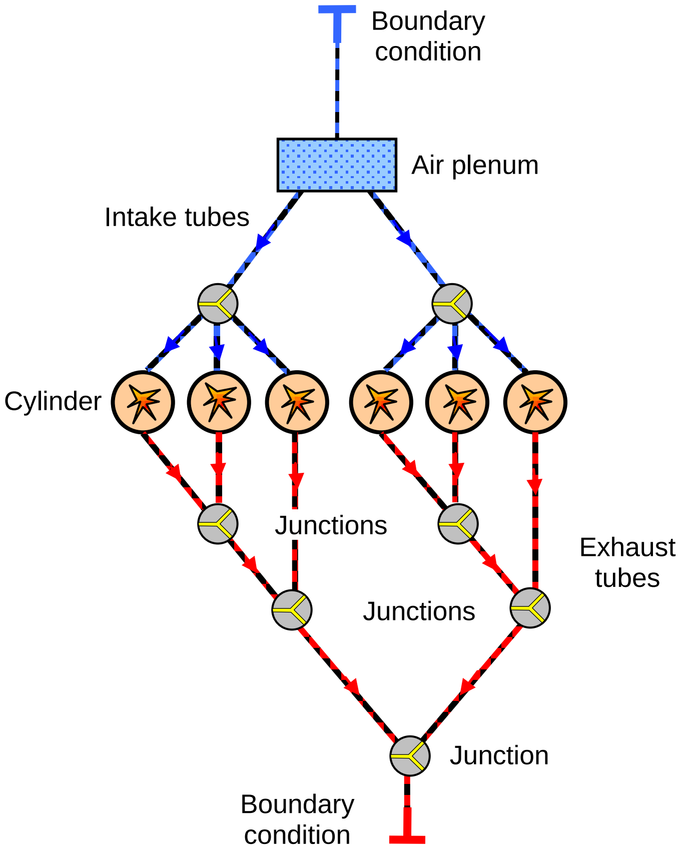

Figure 2 The engine model for numerical simulation

In-cylinder pressure is tested for both tested fuels at various operating regimes. **Fig.** Error! Reference source not found. show the comparison of the in-cylinder gas pressures, obtained numerically (AVL BOOST) and experimentally at rated condition by using B100 fuel and at peak torque condition when D2 fuel is used. A good agreement in the in-cylinder gas pressures at shows that the numerical simulation model is suitable to analyze the influence of B100 on combustion parameters. A similar agreement between experiment and numerical simulation was also obtained for engine power and effective specific fuel consumption.

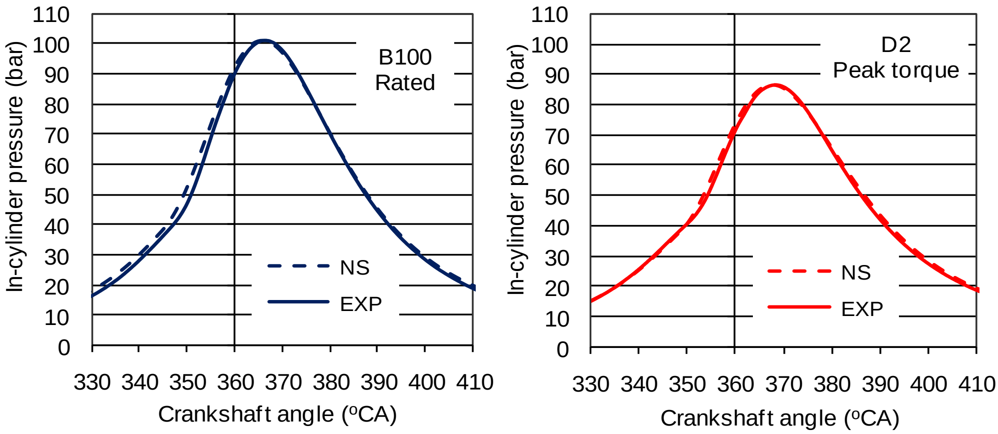

Figure 3 In-cylinder gas pressure at rated and peak torque conditions.

RESULTS AND DISCUSSION

To analyze the influence of fuel properties on bus diesel engine characteristics, the most important injection and combustion characteristics, obtained with B100 and D2, are compared and discussed in this chapter.

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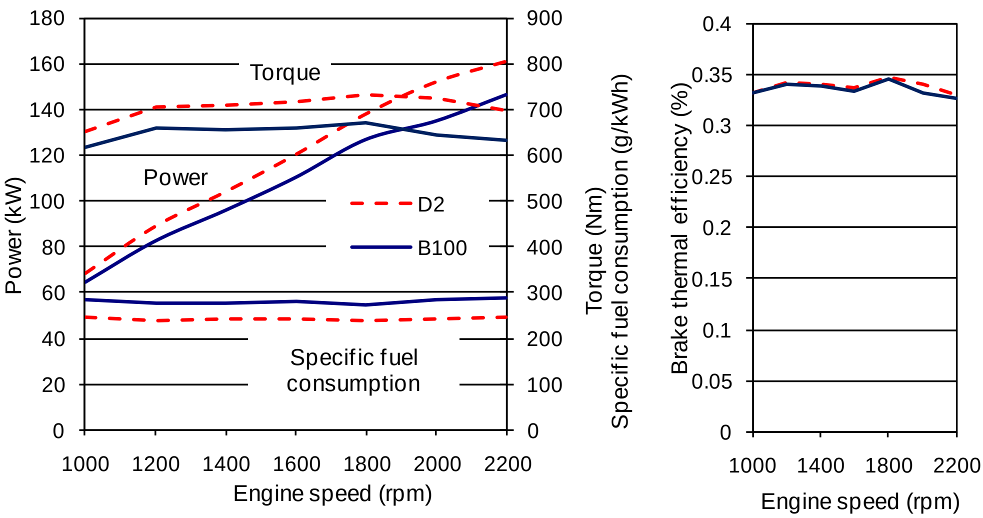

Figure 4 Effective power and torque, injected fuel mass and specific fuel consumption and brake thermal efficiency at full load conditions (numerical simulation).

Engine performance and harmful emissions are measured at various engine regimes. From the Fig. 4 the good agreement between numerical and experimental results is evident. B100 has lower effective power and torque by about 10 % and higher effective specific fuel consumption. The obvious reason is the lower heating value of B100.

Because the obtained power at the same operating regime is not the same for B100 and D2, the relative emissions are compared. Fig. **Error! Reference source not found.** presents the comparison of NOX, HC, CO, and smoke relative emissions, obtained experimentally. When B100 is used, NOX and HC relative emissions are higher; meanwhile CO and smoke relative emissions are lower. The differences of NOX relative emission between B100 and D2 are smaller at lower engine speeds.

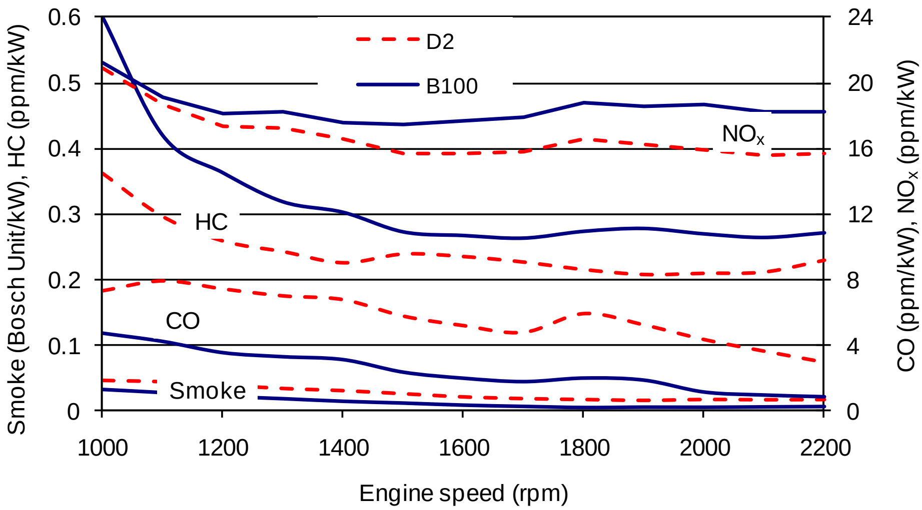

Figure 5 Relative emissions at full load conditions (experiment)

It is obvious that NOX relative emission generally increases with higher engine speed. This is partially due to the gas flow motion within cylinder under higher engine speed that leads to faster mixing between fuel and air and a shorter ignition delay. The reaction time of each engine cycle is reduced causing an earlier and higher in-cylinder gas temperature peak. By using B100 this effect is even more evident.

CONCLUSIONS

The influence of biodiesel produced from rapeseed oil (B100) on a bus diesel engine with direct fuel injection M system is investigated. By doing experiments and numerical simulation the relationships between fuel properties and engine emissions are analyzed.

- Higher density, viscosity, velocity of sound and bulk modulus of elasticity of B100 and lower vapor content in high pressure injection system cause the advanced injection timing and higher injection pressure.
- The advanced injection timing causes the increase of the in-cylinder gas pressure, in-cylinder gas temperature, and an earlier rise of the heat release rate.
- The higher injection pressure, higher oxygen content and other fuel properties of B100 results in lower smoke and CO emissions and in a slightly higher HC emission. The conditions in the cylinder during the first part of injection and combustion process

influence to a great extent the NOX formation. The results show that earlier appearance of temperature and heat release rate maximums prolongs the period with conditions favourable for NOX formation.

Thus, the higher NOX emission is a consequence of advanced injection and combustion process and of higher in-cylinder gas temperature at the beginning of combustion. The timing at which the maximum in-cylinder gas temperatures and heat release rates occur proved to be more important than the magnitude of the maximum temperature and maximum heat release rate.

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