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RESEARCH OF ALTERNATIVE FUEL WATER-FUEL MICRO EMULSION FROM POINT OF VIEW REDUCTION OF EMISSIONS

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Abstract

The paper presents an analysis of the impact and results of the microemulsion fuel (containing micro-particles of water and diesel) on the engine and emission of toxic exhaust gases. The study aimed to determine total engine efficiency (η), the concentration of nitrogen oxides in exhaust gases (NOx) and smoke (D). For this purpose, a fuel samples with different water content were prepared. Executed research was to determine changes in properties as compared to standard diesel fuel (DF). A special test engine rig with a single cylinder diesel engine was made. On the rig, the research by the characteristics of the engine load for some, such as the crankshaft, speed and load values were made. As a conclusion, the advantages and disadvantages of using these fuels and quoted a very significant their impact on the environment through pollution mainly lower NOx emissions, HC and smoke.

1 Introduction

During the dynamic development of internal combustion engines, improved environmental performance and economical of diesel engines it is very important [3, 4, 5, 6]. Improving performance relates primarily to reduce levels of toxic exhaust emissions, especially nitrogen oxides, the most harmful emissions and difficult to eliminate. The use of the microemulsion in a diesel engine is not yet fully identified problem, just as the catalytic aspect of the use of a microemulsion of water and diesel fuel. A new approach is also proposed methodology of research in relation to the microemulsion based on laser techniques PDPA (Phase Doppler Particle Analyzer) and LDV (Laser Doppler Velocimeter).

The solution proposed use of a microemulsion of water and diesel fuel eliminates the disadvantages of prior methods involving the injection of water. Microemulsion advantage over any water injection is to comfort the use and effects relating both to reduce the level of toxic emissions and specific fuel consumption.

It is worth emphasizing that with the ecological effect of economic effect can be achieved, since replacing diesel with water, which share can go up to 50%; it will create conditions for better use of fossil hydrocarbon fuels.

2 Results and conclusion

The most important parameters determining the suitability of the microemulsion for supplying diesel engines, nitrogen oxides, carbon monoxide, smoke engine, fuel consumption are. The research was conducted for the three fuels with which engine were supplied: diesel fuel (designation DF), the microemulsion with a water content of 10% v/v (designation MWF10%) and the microemulsion with a water content of 20% v / v (designation MWF20%). The research was comparative nature.

The research was carried out on a dynamometer test engine rig. The dynamometer test engine rig scheme is shown in Fig. 1. In order to be able to directly compare the measured values, studies have been carried out by characteristics of the engine load for some, such as the crankshaft speed and load condition, of course, outside the idling characteristics and external, which runs "spontaneous" response facility for used fuel.

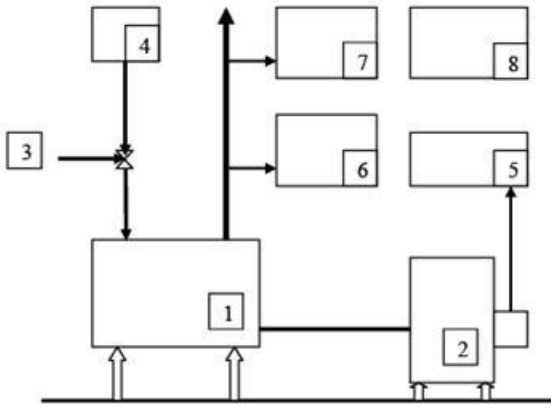

Fig. 1. The dynamometer test engine rig scheme: 1 – engine, 2 – dynamometer, 3 – supply of diesel fuel, 4 – supply of water fuel microemulsion, 5 – gauge of rotational speed and torque, 6 – exhaust gas analyzers, 7 – opacimeter, 8 – gauges of atmosphere state

With this test engine rig, it was possible to measure:

- rotational speed of the engine crankshaft,
- torque,
- time of consumption by engine of a defined volume of engine fuel,
- concentration of nitrogen monoxide NO and nitrogen oxides NOx,
- concentration of carbon monoxide CO,
- engine smoke D

and also parameters of atmosphere state:

- atmospheric pressure p_{ot},
- ambient temperature t_{ot},
- air humidity φ.

Because of the need to avoid the influence of the engine speed regulator, tests were carried out in the range of speeds from 1200 to 2000 rpm.

Influence of the microemulsion fuel for the combustion engine has been determined by determining the total efficiency of the engine (η), the concentration of nitrogen oxides in the exhaust gas (NOx), smoke motor (D). The values of total engine efficiency were determined by the relationship (1):

$$\eta = \frac{1}{W \cdot ge} \quad (1)$$

where: W - calorific value of fuel;
ge - specific fuel consumption [g/kWh].

The research results are presented in graphs, which among other things show the effect of the microemulsion fuel on the observed relative rates of engine operation as a function of engine load relative − relative value reference to the values set for diesel fuel.

First, change the maximum engine power powered by different fuels (Fig. 2) was determined, which stated that the engine power is decreasing with increasing water content of the microemulsion. The biggest difference is for speed 2000 rpm, where (for microemulsion MWF10% water v/v) reaches 9%, while for microemulsion MWF20% is 19%. For other ranges speed maximum power drop it was also lower than the percentage of water in the microemulsion.

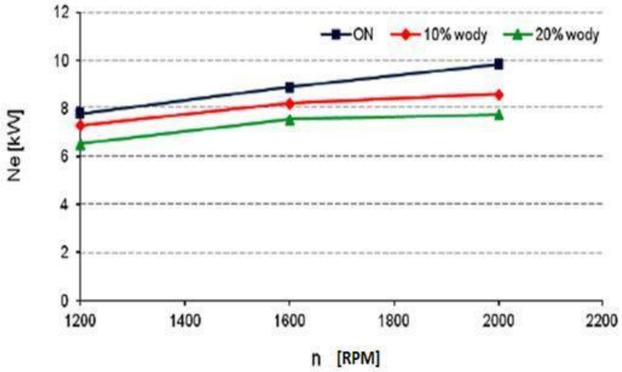

Fig. 2. Changes power (Ne) of the engine supplied with diesel fuel (ON), the microemulsion 10% of the water and the microemulsion containing 20% of water as a function of rotational speed

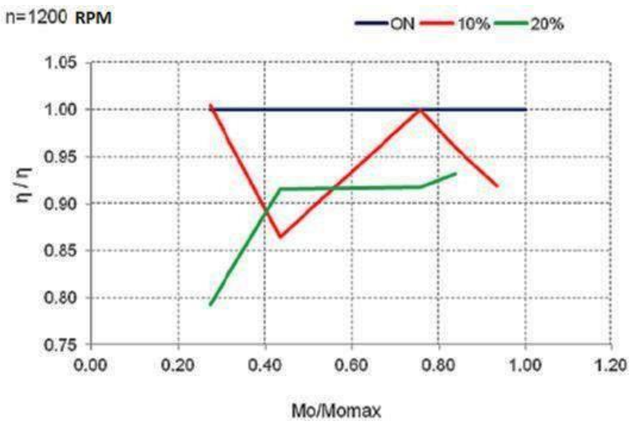

Fig. 3. Relative changes in the overall efficiency of the engine as a function of the relative load changes for different fuels, for speed 1200 rpm

The influence of the microemulsions of water and fuel to a relative decrease in the total efficiency of related to the relative load variations for the various fuels (diesel fuel, 10% water, 20% water) are shown in the following figures.

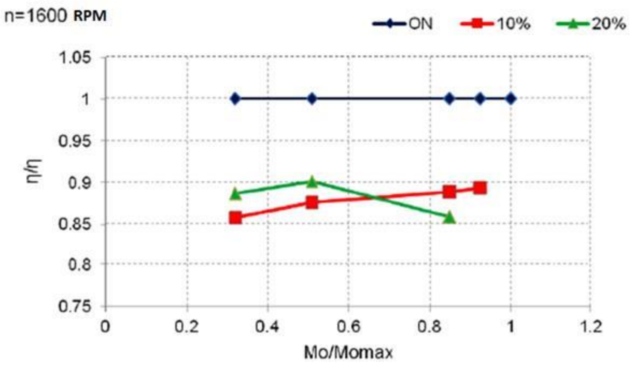

Fig. 4. Relative changes in the overall efficiency of the engine as a function of the relative load changes for different fuels, for speed 1600 rpm

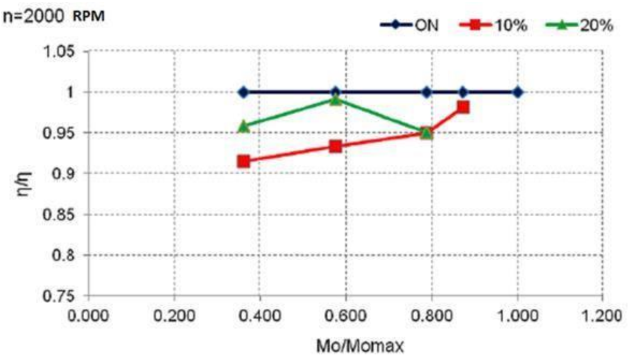

Fig. 5. Relative changes in the overall efficiency of the engine as a function of the relative load changes for different fuels, for speed 2000 rpm

The results indicate that the water microemulsion fuel slightly lowers the overall efficiency of the engine. However, the benefits obtained by the use of microemulsion fuels derived ratios relate to emission of toxic exhaust gases indicators.

Nitrogen oxides (NOx)

When the amount of water increases, the emission of NOx is reduced. The maximum concentration of NOx for the engine at n = 1200 rpm / min supplied with diesel fuel was 2178 ppm, while the maximum concentration of NOx for an engine supplied microemulsion of 10% was 1448 ppm and 20% of a microemulsion of 1132 ppm. Therefore, if the engine torque increases, for the same torque, the difference between emissions level of oxides of nitrogen increases – Fig 6.

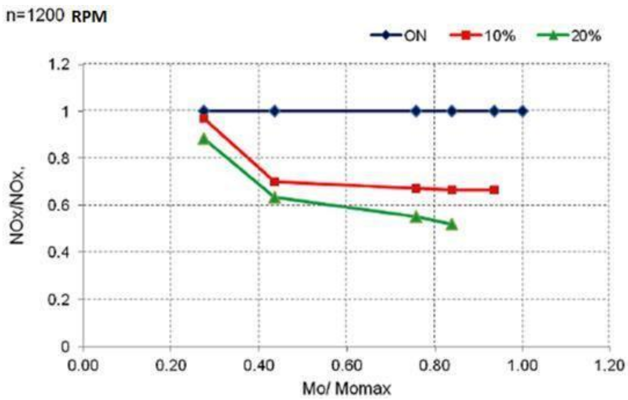

Fig. 6. Relative changes in the concentration of NOx in the engine exhaust gases as a function of the relative load changes for the various fuels for speed of 1200 rpm

For n = 1600 rpm, Fig. 4, and 7, the maximum level of NOx emissions for diesel fuel engine supplied is 1562 ppm, for microemulsion of 10% – 1100 ppm and for microemulsion of 20% – 875 ppm. For these speeds, the maximum reduction in NOx concentration occurred for torque of 27 Nm. For n = 2000 rpm, the greatest reduction in NOx is observed at low values of torque (Fig. 8).

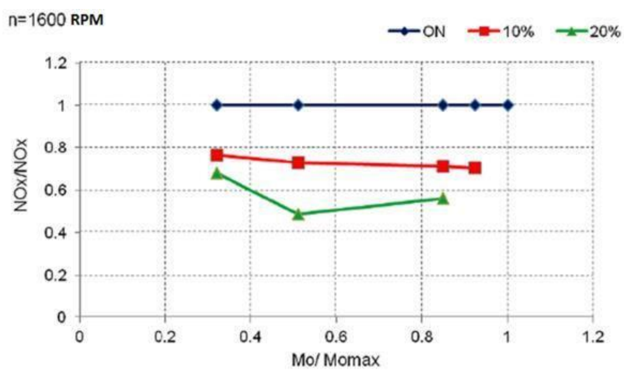

Fig. 7. The relative changes in concentrations of NOx in the exhaust of the engine as a function of the relative load changes for different fuels for rotational speed 1600 rpm

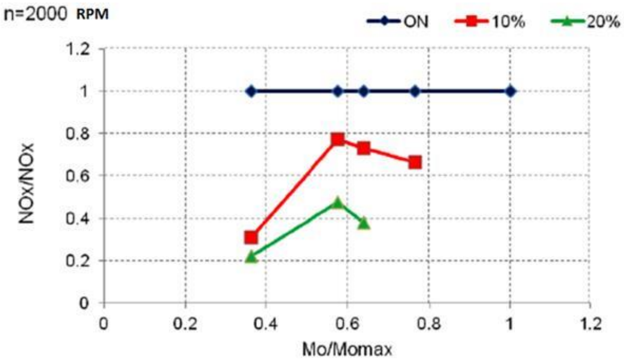

Fig. 8. The relative changes in concentrations of NOx in the exhaust of the engine as a function of the relative load changes for different fuels for rotational speed 2000 rpm

Analysis of the test results shows that both supply of the engine with microemulsion containing 10% water and 20% water dramatically reduces the level of emissions of nitrogen oxides in the whole range of engine operation. The concentration of NOx in the exhaust gas is reduced by up to 60% of baseline − Fig. 6.

Level of engine smoking

The biggest impact of the microemulsion is observed for smoking engine. For the rotational speed of 1200 rpm and for the small torque, greater impact is applied to the engine supplied with the microemulsion of 10% water content. With the increase in the torque, increases the influence of fuel MWF20% − Fig. 9.

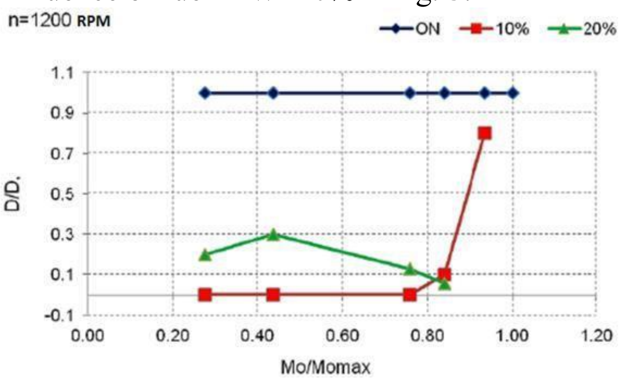

Fig. 9. Relative changes in smoking engine as a function of the relative load changes for different fuels at a rotational speed 1200 rpm

At a speed of n = 1600 rpm and for 2000 rpm both microemulsions significantly reduce the level of smoke engine, with the result that a greater reduction in microemulsion with a higher water content of 20% v / v. The level of smoke when the engine of the microemulsion is reduced by 90% − Fig. 10 and Fig. 11.

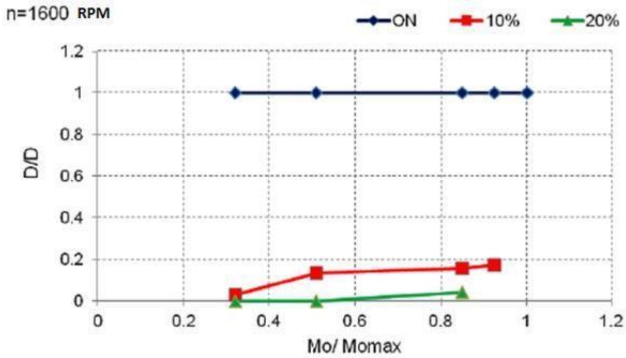

Fig. 10. Relative changes in smoking engine as a function of the relative load changes for different fuels at a rotational speed 1600 rpm

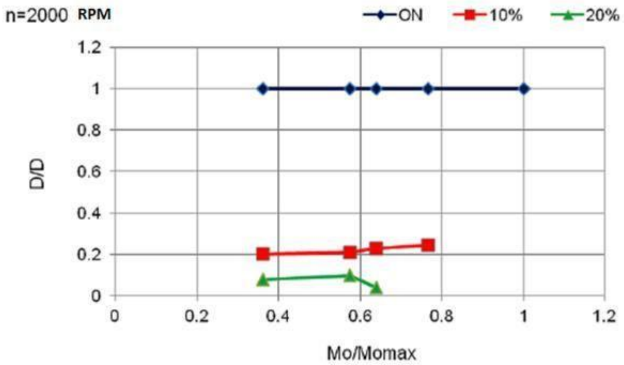

Fig. 11. Relative changes in smoking engine as a function of the relative load changes for different fuels at a rotational speed 2000 rpm

Carbon monoxide (CO)

The level of carbon monoxide depends on the water content of the microemulsion and the operating point of the engine. For rotational speed n = 1200 rpm for fuel MWF10% for small and big torque, reduction of the level of CO occur. However, for the intermediate torque, emissions of CO increase. For fuel MWF20%, increase in the level of carbon monoxide it takes place compared to the level emitted by engine supplied with diesel fuel for small values of torque. For higher torque values determined to reduce the level of CO occurs.

At a speed of n = 1600 rpm both for the fuel MWF10% and MWF20% for small torques, a slight increase in the level of carbon monoxide

is compared to diesel powered engine, for larger moments of reducing the level of CO.
For rotational speed n = 2000 rpm, a small increase followed a big drop in the level of carbon monoxide present in both the fuel MWF10% and MWF20%. Increased levels of carbon monoxide emissions fueled engine microemulsion exists for small engine torque, while the larger − level of emissions decreases when compared to the level emitted by a standard gas-powered engine. The accurate determination that the microemulsion is more importantly reduces emissions of CO. It is depending on the operating point of the engine.

Level of hydrocarbon emissions (HC)
Level of emissions of hydrocarbons is dependent on the water content of the microemulsion, and the operating point of the engine. For rotational speed n = 1200 rpm for fuel MWF10% and MWF20% HC emissions are reduced in the whole engine operating range compared to diesel fuel supplied engine. Greater reduction in emissions of HC is caused by the engine supply with MWF20% microemulsion. At a speed of n = 1600 rpm, emissions of HC is similar to that for n = 1200 rpm. For speed n = 2000 rpm emissions of hydrocarbons it is much higher compared to the level of supplied generated by the motor fuel base.

Specific fuel consumption
Generally, in the whole engine operating range increase specific fuel consumption occurs in comparison to fuel consumption fueled engine with diesel fuel to the fact that a greater increase regardless of the rotational speed occurs at small torque. In addition, increase in fuel consumption is higher when the engine is fueled microemulsion MWF20%.

Conclusion

In summary, it can be stated that the development of a stable and durable microemulsion after two years from the execution is possible. The microemulsion water-fuel showed no tendency to stratification. Moreover, by using a microemulsion as fuel, NOx reduction seen in the whole engine operating range occurs, up to 60% of its output.
The level of CO by using microemulsions of water-diesel fuel, with respect to the base fuel (DF) varied depending on the amount of water in the diesel fuel, and depending on the operating point of the engine. At the rotational speed 2000 rpm, reducing the level of carbon monoxide is followed with respect to the base fuel (DF) over a whole range of engine operation. At other rotation speeds, CO emissions increased or decreased, depending on the operating conditions of the engine. In the range of low values of torque, CO emissions increase and at high values − decrease.
Test results have shown a decrease in emissions of HC for low speeds and increase the level of HC at the rotational speed of 2000 rpm. However, the greatest effect of the microemulsion occurs on the engine smoke. Test research shown that the level of smoke is reduced by 90% when the engine is supplied with the microemulsion containing 20% v / v water − Fig. 11.

Moreover, the test research shown that power output when using microemulsion slightly decreases, while fuel consumption − grows. Reducing power depends on the rotational speed of the engine and amount of water in microemulsion. The use of water-diesel fuel microemulsion fuel reduces the total efficiency of the engine, but to a lesser extent than that of water in the diesel fuel. For this reason, an additional economic effect takes place.

References

[1] Abu-Zaid, M.: Performance of Single Cylinder, Direct Injection Diesel Engine Using Water Fuel Emulsions, Energy Conv. and Manag., 45, pp. 697-705, 2004.

[2] Cheng, A., Upatnieks, A., and Mueller, C.: “Investigation Of The Impact Of Biodiesel Fuelling On NOx Emissions Using An Optical Direct Injection Diesel Engine, Int. J. Engine Res., 7(22), 297-318, 2006.

[3] Jankowski A.: Influence of chosen parameters of water fuel Microemulsion on combustion processes, emission level of nitrogen oxides and fuel consumption of CI engine. Journal of KONES, Vol. 18, No. 4 2011.

[4] JankowskiA.: Kowalski M.: Mechanism of formation of toxic substances emission of combustion engines. Journal of KONBIN. 1(30) Warsaw 2015 (in Polish).

[5] JankowskiA., Kowalski M.: The impact of the quality of fuel atomization on toxic substances emission emissions of combustion engines. Journal of KONBIN. 4(30) Warsaw 2015 (in Polish).

[6] Jankowski, A., Sowa, K., Zablocki, M.: Some Aspects Using of Micro Emulsion Fuel-Water for Supply of Combustion Engines, Journal of KONES, Powertrain and Transport 2009, Vol.16 No. 4 pp.531-538, 2009.

[7] Khalek I. A.: Transient Emissions Testing of Micro Emulsified Diesel-Water Fuel Blends. SwRI Report 08.04261. 2001.

[8] Tajima, H., Takasaki, K., Nakashima, M., Kawano, K., Ohishi, M. Yanagi, J., Osafune, S.: Visual Study on Combustion of Low-Grade Fuel Water Emulsion, The Fifth International Symposium on Diagnostics and Modeling of Combustion in Internal Combustion Engines COMODIA, 2001.

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