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# Adhesion of canola and diesel oils to some parts of diesel engine in the light of surface tension components and parameters of these substrates

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ABSTRACT

Measurements of the surface tension of canola oil from different manufacturers, diesel oil and water–oil interface tension as well as the contact angle on different parts of the diesel engine were made. The contact angle for canola and diesel oils on polytetrafluoroethylene (PTFE) and polymethyl methacrylate (PMMA) surfaces as well as for water, diiodomethane and formamide on different parts of the diesel engine was also measured. On the basis of the obtained results as well as the van Oss et al. approach to the interfacial tension and the Young equation the Lifshitz–van der Waals component of the surface tension and electron-donor and electron-acceptor parameters of the acid–base components of this tension of canola and diesel oils and parts of diesel engine were determined. Taking into account the determined values of the parameters and components of the surface tension of diesel and canola oils, their adhesion to the particular parts of a diesel engine was determined by using the van Oss et al. equation and compared to the adhesion work determined from the Young–Dupre equation. It appeared that the adhesion work determined from the van Oss et al. equation which decreased the precursor film pressure is comparable to that determined from the Young–Dupre equation. Adhesion work of the diesel oil to different parts of the diesel engine is somewhat lower than that of canola oils. In addition the water–diesel oil interface tension is lower than that for water–canola oil.

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## 1. Introduction

Biodiesel is used as an additive to improve the lubricity of petroleum fuels [1–25] because of its good lubrication properties. Of the biodiesel vegetable oils canola oil is especially frequently used. Under normal operating conditions such parts of a diesel engine as piston, cylinder, valve, piston rings and engine head are lubricated by engine oil and fuel film created as a result of fuel injection into the combustion chamber [26]. The lubrication properties of canola oil depend, among other things, on its surface tension as well as different parts of the diesel engine because this lubrication is equal to the difference between the adhesion of canola oil to the particular parts of diesel engine and its cohesion work. It is possible to find in the literature only the total surface tension of canola oil. However, the contribution of particular intermolecular interactions to this tension is not known. Moreover, the surface tension of particular parts of the diesel engine has not been considered in the light of different kinds of intermolecular interactions. As it is known, wettability or lubrication processes depend not only on the total surface tension of the solid or liquid but also on the components and parameters of this tension resulting from different kinds of intermolecular interactions.

In most cases solid surface tension cannot be measured directly. Therefore, several independent approaches have been used to estimate it. Of indirect methods those based on the contact angle of liquids and the Young equation are commonly used. However, to solve the Young equation [27,28] with regard to the surface tension of a solid, the relationship between the solid–liquid interface tension and the liquid and solid surface tension should be known. Two main approaches to this relationship are commonly used. One of them proposed by Neumann et al. [29] assumes that the solid–liquid interface tension is a function of the total surface tension of the solid and liquid. The other one, treats the relationship between the solid-liquid interface tension as a

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sum of the surface tension of the solid and liquid reduced by the components of the adhesion work of the liquid to the solid resulting from the Lifhsitz–van der Waals and acid–base interface interactions [27]. It was found that in the range of the solid surface tension 15–40 mN/m both approaches to the interface tension introduced to the Young equation provide comparable values of the solid surface tension and used together give more information about the solid surface properties [30]. Using these approaches the surface tension of canola and diesel oils as well as the parts of the diesel engine as piston, cylinder, piston ring, engine head, valve and their Lifshitz–van der Waals components and electron-donor and electron-acceptor parameters of the acid–base components were studied. Then on the basis of the obtained values of these components and parameters the spreading and lubrication processes of oil on some parts of the diesel engine were considered. For this purpose the measurements of the surface tension of canola oil from different manufacturers and diesel oil as well as the contact angle on different parts of the diesel engine were made. The contact angle for canola oil on polytetrafluoroethylene (PTFE) and polymethyl methacrylate (PMMA) surfaces as well as for water, diiodomethane and formamide on different parts of a diesel engine were measured.

## 2. Experimental

### 2.1. Materials

Polytetrafluoroethylene (PTFE), (ZA Tarnów, Poland) and polymethyl methacrylate (PMMA), (Z. Ch. Oświęcim, Poland) plates were used for contact angle measurements. These plates were washed sequentially with detergent and next with methanol, placed in an ultrasonic bath in Milli-Q water twice for 15 min. with warm flowing tap water (about 50 °C), and Milli-Q water and then dried in a desiccator at room temperature. The quality of the surface of each plate was monitored by using a polarizing microscope (Nikon, ECLIPSE E 600 POL). Also AFM images were made for the commercial non-modified surfaces of PTFE and PMMA plates (Nanoscope 3, VEECO) (Figs. 1 and 2, as an example). Only the plates, in which the rms roughness were the smallest were used for contact angle measurements. The PTFE and PMMA plates were additionally tested by measuring contact angles for model liquids (water, diiodmoethane and formamide).

Piston, cylinder, valve, piston rings and engine head were prepared by removing the products of combustion and subsequent polishing. All the materials were polished through mechanical

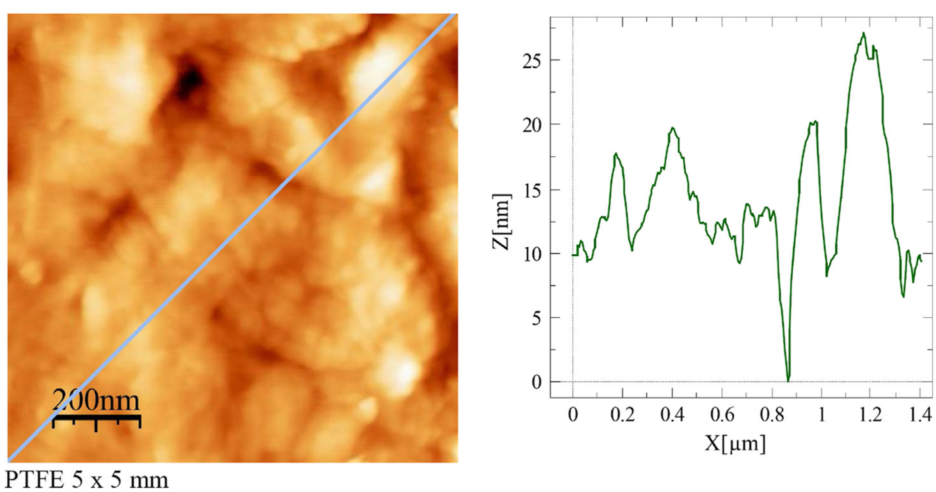


**Fig. 1.** 3D AFM images of PTFE surface ($R_{RMS}$ (root mean square parameter expresses the standard deviation of the surface height distribution) = 19.0 nm, $R_A$ (average roughness expresses general quality control) = 24.6 nm, $R_t$ = 105.0 nm(max profile height)).

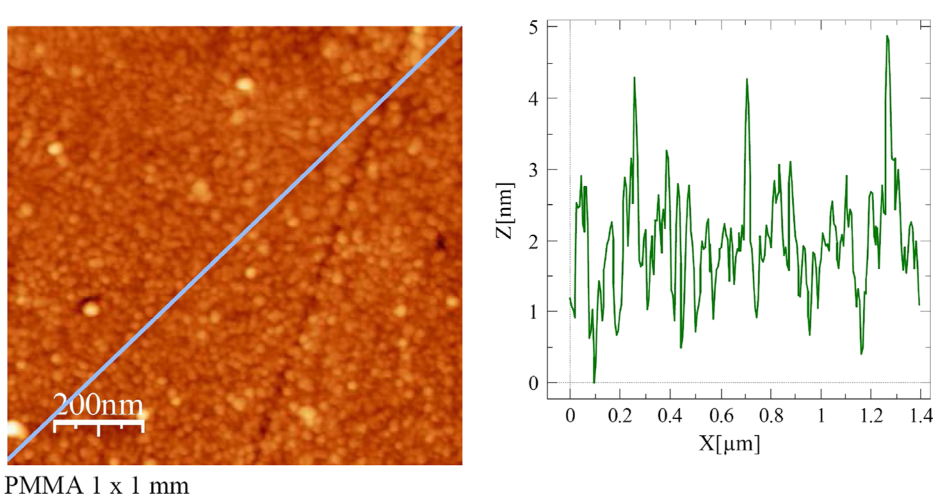


**Fig. 2.** 3D AFM images of PMMA surface ($R_{RMS}$ = 0.88 nm, $R_A$ = 0.66 nm, $R_t$ = 4.8 nm).

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