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Analysis of the Operation of CI Engine Fuelled with Crop-Based Fuels

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Summary. This paper presents an analysis of the effect of crop-based fuels (rapeseed oil, biodiesel) on the operating parameters of compression-ignition engine in relation to diesel fuel. Experimental tests were conducted on a Star 359 engine fuelled with different fuel types at specific engine control parameters. As a result of engine test bench testing, the speed characteristic curves were made and then analysed.

Key words: internal combustion engine, rapeseed oil, biodiesel, diesel fuel, speed characteristics.

INTRODUCTION

The designers of modern internal combustion engines have been challenged with steadily growing demands, both in the aspect of reliability and ecology. For the above objectives to be implemented, the fuels supplying modern drive units have to be constantly improved due to their key role played in the process of pumping, injection, and combustion in the engine working chamber and emission of the by-products resulting from the combustion inside a drive unit into the atmosphere [5,11,14,15,16]. Therefore, they are required:

– to provide correct production of the air-fuel mixture,
– to provide correct and efficient combustion,
– to not have a negative impact (directly or indirectly) on the natural environment,
– to maintain their stability in the process of storage and distribution and in the vehicle fuel supply system [1, 5].

The fulfilment of these functions is determined by the physical properties of fuel which include, among others, fractional composition and viscosity or density of these fuels as well as by engine operation control parameters, fuel injection pressure and ignition timing advance [7, 9, 13].

Crop-based fuels differ from petroleum-derived fuels in physical properties; they are characterised by different fractional composition and have different ranges of fuel drip-point or boiling point (10, 50, 90%) which are responsible for their ability of evaporation and attest to engine starting ability, warm-up ability and regular operation and, furthermore, provide information about the amount of heavy, hardly evaporating fractions which adversely affect the operation of a drive unit [3, 4]. Significantly increased viscosity and density of crop-based fuels have a direct effect on the process of fuel pumping through the fuel supply system components to the combustion chamber; there is an increased flow resistance which has an adverse effect on the cylinder filling and worse fuel spraying, larger fuel drop diameters, extension of the range of sprayed fuel jet and non-combustion of a part of fuel which, as a result, may deposit on the cylinder walls and transfer to the lubricating oil [2, 5, 8, 10]. There are also advantages of such high fuel viscosity and density, namely an increase in tightness in the fuel supply system is observed, which increases the volume of fuel dose. The lubricity of co-operating components is improved as well [6, 7, 12].

EXPERIMENTAL TEST METHODS

Experimental tests were performed on an engine test bench on a Star 369 engine fuelled with diesel fuel and mixtures of rapeseed oil (OR) with diesel oil (ON) and biodiesel (RME or B) with diesel fuel (ON) at the concentration of 20, 40, 60%.

During the experimental tests, the engine operated at the constant value of fuel injection pressure of 24 MPa and the constant value of fuel injection timing of 18.5° of crankshaft revolutions before the top dead centre (TDC).

Based on these tests, the following engine operation parameters were determined: torque (M_o), power output (N_e), specific fuel consumption (g_e) and hourly fuel consumption (G_e). The obtained engine operation parameters enabled the engine speed characteristic curves to be made and next analyzed.

Table 1. Technical specification for the Star 359 engine.

Arrangement of cylinders	In-line
Number of cylinders	6
Cylinder diameter	110 mm
Piston travel	120 mm
Engine cubic capacity	6840 cm³
Compression ratio	17 (ZS)
Maximum power	150 KM
Rotations at maximum power	2800 rpm
Maximum torque	432 Nm
Rotations at maximum torque	1600 rpm
Fuel supply	Direct fuel injection
Type of timing gear	OHV
Firing order	1-5-3-6-2-4
Engine dry weight	510 kg

EXPERIMENTAL TEST RESULTS AND THEIR ANALYSIS

The conducted tests allowed observation of the differences occurring between the operation of engine fuelled with mixtures of crop-based fuels with diesel fuel in different concentrations. The testing was divided into 3 stages – at first the speed characteristic curves for engine fuelled with a mixture of rapeseed oil and diesel fuel were made, then for engine fuelled with a mixture of biodiesel and rapeseed oil, and finally for engine fuelled with pure diesel fuel.

Figure 1 presents the speed characteristic curves made for a mixture of rapeseed oil and diesel fuel with the following percentages of rapeseed oil in the mixture: 20, 40, 60%.

It can be seen that an increase in the OR concentration in the mixture with ON induces a decrease in M_o and N_e and an increase in g_e and G_e. A decrease in the operation parameters generated by the drive unit increases with the increase of OR concentration because the physical properties of this mixture change, fuel viscosity and density grows, but increased oxygen content in crop-based fuels minimises these losses and favourably affects the combustion process itself and the emission of toxic exhaust gas components.

Figure 2 presents the speed characteristic curves made for a mixture of biodiesel with diesel fuel with the following percentages of biodiesel in the mixture: 20, 40, 60%.

Similarly as for the mixture of OR and ON, an increase in the biodiesel concentration in the biodiesel-ON mixture induces a decrease in some engine operation parameters (M_o and N_e) and an increase in others (g_e and G_e).

It can be seen, however, that a decrease in these parameters is not large and amounts to a few percent but these decreases are getting bigger with an increase in the crop-based fuel concentration.

Figure 3 presents the speed characteristic curves comparing the performance of engine fuelled with a mixture of rapeseed oil (OR) and diesel fuel (ON) (with OR concentration of 20% in the mixture), a mixture of biodiesel and diesel oil (ON) (with 20% of biodiesel in the mixture), and pure diesel fuel (ON). The best operation parameters are characteristic of the engine fuelled with diesel fuel (ON), with the highest values of M_o and N_e in the full range of crankshaft rotational speed and the lowest values of g_e i G_e in the full range of crankshaft rotational speed. The drive unit fuelled with mixtures of crop-based fuels and diesel fuel (ON) is characterised by slightly worse operation parameters and a 15% increase of G_e consumption for rapeseed oil (OR) and a little over 10% for biodiesel. The values of M_o and N_e have a similar course in the full range of engine rotational speed as in an engine fuelled with diesel fuel (ON), with decreases reaching the maximum of 10% for fuel mixtures.

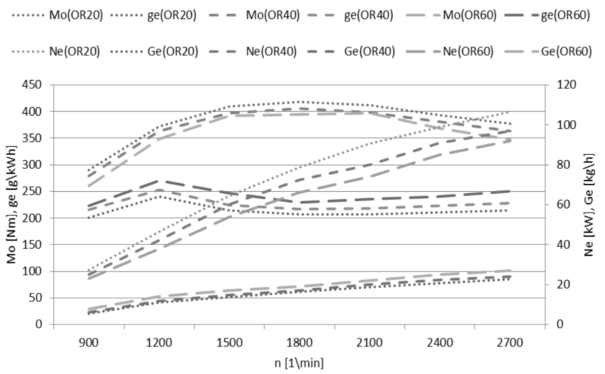

Fig. 1. Speed characteristic curves for the Star 359 engine fuelled with mixtures of rapeseed oil (OR) and diesel fuel (ON) with different OR concentrations (20, 40, 60%)

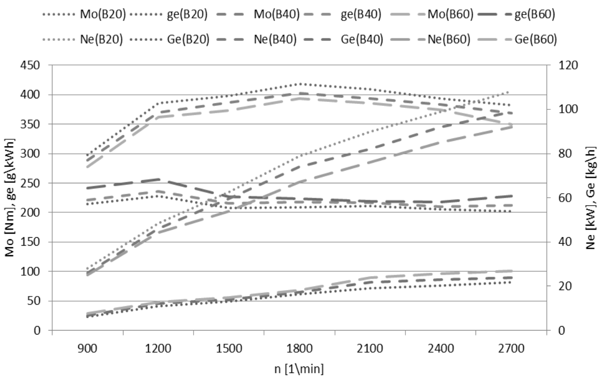

Fig. 2. Speed characteristic curves for the Star 359 engine fuelled with mixtures of biodiesel and diesel fuel (ON) with different biodiesel concentrations (20, 40, 60%)

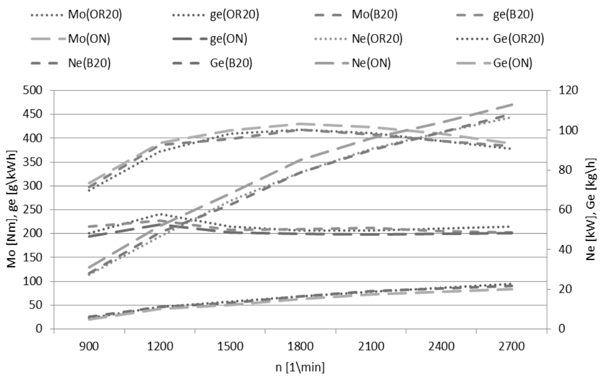

Fig. 3. Speed characteristic curves for the Star 359 engine fuelled with mixtures of crop-based fuels with diesel fuel (ON) and pure diesel fuel (ON)

CONCLUSIONS

The analysis of engine test bed testing for a combustion-ignition engine fuelled with mixtures of crop-based fuels and diesel fuel shows that crop-based fuels are a valuable indirect source of energy for drive units because it is reasonable to use them together with petroleum-derived fuels in the form of mixtures.

The presented speed characteristic curves clearly indicate that a combination of these two groups of fuels provides mutual benefits; the physical properties of biofuels, particularly their density and viscosity, significantly improve, whereas the combustion process in the engine working chamber is more complete and total owing to the presence of increased content of oxygen molecules in biofuels. The observed decreases in engine operation parameters and fuel consumption amounted maximally to 15% in the whole range of crankshaft rotational speed.

It should be noted that the conducted tests were performed at constant engine control parameters, at stable values of fuel injection pressure or fuel injection timing. These parameters have a significant effect on the performance results generated by drive units, which may induce their improvement.

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ANALIZA PRACY SILNIKA ZS ZASILANEGO PALIWAMI POCHODZENIA ROŚLINNEGO

Summary. W artykule przedstawiono analizę wpływu paliw pochodzenia roślinnego (oleju rzepakowego, biodiesel) w odniesieniu do oleju napędowego na parametry pracy silnika z zapłonem samoczynnym. Badania eksperymentalne zostały przeprowadzone na silniku Star 359 zasilanym różnymi rodzajami paliw, przy określonych parametrach regulacyjnych silnika. W wyniku badań hamownianych zostały wykonane charakterystyki prędkościowe, które następnie poddano analizie.

Key words: silnik spalinowy, olej rzepakowy, biodiesel, olej napędowy, charakterystyka prędkościowa.