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Reduction of Fuel Consumption in Fishing Fleet Engines

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ABSTRACT

The article presents the results of tests of high speed diesel engines used in fishing boats and vessels. The reduction of unit fuel consumption and exhausts toxic emission was possible by implementing preliminary fuel treatment that takes place directly in the fuel injector containing catalytic material. The catalyst works more effectively when fuel is turbulized in crossing fuel passages made in a part of the injector needle. Preliminary fuel treatment results in the average reduction of unit fuel consumption of those engines by 8%, while toxic emission of carbon and nitrogen oxides drops by 15%.

1. Introducction

Currently, the main requirements for modern internal- combustion engines are mainly related to the reduction of toxic compounds' emission. The standards, both Tier and EURO, considerably require the emission of nitrogen and carbon oxides and hydrocarbons and particulates to be limited. It should be highlighted that these requirements refer to newly constructed internal-combustion engines, while older generation engines, whose toxicity of exhaust gases exceeds occasionally the implemented standards, are operated (Klyus O.V. et al, 2012). In addition to that, the shipowners of fishing vessels, in the first instance, Figure their attention to the reduction of operational costs - fuel consumption reduction, which from the theoretical point of view - simultaneously affects the reduction of exhaust gases toxicity and fuel consumption, which faces a number of problems. Indeed, the increase of operational process effectiveness, and consequently - the reduction of fuel consumption are associated with the increase of maximum cycle temperatures. This facilitates the formation of nitrogen oxides. Therefore, designers optimise these two issues - they reduce the level of toxic compounds emissions to the detriment of fuel consumption. The research projects of the Maritime University of Szczecin are directed at the solutions of simultaneous reduction of exhaust gases emission as well as unit fuel consumption in the engines of the Polish fishing fleet. For that purpose pioneering solutions have been proposed, which are related with the use of catalysis directly in the body of injectors for self-ignition combustion engines.

2. Preliminary Fuel Treatment

Combustion processes in self-ignition combustion engines are affected significantly by the first stage - delay time of self-ignition consisting of physical phenomena - atomization and evaporation of injected fuel drops, and of chemical phenomena - primarily oxidation reactions. It is advantageous to reduce the time which shall cause that lower volume of fuel injected at that time limits the increase of pressure and maximum cycle temperature. However, in that case a fairly large amount of fuel combusts during the extending process, thereby reducing the efficiency of working process.

The delay time of self-ignition τ is illustrated under the Arrhenius equation, which with the reference to piston engines,

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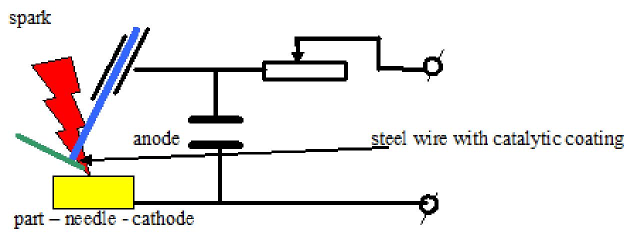
Figure 1: Scheme for electro-spark alloying



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may be presented in a general form (Hejwood J.B., 1988)(Klyus O.V. et al, 2012):

$\tau = ABCe^{\frac{E}{RT}}$

where:

A, B and C present the operational, geometric and load parameters of an engine,

R - universal gas constant [kJ/kmol.K],

E - activation energy [kJ/kmol],

T - temperature in a combustion chamber [K].

During an analysis of the equation it may be noticed that practically all components for an engine in operation are virtually constant, except the volume of activation energy. Reduction of E may lead to the reduction of τ. An energy barrier, which is the activation energy, may be reduced by an impact of catalysts, while the presence of a heterogeneous catalyst may lead to the dehydrogenation reactions of hydrocarbon fuels. In that case the largest group of paraffinic hydrocarbons C_nH_{2n+2} in fuel may change into the olefins C_nH_{2n} and hydrogen molecules H_2 are released, which due to its properties - volatility and diffusion favours not only the reduction of self-ignition time, but also contributes to a more complete fuel combustion (Klyus O., 2011).

The location of catalytically active material is subject to the temperature of elements on which it is applied due to the fact that catalyst efficiency is higher at higher temperatures. Therefore, it has been suggested to locate the catalyst on the most thermally loaded element of injector instruments - an atomizer needle(Klyus O., Wtryskiwacz paliwa, 2008). In that case it is possible to use the part of the atomizer which joints the precise part of the needle and the cone. As the technological process of catalyst application is anticipated as for new needles as well as on those which are in operation, a selection of a catalyst application method is subject to process temperature. One of the methods feasible for use is the technique of material thick layers in the area of electrical spark presence. Figure 1 presents a scheme and Figure 2 includes a photograph of the suggested electro-spark alloying of catalyst application on an atomizer needle.

The technological process anticipates an introduction of a thin steel wire into the spark area, on the surface of which the catalytic material from the platinum metals group was applied.

Since the catalyst efficiency improves at extending a contact surface of the catalyst with fuel, it has been proposed additionally that turbulizing passages shall be cut on the same surface

Figure 2: Catalyst application on atomizer needle

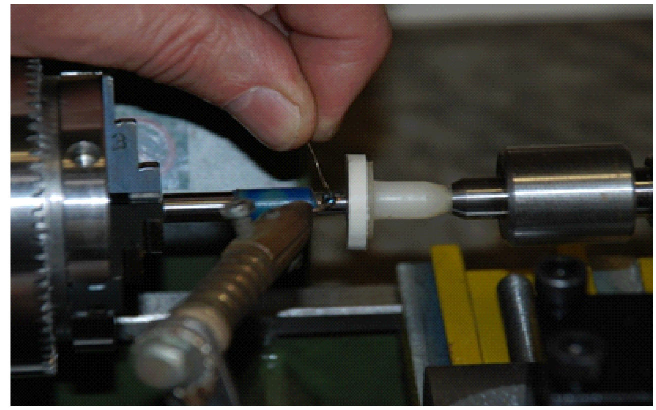

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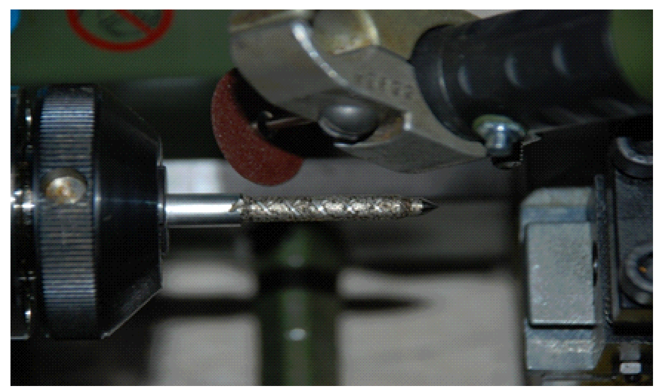
Figure 3: Grinding turbulizing passages on atomizer needle



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where the catalyst is applied. Due to the turbulizing passages, fuel flow is forced and increases the contact frequency of the fuel and the catalyst material. Figure 3 presents a grinding process of turbulizing passages on the atomizer needle. The form of the passages presents intersecting left-hand and right-hand threads. Except for turbulizing effect, in that case, it is possible to obtain a homogenization effect.

3. Laboratory Tests

Particle size distribution in an atomized fuel jet was determined at the first stage of the tests for the proposed method of preliminary fuel treatment. For that purpose a laser diffraction method was applied with the use of an instrument, made by Malvern, of Spraytec type and of a common rail injector test bench of Bosch EPS200A type (Figure. 4). As a research facility, an injector for engine of 359 type equipped with three hole atomizer was selected. The selection of this injector was justified by the fact that most of fishing vessels is equipped with engines with direct fuel injection and 359 engine constitute their representative part. Apart from the study, the atomized fuel jets were directed to one of the jets in the area of laser beam. Therefore, separating of two remaining jets from that area did not constitute a technical issue. Figure 5 presents the photographs

Figure 4: Test stand for particle distribution in atomizer fuel jet

Source: Authors

of the measurement process of particle distribution and the suggested system for fuel discharge from two fuel jets.

The laboratory tests results (Figure. 6) proved an improvement of fuel atomization characteristics - at the application of primarily treatment the value of a mean Zauter diameter decreased, the number of particles of smaller diameter increased (Klyus O., 2008).

4. Field Tests

The field tests were conducted on a four stroke self-ignition engine with direct fuel injection, 359 type (Figure. 7). The set of instruments included an option to measure both the operational parameters and the ecological ones during the work according to a speed characteristics.

Figure 8, 9 and 10 present a speed characteristics in a form of a unit fuel consumption and carbon and nitrogen oxides emission (using analyzer type IMR3000). Series 1 corresponds to the parameters of an engine at work with a factory set of injection equipment, series 2 - equipped with a set of injectors with preliminary fuel treatment.

As the obtained results show, the preliminary fuel treatment improves both the economical and ecological parameters of self-ignition engine work practically in the entire range of rotational frequency. The unit fuel consumption decreased to 8%, while nitrogen oxides emission to 15% and carbon oxides emission to 300% (3 time).

5. Conclusions

Simultaneous improvement of the economical and ecological parameters of self-ignition engine indicators used in fishing fleet is possible due to the preliminary fuel treatment. The

Figure 5: Measurement of particle distribution in the laser beam area and separation of two remaining jets from the laser beam area

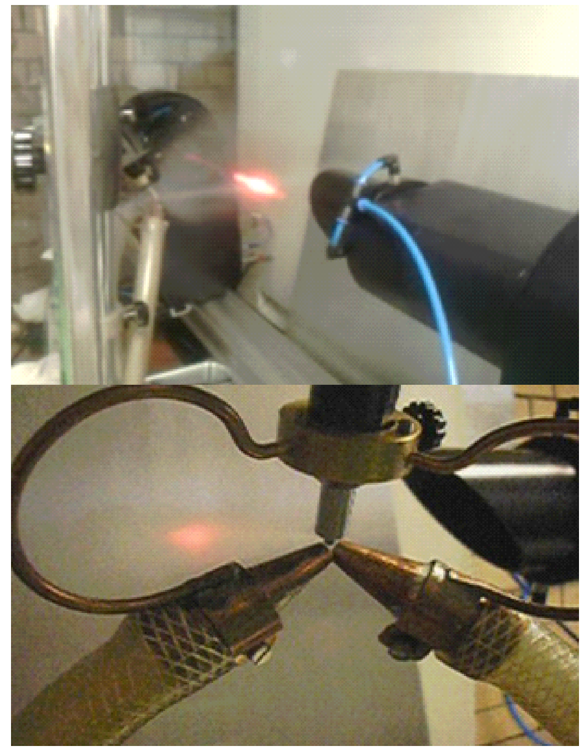

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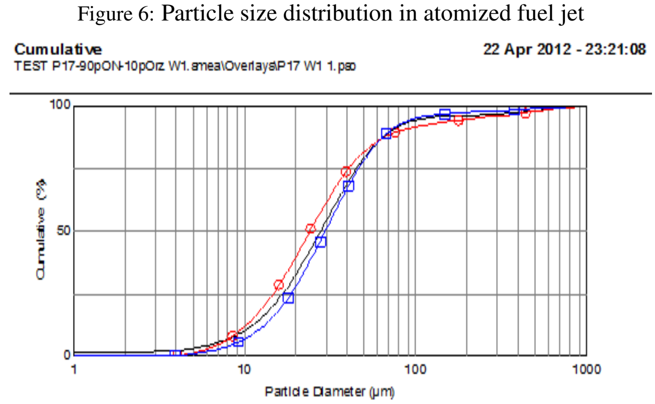
Figure 6: Particle size distribution in atomized fuel jet



	Date-Time	File	Sample	Dx(10)	Dx(50)	Dx(90)
[V]	3 Oct 2011-...	P17 W1	RYBY01	9.86	27.87	71.73
[V]	3 Oct 2011-...	P17 W2I	RYBY01	9.31	24.14	80.92
[V]	3 Oct 2011-...	P17 W3	RYBY01	11.79	29.66	70.64

[V]=Volume [N]=Number

Source: Authors

Figure 7: Test stand with 359 type engine

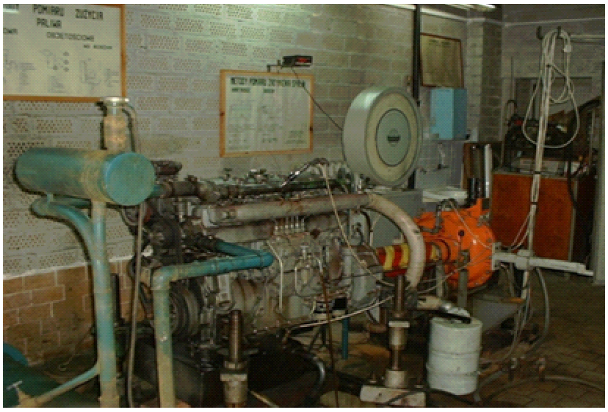


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Figure 8: Unit fuel consumption characteristics

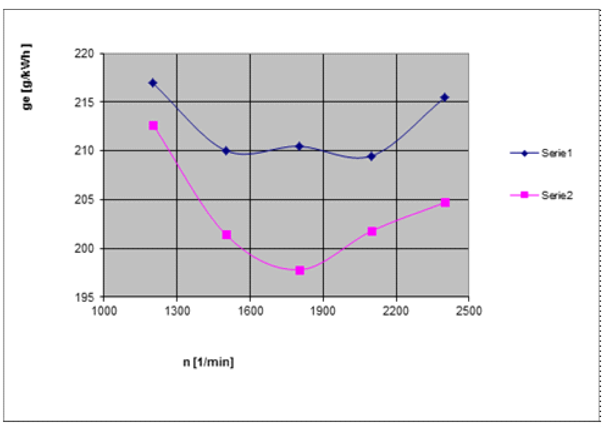

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Figure 9: Emission level of nitrogen oxides

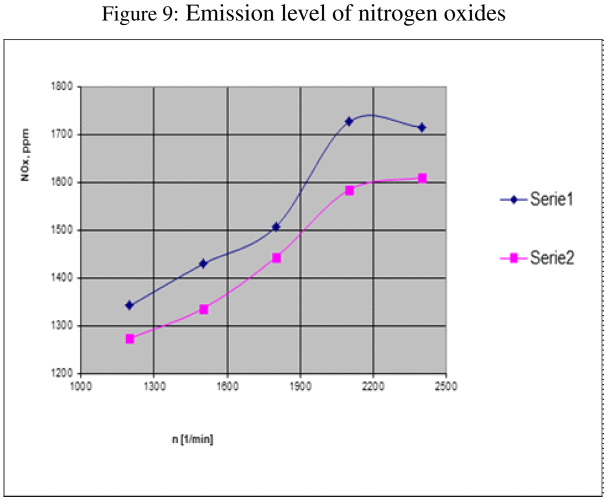

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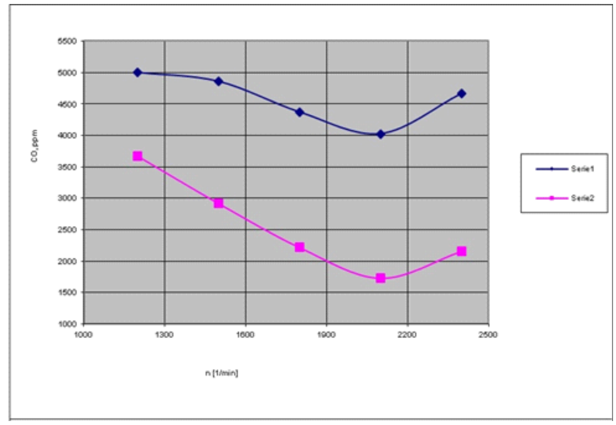
Figure 10: Emission level of carbon oxides



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method does not constitute technological problems since it may be applied both at the stage of a production process of the elements of injection instruments and for those which are already in operation. The application of catalytic coatings by elektro-spark alloying does not change the accuracy of precision pairs, while grinding turbulizing passages at a properly prepared station (as for example a mini lathe) does not provide for an operator to be professionally trained.

As a result of the tests related with the comparison of the engine parameters with the factory completion of injection systems and the suggested instrumentaion with the fuel pretreatment show that the unit fuel consumption reduction to 8% was obtained as well as the nitrogen oxides emission to 15%, while oxides emission, carbon oxides emission to 300% and exhaust gas opacity improved.

The further studies anticipate the improvement of a technological process for preliminary fuel treatment by, inter alia, a development of a NC machine tool, searching for catalytically active materials in low temperatures and development of the structure of fuel turbulization system in injector body.

Acknowledgements

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