BASIS FOR ACHIEVING PROJECT OBJECTIVES

Attempts to obtain technically optimal economical and ecological parameters in piston diesel engines face a number of difficulties, mainly concerning the arrangement of the engine working process. We can achieve lower fuel unit consumption, i.e. increased engine efficiency, by raising maximum temperatures of the cycle, which leads to increased toxic emissions of exhaust gases, mainly nitrogen oxides. Common Rail injection systems with electronic control of fuel injection characteristics are used in newly built engines, while exhaust components are equipped with catalytic reactors, solid particle filters and others. Still the simultaneous reduction of fuel consumption and level of toxic emissions remains a major problem. The same refers to engines currently operated in ships, whose construction does not leave much space for essential improvements in fuel, exhaust and other systems.

The Maritime University of Szczecin with the West Pomeranian University of Technology in Szczecin conducts research on medium and high speed self-ignition engines used in fishing boats and vessels which focuses on the use of preliminary fuel treatment directly in the injector body. Such treatment is possible in new design engines leaving factories as well as those in operation.

Considering a diesel engine indicator diagram we can observe that the basic time interval directly affecting economical and ecological engine parameters is the self-ignition delay time; its shortening may lead to both a slower increase of pressure and decreased maximum temperatures in the combustion chamber while a range of effective work remains at the same level [Hejwood J.B.: Internal combustion engines fundamentals, McCraw – Hill Book Co., NY, 1988].

From an analysis of various research findings we can calculate self-ignition delay using this relation:

$$\tau = B \cdot 10^{-2} \sqrt{C} \sqrt{\frac{T_k}{p_k} \cdot e^{\frac{E_a C^{0,34}}{\bar{R} T_k}}}$$

where

$$B = 2 \cdot 10^{-4} \left(1 - 1{,}6 \cdot 10^{-4} n_s\right)$$

$$C = \frac{1}{\varepsilon}\left[1 + 0{,}5\delta \frac{V_h}{V_{h_1}}(\varepsilon - 1)\right]$$

$$\delta = \left[\left(1 + \frac{\lambda}{4}\right) - \left(\cos\theta + \frac{\lambda}{4}\cos 2\theta\right)\right]$$

B, C, δ – constants, T_k – temperature in the combustion chamber when fuel injection starts, p_k – pressure in the combustion chamber when fuel injection starts, V_h, V_{h1} - actual cylinder volume and volume corresponding to piston stroke with inlet valves closed, ε – compression ratio, θ - connecting rod inclination, λ - piston stroke to connecting rod ratio.

According to Heywood, the delay time can be determined from this relation:

$$\tau = (0{,}36 + 0{,}22 \cdot c_m) \cdot \exp[E_a (\frac{1}{\bar{R} T_2} - \frac{1}{17{,}19}) \cdot (\frac{21{,}2}{P_2 - 12{,}4})^{0{,}63}]$$

where

c_m – mean piston speed,

P_2 and T_2 – pressure and temperature in the combustion chamber.

Analyzing the relations defining self-ignition delay time we can see that it depends on such factors as pressure and temperature in the combustion chamber, rotation speed of the shaft and engine kinematics as well as activation energy. It should be noted that in attempts to improve economical and ecological performance of new and used engines there is no practical possibility to change parameters such as pressure or temperature, and basic design features. One possible direction to affect these self-ignition engine parameters is to decrease values of activation energy.

For polyatomic molecule compounds (to which hydrocarbon fuels belong) activation energy is defined as the minimum kinetic energy by which the potential energy of a system should be greater for a chemical reaction to occur.

Activation energy depends on molecule structure and bond strength. In the work of prof. A.Ambrozik and prof. B.Fejnlejb the behavior of paraffin hydrocarbons C_nH_{2n+2} is discussed in this context. In these hydrocarbons the energy of breaking *C–H* bonds is greater than the energy of breaking *C-C* bonds, that is why the more carbon atoms there are in a molecule, the less activation energy is needed to break the bonds. This explains a high stability of isooctane C_8H_{18}, used as reference fuel to determine octane ratings of other fuels. To facilitate overcoming the activation energy, we can deliver more energy to the reaction environment (e.g. by heating) or use a substance that easily reacts with the substrate (low activation energy), and thus formed compound easily converts into a product (also low activation energy). A catalyst is a substance that facilitates a conversion from a reactant into a product and, notably, is not consumed in the reaction. It follows that the presence of a catalyst (e.g. metals of the platinum family) and its contact with fuel before injection into the combustion chamber is desired.

The presence of a catalyst in the fuel system has another justification. Chemical properties of fuels used in self-ignition engines can be changed. In paraffin hydrocarbons, the most common group among diesel fuels, paraffin can be dehydrogenated in the presence of a catalysts. In the relevant reactions paraffin hydrocarbons change into olefins C_nH_{2n} and hydrogen molecules are released. Hydrogen, with its high diffusion coefficient, high flammability, high rate of combustion and a wide range of mixture combustibility, reduces self-ignition delay time in the conditions prevailing in the combustion chamber.

The presence of hydrogen in the injected fuel may affect chemical and physical phenomena. For instance, the self-ignition delay time depends on such physical factors as the diffusion rate of fuel, oxidizer and active nuclei of reaction. The process of diffusion is accompanied by evaporation of liquid fuel; its mathematical description has a form of drop evaporation rate:

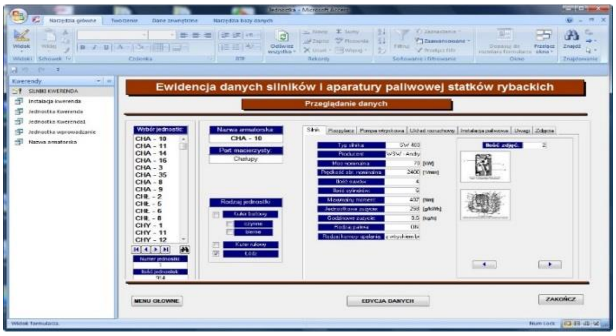
$$\frac{dm}{d\tau} = \pi Nu_D D_p d_k \left(p_s - p_0\right) = \int_0^{\tau} \frac{2Nu_D D_p}{\rho_{pal}} \left(p_s - p_0\right) d\tau ,$$

where Nu_D –Nusselt criterion for diffusion processes, D_p – coefficient of vapour diffusion in reference to partial pressure gradient, p_s, p_0 – partial pressure of fuel vapor in vicinity of a drop with a diameter d_k and in a medium surrounding drops, ρ_{pal} – fuel density.

It is known that a catalyst will be more effective if it is used in high temperature and the fuel has turbulent flow along catalyst surfaces. For this reason we propose 'preliminary fuel treatment' that consists in depositing a catalytic material on the surface of an atomizer needle. The injector has the highest thermal load of all engine elements. To create turbulent fuel flow, the needle surface has properly situated passages. The part of the atomizer needle connecting the precision surface and the conical tip was chosen for preliminary fuel treatment. Such solution makes deposition of a catalyst (e.g. by electro-spark alloying) and machining of turbulizing passages technologically feasible in new as well as used injectors (fig).

THE SCOPE OF PROJECT OBJECTIVES CONSISTS IN:

1. Development and completion of a database of internal combustion engines and injection equipment used on fishing vessels, selection of injector designs for engines with indirect and direct fuel injection for further research.



Database of Polish fishing fleet engines

2. To carry out analytical studies on fuel pretreatment and to develop a technological process for the application of low-temperature catalysts and turbulization channels to fuel atomizer elements. <u>*This operation provides for the development of a patent application and has an innovative character*</u>

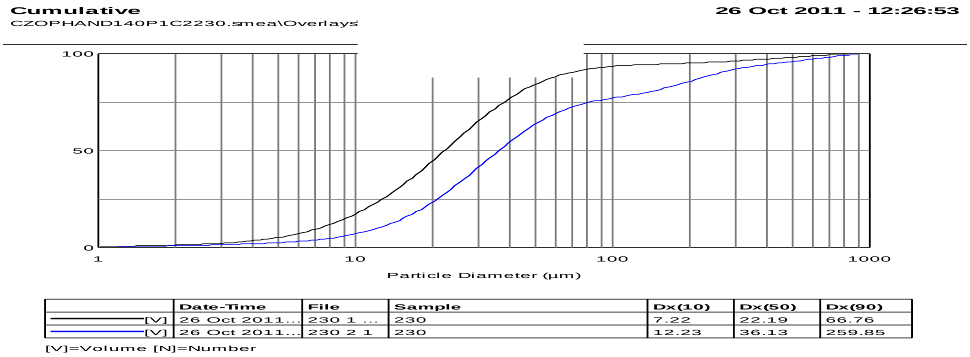
Applying a catalyst and making a turbulization system

3. Carrying out laboratory tests to determine the physico-chemical parameters of fuels after the process of atomization in the classical injection apparatus and in the injection apparatus having turbulization systems and low-temperature catalysts, including with the use of petroleum-derived fuels and their mixture with synthetic polymer fuels derived from the processing of lost fishing gear*. This operation will be carried out for the first time at home and abroad and has an innovative character*

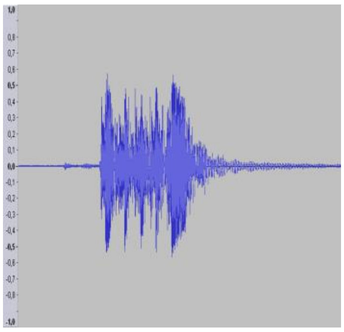
Used fishing nets

Conversion of used fishing nets into fuel for diesel engines

4. Conducting laboratory tests on acoustic emission and determination of fuel spray parameters in the process of atomization in the classical injection apparatus and in the injection apparatus having turbulization systems and low-temperature catalysts, including with the use of petroleum-derived fuels and their mixture with synthetic polymer fuels derived from the processing of lost fishing gear. *This operation will be carried out for the first time at home and abroad and has an innovative character.*

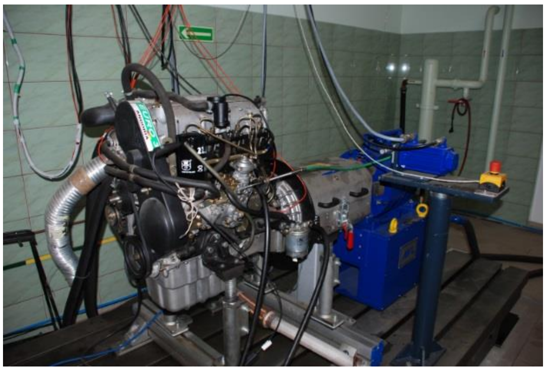


Registration of droplet distribution in the fuel spray stream

Registration of droplet distribution in the fuel spray stream

5. Bench testing of selected engines with direct and indirect fuel injection of fishing vessels with turbulence systems and low-temperature catalysts in the injection apparatus, including the use of petroleum-based fuels and their mixtures with synthetic polymer fuels derived from the processing of lost fishing gear. *This operation will be carried out for the first time at home and abroad and has an innovative character.*

Braking stands for testing engines with fuel pre-treatment

6. To carry out tests of engines on selected fishing vessels and boats with the use of turbulization systems and low-temperature catalysts in the injection apparatus *This operation will be carried out for the first time at home and abroad and has an innovative character.*

Conducting tests on fishing vessels

7. Development of guidelines concerning the application of turbulization systems and low-temperature catalysts in fishing engines of vessels