Silica Based Shear Thickening Fluids (STFs) and Their Composites

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Key words: Shear thickening fluids, stab resistance

The fluids can be categorized into two groups according to their behaviour under shear stress; Newtonian and non-Newtonian. Most fluids follow Newton's law with the constant viscosity [1]. However, concentrated suspensions do not show a constant viscosity under shear stress and they can be given as an example of non-newtonian fluids. Shear thickening fluids (STFs) are non-Newtonian fluids which show continuous and sudden increase in viscosity beyond a critical shear rate [2-3]. Viscosity of these suspensions increase while increasing shear rate due to the order-disorder transition and hydrodynamic clustering theories [4]. The shear thickening fluids consist of two phase; nano-scale particles such as silica, calcium carbonate, PMMA particles and medium fluid inwhich the particles are dispersed such as water, PEG, etc. [5]. In recent years, shear thickening fluid (STF) was used within the systems such as body armors, adhesives and sealants, flame resistant clothing, body armor whether bullet or stab proof, motorcycle protective clothing etc. [6].

In this study, STFs which contains fumed silica dry nanoparticles (90-250 nm particle sizes) and polyethylene glycol (PEG) (300g/mole) were prepared by sonochemical method at different weight ratios. The reological properties of STFs were investigated using a (TA AR2000ex) rheometer. STF/fabric composites were obtained by impregnation of STFs into Kevlar fabric with rolling. Quasitatic stab resistance of composites was determined by Schimadzu AGI universal test machine with a 5 kN load cell.

In order to produce STF a variety of weight fractions of nanoparticles were added to PEG and they were blended in excess amount of ethyl alcohol for 8 hours by sonochemical method. After obtaining the solution of the STF, the solution was held in an air-circulating oven at ethyl alcohol evoporation temperature (79 ºC) in order to remove all ethyl alcohol in the reaction mixture. After all ethyl alcohol are removed, STF was grinded in a agate mortar and in order to eliminate the bubbles, STF was placed in a vacuum oven for several hours until no bubbles were observed. In order to prepare STF/fabric composites, 10 200 mm×200 mm layers of Kevlar fabrics were cut and individual layers were impregnated by diluted with ethyl alcohol STF. Composites were held at room temperature until their weights become stable.

Based on the rheological results, it was observed that the PEGs viscosity remains constant as shear rate increases. The additions of silica nanoparticles into the PEG results with the increase of the viscosity over the entire range of shear rates. It was also seen that the viscosity of the STF samples increases with increasing silica weight fraction. For the sample containing 30 wt% of silica, the viscosity changes from

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42.49 Pa·s at 20.24 s^{-1} shear rate to 1241 Pa·s at 42.49 s^{-1} shear rate. The increasing value of viscosity indicates an incredibly high shear thickening effect. The quasitatic stab resistance of composites is also being measured based on the NIJ Standart 0115.0 for stab resistance of personal body armor and it will be presented.

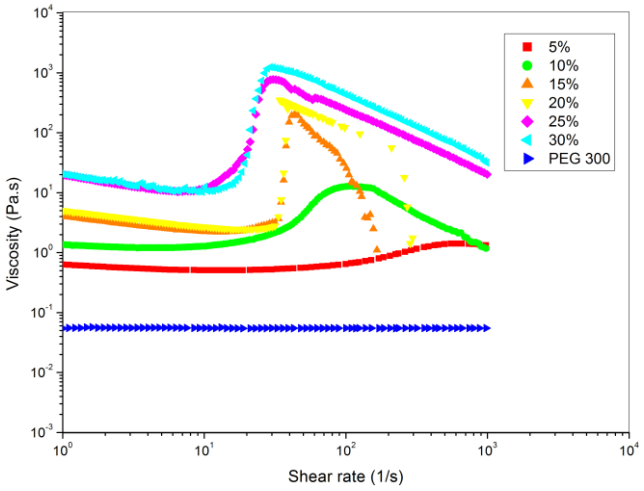

Fig. 1 Steady shear viscosity as a function of shear rate for colloidal dispersions at varying weight fractions

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