BIODIESEL IMPACT ON DIESEL ENGINE HIGH PRESSURE PUMP PLUNGER PAIRS

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Abstract. Biodiesel is increasingly used as an additive to fossil diesel fuel. For summer periods it is compulsorily in Latvia to use diesel fuel with 5 % biodiesel fuel mix. Under certain circumstances fossil diesel can be purchased blended with biodiesel up to 10 %. Using such fuel can cause problems, for example, with fuel freezing in cold weather, reduced energy density, and degradation of fuel under storage for prolonged periods. This study was carried out to determine biodiesel and its blend with fossil diesel fuel impact on high pressure fuel pump plunger pairs, if vehicles are idle for over 6 months. In order to determine with what force the plunger will move after long-term idle time, six different fuel samples were used: pure diesel fuel, diesel fuel with 5 %, 7 % and 10 % mix of biodiesel, pure rapeseed oil, and pure biodiesel. The obtained results show that increasing the biodiesel content in fuel blend with fossil diesel the agglutination force increases. As the agglutination force is much more less than the plunger spring force it allows the plunger to make a full stroke and the high-pressure fuel pump operation will not be disturbed.

Keywords: biodiesel, plunger pair, agglutination force.

Introduction

Taking into account the EU legislation on the use of biofuels in vehicles, biodiesel is increasingly used as an additive to fossil diesel fuel. Biodiesel fuel producers do not recommend storing their products longer than two months, otherwise uncontrolled fuel decay process may begin. For summer periods it is compulsorily in Latvia to use diesel fuel with 5 % mandatory biodiesel fuel mix. To reduce the sulphur content in fossil fuels it is allowed to mix in addition 2 to 5 % of biodiesel fuel. Thus, a lot of people unknowingly fill their vehicle fuel supply system with diesel fuel that contains 7 to 10 % biodiesel. Storage period of this type of fuel is 5 to 6 months.

Most investigations in the field of the use of biodiesel are devoted to biodiesel production, combustion, performance and emissions. Even wide study based on the reports of about 130 scientists who published their results between 1980 and 2008 [1] does not touch the problems associated with long-term storage of fuel and its impact on the fuel system components.

Some technical disadvantages of biodiesel/fossil diesel blends are mentioned by K. Bozbas – problems with fuel freezing in cold weather, reduced energy density, and degradation of fuel under storage for prolonged periods. As fuels can form a layer of deposits on the inside of tanks, hoses, etc., biodiesel blends loosen these deposits causing them to block fuel filters [2]. The same drawback of biodiesel, i.e. forming insoluble gums and sediments that can plug fuel filters was pointed out also by A. Monyem and J.H. Van Gerpen [3]. D.Y.C. Leung et al. investigated degradation of biodiesel under different storage conditions [4]. The properties of biodiesel samples were monitored at regular interval over a period of 52 weeks. Studies showed that the biodiesel degraded less than 10 % within 52 weeks for the samples stored at 4 and 20 ºC, while nearly 40 % degradation was found for the samples stored at temperature 40 ºC. Long storage stability of biodiesel was investigated also by A. Bouaid et al. [5]. The study was conducted for a period of 30 months. At regular intervals the samples were monitored and it was concluded that the acid value, peroxide value, viscosity, and insoluble impurities increased, while the iodine value decreased with increasing storage time of the biodiesel samples.

This study was carried out to determine biodiesel and its blend with fossil diesel fuel impact on high pressure fuel pump plunger pairs, if vehicles are idle for over 6 months, for example, in crop combine harvesters. The section pumps are still commonly used for diesel engines, because they have comparatively simple construction, high work safety, as well they are intended to regulate fuel dose supply at a wide range. The main component of a section pump is plunger pair that provides fuel supply to a diesel engine cylinder. The working stroke of a plunger from the BDC (Bottom Dead Center) to the TDC (Top Dead Center) (Fig. 1) is provided by a rotating camshaft, but movement to the BDC is provided by a spring. Consequently, the task of the research is to ascertain if in a long vehicle idle time plunger pairs do not agglutinate and that the agglutination force is not higher than the spring force and allows the plunger to return to the BDC.

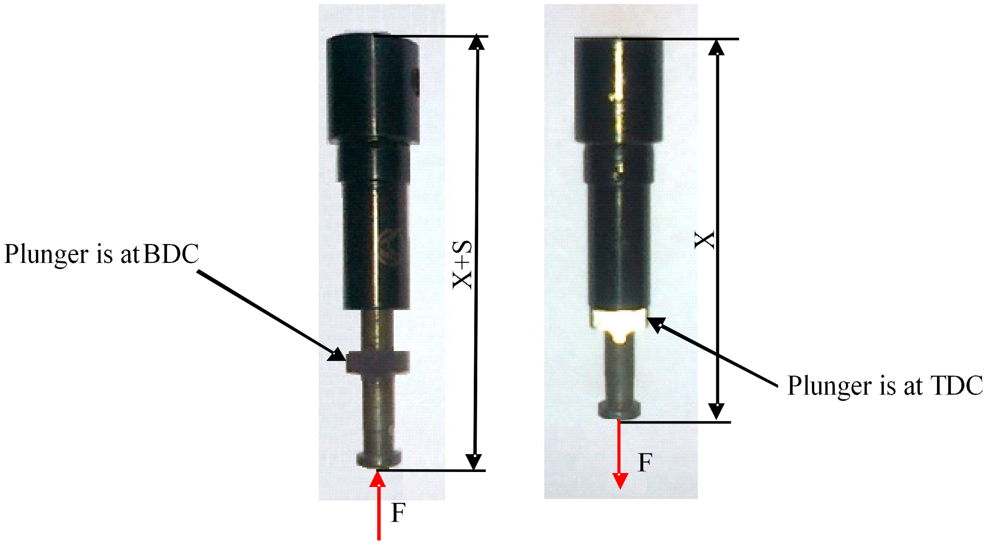

Fig. 1. **Plunger pair**

Materials and methods

In order to determine with what force the plunger will move after long-term idle time, the following fuel samples were used:

- diesel fuel without any mix of biodiesel (DF);
- diesel fuel with 5 % mix of biodiesel (B5);
- diesel fuel with 7 % mix of biodiesel (B7);
- diesel fuel with 10 % mix of biodiesel (B10);
- pure rapeseed oil (RO);
- pure biodiesel (B100).

There were two plunger pairs immersed in each fuel, one in the position when the plunger is at the BDC, the other – at the TDC (Fig. 2). In such position the research objects were kept for 360 days, then taken out from the fuel and measurements were made.

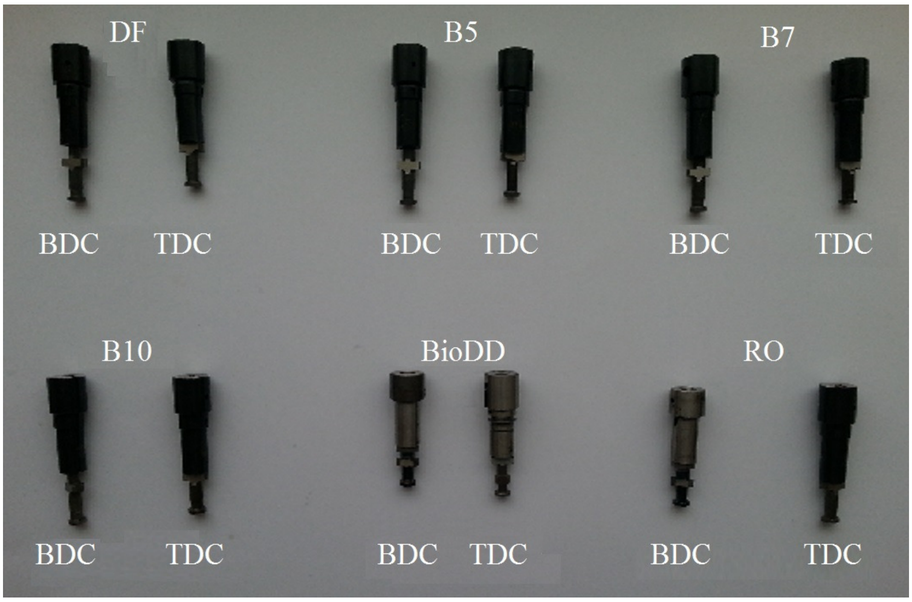

Fig. 2. **Research objects**

Experiments were carried out using a self-made experimental facility (Fig. 3) in a well-lit, ventilated room with a surrounding air temperature of 22 ºC.

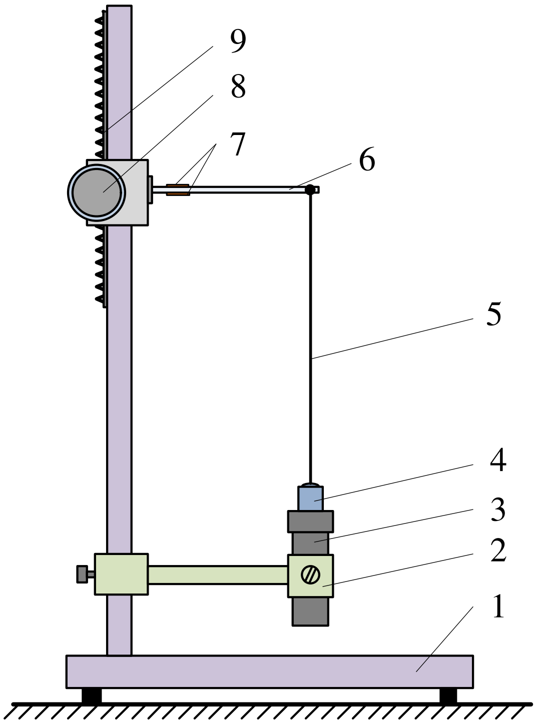

Fig. 3. **Scheme of the experimental facility**: 1 – stanchion; 2 – binding; 3 – plunger liner; 4 – plunger; 5 – flexible string; 6 – power sensor; 7 – resistance strain gauges; 8 – hand wheel; 9 – rack

To determine the agglutination force a special force sensor was created (Fig. 4). It consists of a flexible duralumin plate to which four resistance strain gauges are glued on in full bridge circuit.

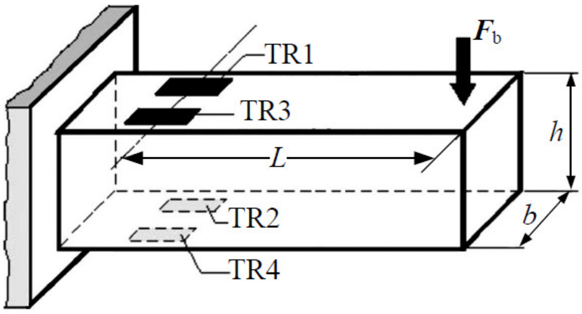

Fig. 4. **Force sensor structure**: TR1, TR2, TR3, TR4 – resistance strain gauges; L –distance between the center of attachment of resistance strain gauge to the location where the force is applied; F_b – applied force; h – height of the metal plate; b – width of the metal plate

The location of resistance strain gauges provides high sensitivity, linearity and full temperature compensation.

Prior to the measurement the device was calibrated using standardized weights. To determine the force sensor bias, calibration was done gradually loading and then unloading the pressure sensor.

As the result the calibration curve was obtained (Fig. 5).

The equation of the obtained calibration curve is:

$$U_o = \frac{1}{K} \cdot F_c = 2.4989 \cdot F_c, \quad (1)$$

where U_o – output voltage of the sensor, mV;
F_c – calibration force, N;
K – static coefficient of sensitivity of the sensor, $N \cdot mV^{-1}$.

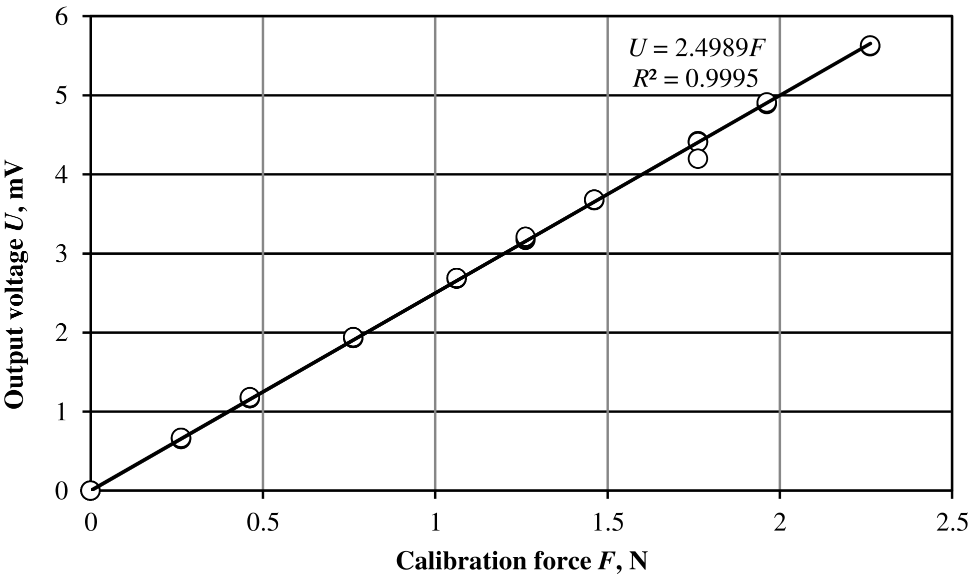

Fig. 5. **Calibration curve of power sensor**

Considering that the measuring process of the force is determined by reading of the output voltage we can find the static coefficient of sensitivity of the sensor [6]:

$$K = \frac{1}{2.4989} = 0.39\ \text{N}\cdot\text{mV}^{-1}. \quad (2)$$

Performing the measurements the force value was calculated using the formula:

$$F = K \cdot U_o, \quad (3)$$

where F – measured force, N.

Measurement data registration was carried out using a virtual instrument *Pico ADC 24* with a resolution of 24 bits. Force change was recorded into a spreadsheet using computer software *Picolog*.

Before measurements all of the above mentioned devices were installed and prepared, and the first plunger pair was mounted into the experimental facility in vertical position so that the plunger rod is on top. Plunger was attached to the force sensor with a flexible string, and the "Record" button was pressed in computer software to start recording the experiment measurements. Then, the hand wheel was rotated moving the plate up and measuring of the adhesion force of the piston was performed. The operation was continued until the plunger has made a full stroke. Then the "Stop Record" button was pressed and the gauge holder was placed back to the starting position.

Only one agglutination force measurement was carried out for each plunger pair, because the plunger has grinded its moving route, thus re-measurement could not be objective.

Results and discussion

Figure 6 summarizes the results of measurements from both moving the plunger from the TDC to the BDC and from the BDC to the TDC. The obtained results show that increasing the biodiesel content in fuel blend with fossil diesel the agglutination force increases. For pure biodiesel it reaches 2.48 N in a moving phase from the BDC to the TDC. As the agglutination force is much more less than the plunger spring force (about 500 N), it allows the plunger to make a full stroke and the high-pressure fuel pump operation will not be disturbed. Of course, agglutination can negatively impact the quality of the plunger pair friction surfaces.

It is important to note that, despite the fact that rapeseed oil has a higher viscosity than biodiesel, its adhesion strength is lower by approximately 0.7 N.

It is difficult to compare the obtained results directly with the investigations of other researchers, because there have not been any similar studies on fuel long term impact on diesel engine high pressure pumps carried out. In several studies there are conclusions about preparing a vehicle for biodiesel use, respectively the engine fuel delivery system has to be prepared, rubber fuel pipelines, fuel filter parts, sealing rings etc. have to be replaced, except for cases when the vehicle manufacturer has already prepared the vehicle for the use of biodiesel. It is also evident that biodiesel has good solvent qualities that can adversely affect painted surfaces and at the beginning of the use of fuel can contribute to more frequent fuel filter changes [7].

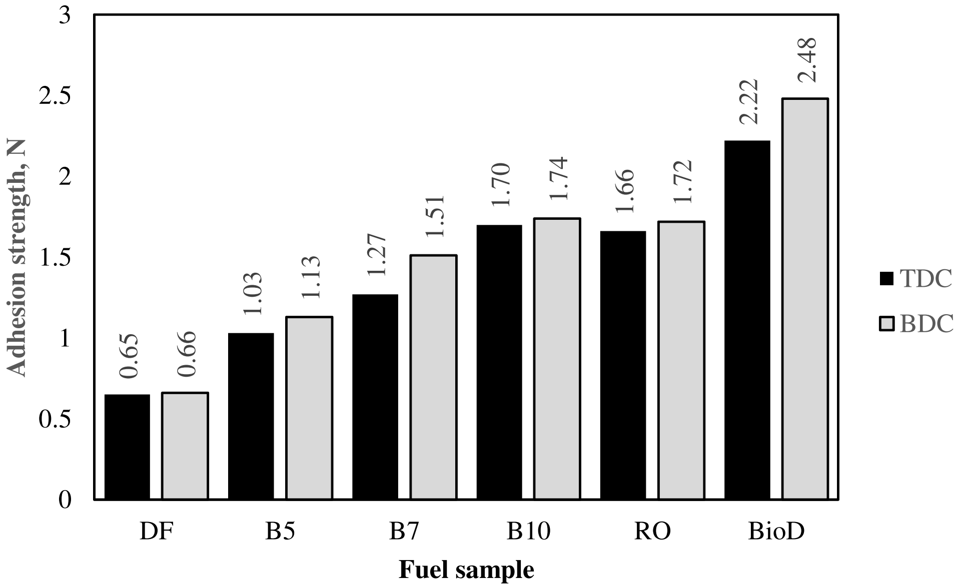

Fig. 6. **Agglutination force measurement results**

Conclusions

1. According to the Latvian legislation under certain circumstances fossil diesel can be purchased blended with biodiesel up to 10 %. Long-term storage of such fuel can impact the fuel system components due to fuel degradation.
2. This study was carried out to determine biodiesel and its blend with fossil diesel fuel impact on high pressure fuel pump plunger pairs, if vehicles are idle for over 6 months. Six different fuel samples were tested.
3. The obtained results show that increasing the biodiesel content in fuel blend with fossil diesel the agglutination force increases. As the agglutination force is much more less than the plunger spring force it allows the plunger to make a full stroke and the high-pressure fuel pump operation will not be disturbed.

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