THE INFLUENCE OF SELECTED NANOPARTICLES ON RHEOLOGICAL PROPERTIES OF ARTIFICIAL MUCUS

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Abstract

Functionality of body fluids largely depends on their rheological properties. On the other hand, the increased of exposure of the organism to environmental nanoparticles, i.e. desert dust or nanoparticles of carbon black resulting from fuel combustion in a diesel engine was observed. The research focused on investigating the impact of selected nanoparticles (Arizona Dust Nominal 0-3 micron (Powder Technology INC, USA), DEP (Diesel Exhaust Particles)) from the combustion of various diesel fuels on the rheological properties of artificial mucus.

In research artificial mucus (2% and 20% concentration of mucin) [Sosnowski et al., 2009] and nanoparticles' suspensions in artificial mucus (0.06 and 6 mg/ml) were prepared and their rheological properties (flow curve, viscosity dependence of shear stress, storage modulus and loss modulus) were studied. All rheological parameters were measured by an oscillating rheometer (MCR102, Anton Paar, Austria) at temperatures of 22°C, 36.6°C and 40°C. The size of nanoparticles in water was determined by Malvern Zetasizer. Size distribution by number of nanoparticles are 654.3 nm (100%) for fuel 1, 565.9 nm (100%) for fuel 2, 131.1 nm and 363.7 nm (13.7%, 86.3% respectively) for Arizona Dust. The influence of nanoparticles on mucus rheological properties was observed. The high concentration of nanoparticles increases apparent viscosity while the impact of low concentration of nanoparticles on mucus rheology is negligible. On the other hand the presence of nanoparticles in mucus does not change mucus viscoelastic properties. The viscous properties dominate over elastic properties, both in clean mucus and in mucus with selected nanoparticles.

Keywords: Mucus, Arizona Dust, diesel exhaust particles, rheology

1. INTRODUCTION

In the human body, nasal and bronchial mucus (viscous colloid consists water (93%), lipid (5%), protein (1%) and inorganic compound (2%) [1]) has protective function. It protects respiratory system by trapping exogenous particles and pathogens. Functionality of mucus depends on their rheological properties. Changes in mucus rheology may cause disorder of transport through it. This can have dangerous consequences e.g. influence for dose of inhaled drug. Therefore the increased of exposure of the organism to environmental nanoparticles, i.e. desert dust or nanoparticles of carbon black resulting from fuel combustion in a diesel engine should be examine. The research focused on investigating the impact of selected nanoparticles (Arizona Dust, DEP (Diesel Exhaust Particles) on the rheological properties of artificial mucus.

2. METHODOLOGY

2.1. Artificial Mucus

The artificial mucus of 2% and 20% mucin content prepared by the simple procedure proposed by Sosnowski et al. [2] was used in the study. It contained only Type II mucin (Sigma Aldrich) [20 - 200 g/l] responsible for the appropriate viscosity of the solution and NaN_3 (POCH) [0.01 g/l] as a preservative. The ingredients were dissolved in ultra-pure water and then placed on 2h (2% mucus) or 20h (20% mucus) on a magnetic stirrer

(500 rpm). After this time, the pH of the solution (7.4) was adjusted with HCl and NaOH. The artificial mucus was stored at 4°C in a sealed container.

2.2. Arizona Dust

Arizona Dust Nominal 0-3 micron (Powder Technology INC, USA) was used in the study as a sample of natural nanoparticles. The structure of Arizona Dust was shown in **Figure 1**. According to the data sheet, the particle size of Arizona Dust in water should be 778 nm - 18 µm, d_{10} = 0.857 µm, d_{50} = 1,203 µm and d_{90} = 2,166 µm and the composition of Arizona Dust is as follows (ww): SiO_2 (68-78%, Al_2O_3 (10-15%, Fe_2O_3 (2-5%, CaO (2-5%), KCl (2-5%), Na_2O (2-4%), MgO (1-2%), TiO_2 (0.5-1%). The size of Arizona Dust particle before and after sonification (**Figure 2**) in water was determined with the used of Zetasizer (Malvern, UK). The average diameter is 513 nm and 433 nm respectively.

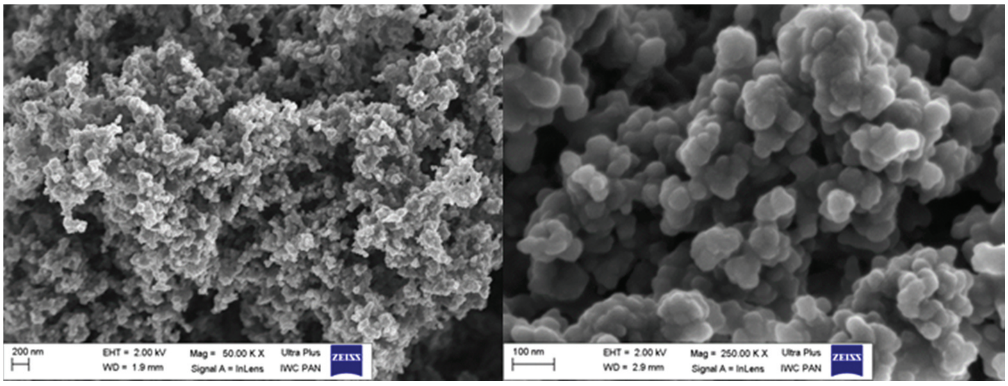

Figure 1 The scanning electron microscopy photo of Arizona Dust

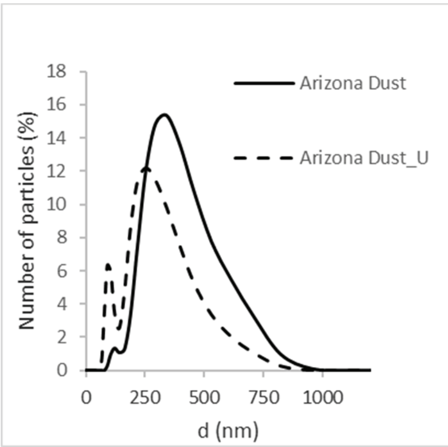

Figure 2 Size distribution by number of Arizona Dust in water before (Arizona Dust) and after sonication (Arizona Dust_U)

2.3. Diesel Exhaust Particles

Diesel Exhaust Particles (DEP) from the combustion of various fuels (fuel I - VERVA ON (PKN Orlen, min CN = 55) and fuel II - Ecodiesel ULTRA (PKN Orlen, min CN = 51)) in diesel engine (Mercedes, 1982, 4 cylinders, capacity 2399 cm^3) were collected and characterized. The size of particle before (Fuel **I**, Fuel **II**) and after sonication (Fuel I_U, Fuel II_U) in water was determined with the used of Zetasizer (Malvern. UK) (**Figures 3** and **4**). The average diameter is: Fuel **I** 1548 nm and 321.1 nm, Fuel **II** 1197 nm and 334.6 nm. The structures of DEP are shown in **Figures 5** and **6**.

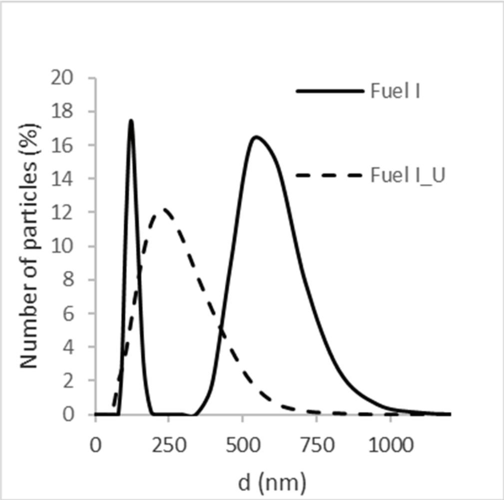

Figure 3 Size distribution by number of DEP from fuel I in water before (Fuel I) and after sonication (Fuel I_U)

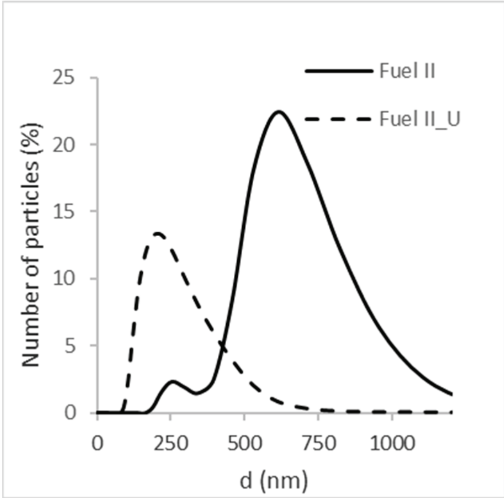

Figure 4 Size distribution by number of DEP from fuel II in water before (Fuel I) and after sonication (Fuel II_U)

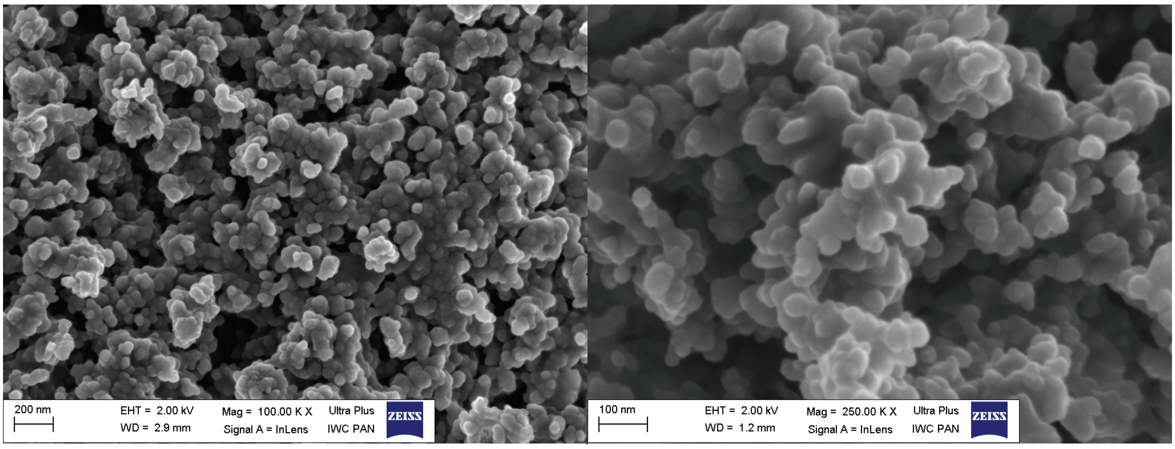

Figure 5 The scanning electron microscopy photo DEP from fuel I

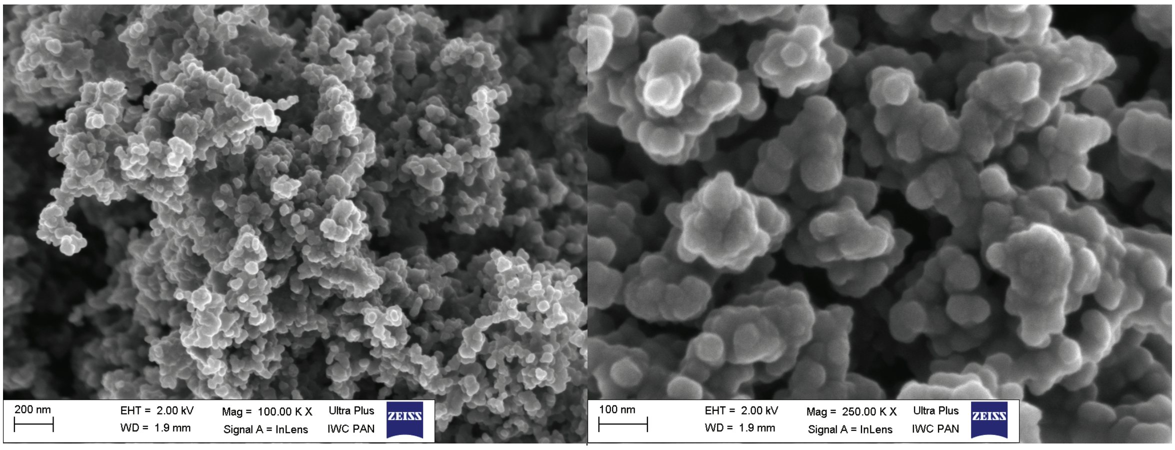

Figure 6 The scanning electron microscopy photo DEP from fuel II

All rheological parameters were measured using the oscillating rheometer (MCR102, Anton Paar, Austria) at temperatures of 22°C, 36.6°C and 40°C.

3. RESULTS

3.1. 2% Mucus

The artificial mucus contains 2% of mucin, both pure and with selected nanoparticles (Arizona Dust, DEP I and DEP II) is Newtonian fluid (the dependence of shear rate to shear stress is linear - **Figures 7-9**). The influence of Arizona Dust on mucus' rheological properties is observed only at 36.6°C (**Figure 7**). The presence of DEP I in mucus (6 mg/ml concentration) increases viscosity of 2% mucus, while the impact of low concentration of DEP I on mucus rheology is insignificant especially at 36.6°C and 40°C (**Figure 8**). The presence of DEP II in mucus (6 mg/ml concentration) increases viscosity of 2% mucus at 22°C and 40°C. The impact of low concentration of DEP II on mucus rheology at 40°C and both concentration of DEP II at 36.6°C is negligible (**Figure 9**).

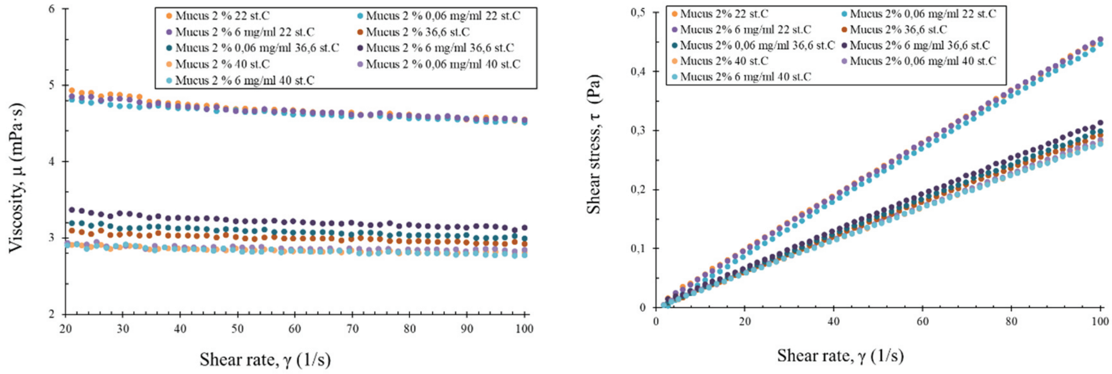

Figure 7 Influence of Arizona Dust on viscosity dependence of shear stress and flow curve

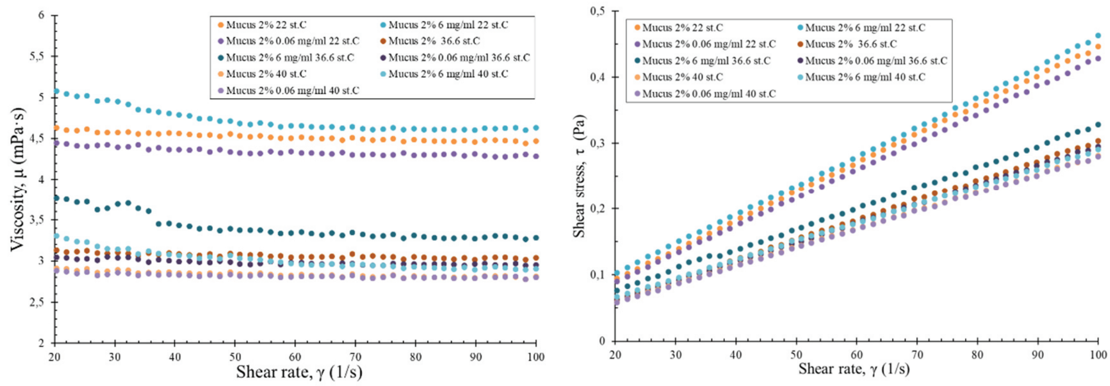

Figure 8 Influence of DEP I on viscosity dependence of shear stress and flow curve

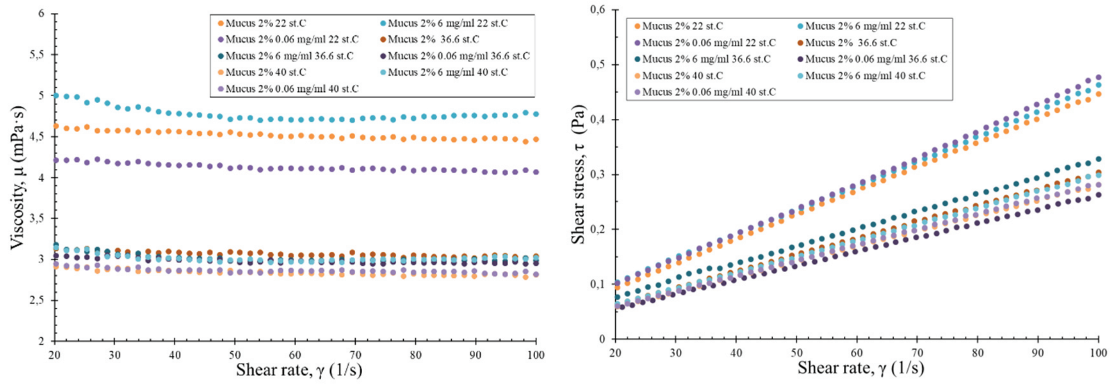

Figure 9 Influence of DEP II on viscosity dependence of shear stress and flow curve

3.2. 20% Mucus

The pure artificial mucus contains 20% of mucin and the artificial mucus with addition of nanoparticles is shear-thinning fluid (**Figures 10-12**). Arizona Dust increases viscosity of 20% mucus (**Figure 10**). This effect is noticeable at all temperatures. Viscosity of 20% mucus increases with the increase of concentration of DEP I and DEP II (**Figures 11 and 12**). Influence of DEP I is more visible at higher temperature (**Figure 11**). For DEP II, the most significant increase of viscosity was observed at 22°C (**Figure 12**). The presence of nanoparticles in 20% artificial mucus does not change shape of flow curve (**Figures 10-12**).

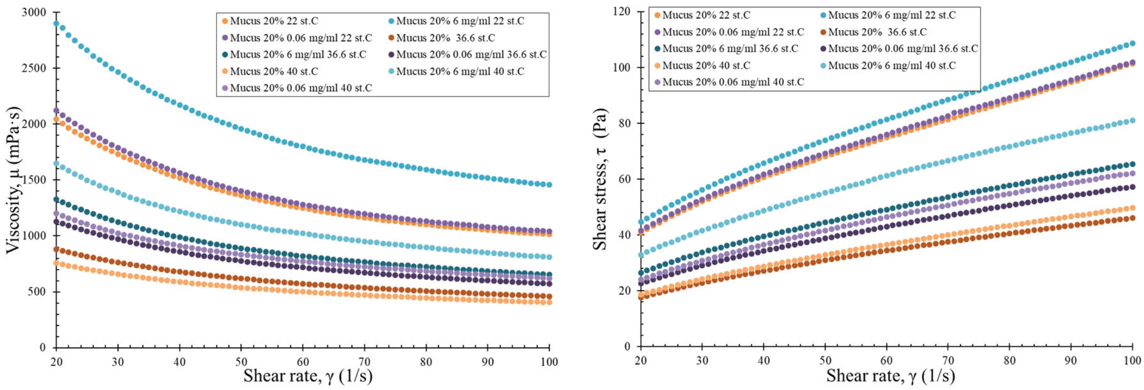

Figure 10 Influence of Arizona Dust on viscosity dependence of shear stress and flow curve

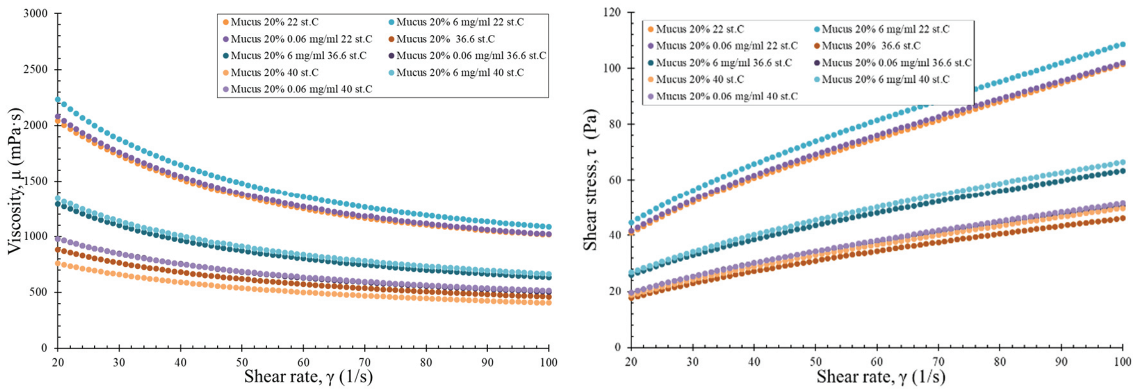

Figure 11 Influence of DEP I on viscosity dependence of shear stress and flow curve

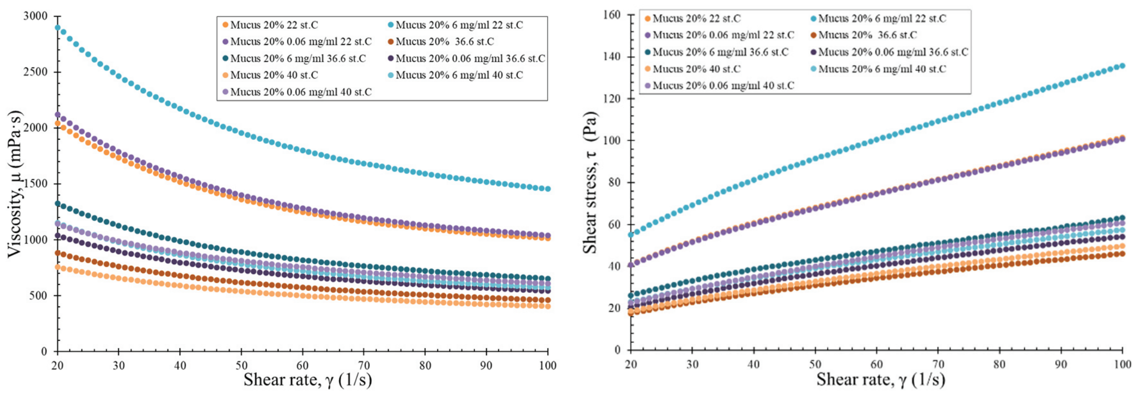

Figure 12 Influence of DEP II on viscosity dependence of shear stress and flow curve

4. CONCLUSION

The selected nanoparticles are characterized by wide range of size and tendency to aggregate. The high concentration of nanoparticles increases apparent viscosity, while the impact of low concentration of nanoparticles on mucus rheology is slight. Therefore, it is necessary to confirm in further experimental if differences in viscosity do not arise from measurement errors. The presence of nanoparticles in artificial mucus does not change Newtonian fluid into Non-Newtonian fluid (this effect is described in the literature as a result of suspension's formation), which may be due to the low proportion of the dispersed phase in the continuous phase.

ACKNOWLEDGEMENTS

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