The impact of the temperaturę of rapeseed oil methyl esters on nitrogen oxides emissions

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Abstract. The purpose of the tests described in this publication was to examine the effect of the temperature of the biodiesel burned, resulting from the transesterification of rapeseed oil with methanol, on the level of nitrogen oxides emissions. The tests were carried out on a test stand equipped with a 9.5 kW engine. Electricity was transffered directly to the power grid. The measurements were started after the engine has warmed up, when the oil temperature exceeded 85°C. In the first stage, the engine was loaded with the maximum achievable torque (100%), in the second stage the torque was set at 75% of the maximum value, and for measurements in the third stage the torque was 50% of the maximum value. Three tests were carried out, one for each of the three fuel temperatures: 20, 40 and 55°C.

1. Introduction

Combustion of fossil fuels (i.e. coal, oil) causes harmful gases (SO_2, NO_x) and greenhouse (CO_2, CH_x) gases emissions to the atmosphere [1]. However, in recent years there has been an increase in the interest of politicians and scientists in issues related to climate protection and air quality [2]. Liquid biofuels of vegetable origin can be an ecological alternative to fossil fuels [3–5]. They are synthesized by transesterification of vegetable oils with methanol. Their combustion does not deepen the greenhouse effect, but is associated with higher emissions of nitrogen oxides (NO_x). Due to the fact that the world is facing a growing environmental pollution, they are placed increasingly stringent emissions standards from internal combustion engines. One of the main emission of dangerous compounds in the exhaust gases are nitrogen oxides [6]. It is becoming increasingly difficult to meet the requirements of exhaust emissions standards for NO_x emissions, so new methods are being sought that can effectively reduce NO_x formation in combustion chambers of internal combustion engines. One method may be to regulate the temperature of fuel supplied by injection to the combustion chamber of the engine. Published research results indicate a reduction in NO_x emissions by increasing the temperature of the fuel introduced into the internal combustion engine [7,8], however, some reports indicate an increase in NO_x emissions with increasing the temperature of the fuel burned [9]. The purpose of this study was to determine the effect of temperature changes on rapeseed oil methyl esters (RME) used as fuel for a compression ignition engine on nitrogen oxide emissions.

2. Materials and methods

Methyl esters from rapeseed oils were used in the studies. Rapeseed oils were transesterified at 60°C using homogeneous catalyst 2% m/m KOH and methanol in molar share 1:9. The experiment was carried out on an experimental stand consisting of: Yannmar 2TNV70-ASA diesel engine, asynchronous engine, ATMX 2000 control and measurement system, exhaust fumes were tested with VARIOplus Industrial analyser. The composition of the exhaust gas was measured in the exhaust gas pipe, a straight section with a length of 1m at a distance of 1m from the exhaust manifold.The MRU VARIOplusIndustrial exhaust gas analyzer was used to analyze the composition of the emitted exhaust gases. The analyzer included a measuring probe designed for

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high dustiness equipped with a heated metal filter with measurement of exhaust gas temperature and heating regulation. The composition of the exhaust gas was measured using a three-electrode electrochemical sensor. The analyzer made it possible to register emission data expressed in ppm. In addition, the analyzer was equipped with a Pitot tube that allowed measuring the volume of emitted exhaust gases. Thanks to this, the analyzer system could automatically convert the emissions expressed in ppm to $mg \cdot nm^{-3}$ exhaust.

The test stand, the ATMX 2000 dynamometer, consisted of a Yanmar 2TNV70-ASA two-cylinder diesel engine with a pre-chamber, 9 kW, liquid-cooled. It was an engine with indirect fuel injection system and sectional injection pump. The engine was permanently connected via a shaft to an asynchronous motor, controlled by an automatic control and measuring system. The OMT1-160M2 asynchronous motor was a three-phase low-voltage induction motor with a squirrel-cage rotor, air-cooled. The stands were equipped with a 15 kW inverter MFC 710. Electricity was directed directly to the power grid

The research concerned the measurement of nitrogen oxides (NO_x) emission of an RME diesel engine. The tests were carried out in accordance with ISO 8178-4 - test D1 (test for engines operating at constant load). The measurements were started after the engine has warmed up, when the oil temperature exceeded 85°C. During the measurements, the engine worked at 3000 rpm^{-1} ± 10 rpm^{-1} (speed corresponding to the nominal speed of the asynchronous engine), which was set by means of the injection pump regulator. The test consisted of three stages. In the first stage, the engine was loaded with the maximum possible torque (100%). In the second stage, the torque was set at 75% of the maximum value, while during the measurements for the third stage, the torque will be 50% of the maximum value.

During each load change, it was necessary to correct the engine speed so as to obtain the assumed value of 3000 rpm^{-1} ± 10 rpm^{-1}. Each stage lasted 10 minutes, the first 7 minutes served to stabilize engine operating parameters, measurements were recorded for the next 3 minutes. Three tests were carried out, one for each of the three fuel temperatures: 20, 40 and 55°C.

To calculate the specific emissions from the test phase, the resulting NO_x concetration [$mg \cdot nm^{-3}$] was converted into the specific NO_x emission expressed in $g \cdot kWh^{-1}$ (A).

$$E = \frac{NO_x[mg \cdot nm^3] \cdot V\left[\frac{nm^3}{h}\right]}{P[kWh] \cdot 1000} \left[\frac{g}{kWh}\right] \quad (A)$$

The engine load was calculated from the energy generated by the generators to the network. The power obtained was not the engine power but the power of the power generator, which includes transmission losses and gears.Conversion of the unit of nitrogen oxides content in exhaust gases. The measuring system recorded the emission of nitrogen oxides in $mg \cdot nm^{-3}$ exhaust gas.

Then, the NO_x emission concentration was converted to $g \cdot kWh^{-1}$ according to the equation (B):

$$NO_x\left[\frac{g}{kWh}\right] = \frac{NO_x\left[\frac{mg}{nm^3}\right] \cdot V\left[\frac{nm^3}{h}\right]}{Ne[kW] \cdot 1000} \quad (B)$$

• NO_x [$mg \cdot nm^{-3}$] - content of nitrogen oxides in exhaust gases;
• V [$nm^3 \cdot h^{-1}$] - the amount of exhaust gas emitted by the engine;
• Ne [kW] - effective engine power.

3. Results

Table 1. Concentration NOx [$g \cdot kWh^{-1}$]

Temperature [ºC]	Engine load [%]		
	50	75	100
20	13,58	9,42	6,75
50	13,19	9,36	7,05
70	12,87	9,23	7,46

The emission of nitrogen oxides depends on the engine load and the temperature of the fuel introduced into the diesel engine. In the tests performed, engine load had the greatest impact on the change in NO_x emissions. Along with the increase in engine load, NO_x emissions were reduced. The largest reduction of NO_x emissions occurred at a fuel temperature of 20°C and was 50%, at this fuel temperature the NO_x concentration values at the lowest and highest engine loads were 13.5 and 6.75 [$g \cdot kWh^{-1}$], respectively. The increase in fuel temperature at 50% and 75% engine load reduced NO_x emissions by 5% and 2%, respectively, between the lowest and highest temperatures of the introduced fuel. However, in the case of the highest engine load, the increase in fuel temperature resulted in a 10% increase in NO_x emissions. The highest NO_x concentration (13.58 [$g \cdot kWh^{-1}$]) occurred at 50% engine load and 50ºC temperature, while the lowest NO_x emission value (6.75 [$g \cdot kWh^{-1}$]) was recorded during 100% engine load and fuel temperature 20 ºC.
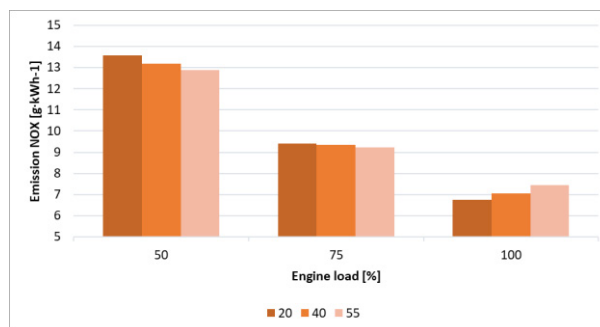

Fig. 1. Impact of fuel temperature on NO_x emissions at 50,75 and 100% engine load.

4. Conclusion

If the temperature of the combusted fuel increases from 20°C to 55°C, there is a reduction of NO_x emissions by approximately 5% for an engine running at 50% maximum load, and by approximately 2% for an engine running at 75% of maximum load, respectively.

At maximum engine load, increasing the fuel temperature increases the emission of nitrogen oxides. When increasing the fuel temperature from 20°C to 55°C, an increase in NO_x emissions of over 10% was observed.

Based on the D1 tests carried out according to ISO 8178-4, it can be stated that raising the fuel temperature in the range of 20°C to 55°C slightly reduces the total emission of nitrogen oxides from a diesel engine. For the above-mentioned test fuel temperature range, the reduction of NO_x emissions was less than 0.3%, therefore it is not cost-effective to equip the engine with a fuel heating system operating in the tested temperature range.

Acknowledgements

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