Fuel Impact on the Response of AD3.152 UR Engine

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Abstract The paper presents results of investigations into the AD3.152 UR engine running on five fuels: commercial diesel oil DO, rapeseed oil fatty acid methyl esters FAME and their blends B10 (90% DO + 10% FAME), B20 (80% DO + 20% FAME), B30 (70% DO + 30% FAME). During the tests, the engine operated in accordance with the full load characteristics. Those characteristics were used to determine the engine response. The paper provides an assessment of the impact of the type of plant-derived fuel on the engine response.

Keywords diesel engine, engine response, biofuel

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1. Introduction

Rapid developments in piston internal combustion engines, aimed at enhancing the dynamic properties of the vehicle, also contributed to the search for new, environmentally friendly energy sources. Fuels produced from natural raw materials are one of such sources. The advantage those fuels have, when compared with hydrocarbon ones, is that they are renewable, biodegradable and emit less carbon dioxide into the atmosphere [1, 2, 3]. The response of an internal combustion engine involves an ability to react to variable loads and crankshaft speeds. That provides one of the important indicators of the engine functional properties. The response of the torque depends on the profile of the engine torque characteristics. The magnitude of torque depends on numerous structural and functional parameters [4, 5]: the intake system, timing, the fuelling system, physical and chemical properties of fuel, etc. Presently, many research and development centres in the country and in the world conduct investigations to improve the dynamic properties of the internal combustion engine. The purpose of this paper is to analyse whether the use of alternative plant fuels may favourably affect the engine response.

The coefficient of the engine response $e$ is determined on the basis of the profile of curves of variation in the effective power and the engine torque [6, 7]. This is the product of the engine torque response $e_M$ and the response of the crankshaft rotational speed $e_n$:

$$ e = e_M \cdot e_n $$  \hspace{1cm} (1)

2. Object of Investigations and the Test Stand

The experimental investigations were performed on the engine test bed, which included the AD3.152 UR engine, the water brake, and the control and measurement cabinet. The diagram of the test bed is shown in Figure 1.

Figure 1. Diagram of the test stand: 1 – AD3.152 UR engine, 2 – water brake, 3 – control and measurement block

The object of investigations was three-cylinder, piston, internal combustion, compression ignition AD3.152 UR engine with fuel direct injection into the combustion chamber located in the piston bottom [9]. The engine was equipped with the fuelling system with the DPA distributor...
injection pump. The injectors had four-hole nozzles. Parameters and specifications of the AD3.152 UR engine are presented in Table 1.

### Table 1. Basic specifications of the engine

| Parameter                        | Unit       | Value         |
|----------------------------------|------------|---------------|
| Cylindrical arrangement          | -          | in-line       |
| Number of cylinders              | -          | 3             |
| Type of injection                | -          | direct        |
| Cylindrical working order        | -          | 1 – 2 – 3     |
| Compression ratio                | -          | 16.5          |
| Cylinder diameter                | mm         | 91.44         |
| Piston travel                    | mm         | 127           |
| Engine cubic capacity            | dm³        | 2.502         |
| Connecting rod length            | mm         | 223.80÷223.85 |
| Maximum engine power             | kW         | 34.6          |
| Rotational speed at maximum power| rpm        | 2250          |
| Maximum torque                   | Nm         | 168.7         |
| Rotational speed at maximum torque| rpm       | 1350          |
| Static angle of injection advance| CA deg    | 17            |
| Idle rotational speed            | rpm        | 750±50        |

3. Fuels Used to Power AD3.152 UR Engine

During the tests, the AD3.152 UR engine ran on five fuels, namely Ekodiesel Ultra D commercial diesel oil (DO), rapeseed oil fatty acid methyl esters FAME and blends of those two fuels. Tests were conducted for the following blends of hydrocarbon and plant-derived fuels:
- 10% (V/V) rapeseed oil fatty acid methyl esters FAME + 90% (V/V) Ekodiesel Ultra D diesel oil → denoted as B10,
- 20% (V/V) rapeseed oil fatty acid methyl esters FAME + 80% (V/V) Ekodiesel Ultra D diesel oil → referred to as B20,
- 30% (V/V) rapeseed oil fatty acid methyl esters FAME + 70% (V/V) Ekodiesel Ultra D diesel oil → labelled as B30.

Basic physical and chemical properties of Ekodiesel Ultra D diesel oil and rapeseed oil fatty acid methyl esters FAME are presented in Table 2.

### Table 2. Basic physical and chemical properties of engine fuels used in investigations

| Parameter                        | Ekodiesel Ultra D diesel oil | Plant-derived fuel FAME |
|----------------------------------|-----------------------------|-------------------------|
| Cetane number                    | 51.4                        | 51                      |
| Calorific value [MJ/kg]          | 43.2                        | 36.7                    |
| Density at 15°C [g/cm³],         | 0.8354                      | 0.883                   |
| Kinematic viscosity [mm²/s] (~40°C) | 2.64                  | 4.47                    |
| Surface tension [N/m] (20°C)     | 3.64·10⁻²                   | 3.58·10⁻²               |
| Ignition temperature [°C]        | 63                          | above 130               |
| Turbidity point [°C]             | -17                         | -2                      |
| Cold filter blocking temperature [°C] | -23                  | -14                     |
| Average elemental composition [%]|                             |                         |
| C                                | 87.2                        | 76.8                    |
| H                                | 12.7                        | 12.1                    |
| O                                | 0                           | 11                      |
| Sulphur content, S[mg/kg]        | 9                           | 8.1                     |
| Water content [mg/kg]            | 43.8                        | 113                     |
| Particulate matter content [mg/kg] | 5                 | 18                      |

4. Results of Experimental Investigations

Figure 2 shows the full load characteristics of the effective power and torque of the AD3.152 UR engine running on five fuels: DO, FAME, B10, B20 and B30.

![Figure 2. Diagram of the test stand: 1 – AD3.152 UR engine, 2 – water brake, 3 – control and measurement block](image-url)
Table 3 presents the values of the determined coefficients of the torque response, the rotational speed response and the response of the AD3.152 UR engine running on five fuels: DO, FAME, B10, B20 and B30.

Table 3. Determined values of response coefficients of the tested AD3.152UR engine

| Fuel type | Torque response | Rotational speed response | Engine response |
|-----------|----------------|--------------------------|-----------------|
| Diesel oil | 1.05           | 1.43                     | 1.502           |
| FAME      | 1.07           | 1.43                     | 1.531           |
| B10       | 1.07           | 1.43                     | 1.531           |
| B20       | 1.07           | 1.43                     | 1.531           |
| B30       | 1.07           | 1.67                     | 1.787           |

5. Conclusions

The following conclusions can be drawn on the basis of experimental results:
- the maximum effective power for the engine powered by the fuels of concern was found at the same rotational speed of 2000 rpm,
- for the engine fuelled by the B30 blend, the maximum torque occurred earlier, i.e. at the rotational speed of 1200 rpm, whereas when engine was powered by the remaining four fuels DO, FAME, B10 and B30, the maximum torque was produced by the engine at the crankshaft rotational speed $n=1400$ rpm,
- the highest value of the rotational speed response, which was equal to $e=1.67$, was obtained for the engine fuelled by B30,
- the torque response, which was $e_M=1.05÷1.07$, was comparable for the engine fuelling with commercial diesel oil, FAME, and also B10, B20 and B30 blends,
- when the engine was powered by FAME, and B10, B20 and B30 blends, the higher value of the engine response was obtained when compared with the engine fuelling with commercial diesel oil. The engine powered by the plant-derived fuel and the blends of this fuel demonstrated the strongest ability to overcome the load.

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