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SHEAR THICKENING FLUIDS (STFS); DEFINITION, THE AFFECTING FACTORS, AND THEIR GENERAL APPLICATIONS: A REVIEW

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ABSTRACT:

Shear thickening fluids STFs are a new kind of materials that consist of nano/micro particles that dispersed in another material such as polymer. In this review paper, the definition of this type of materials and the mechanism of its work are explained. In addition, the main factors that can effect on this behavior and their applications in different area from simple applications to complex applications are shown briefly.

Keywords: Shear thickening fluids; STFs; Body armor; Dilatant; Non-Newtonian flow.

I. INTRODUCTION TO SHEAR THICKENING FLUIDS (STFS):

This type of fluid has a non-Newtonian behavior as its viscosity increases with increasing shear rate; it is often seen in concentrated colloidal dispersion. This kind of materials show a solid like behavior for a split second when the stress is applied on the material and return to its liquid behavior after the removal of stress[1]–[4]. Figure 1 shows the two main types of fluids: Non-Newtonian (the viscosity change with changing the shear rate) such as shear thinning (pseudoplastic) and shear thickening (dilatent), and Newtonian fluids (the viscosity constant with shear rate change)[5].

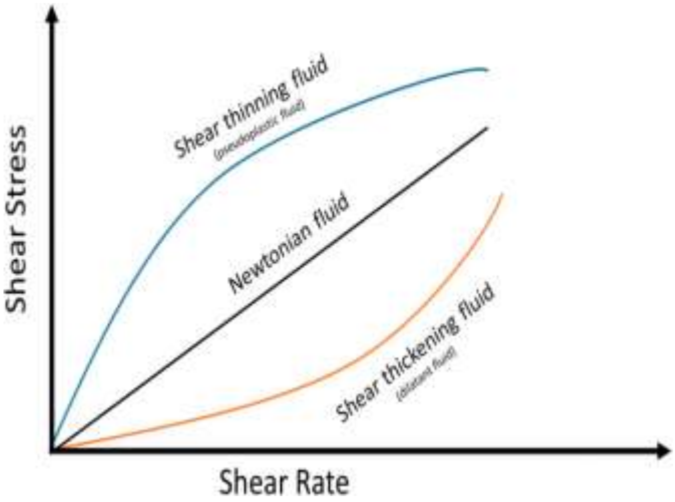

Figure 1: Types of fluids[5].

At low shear rates, shear thinning behavior appears, and with increasing shear rate, the viscosity increases to a higher value and turns into shear thickening. These fluids are characterized by the fact that removing the shear stress leads to a decrease in viscosity. This type of fluid has good mechanical properties because of the unique rheological properties that make it distinctive applications, as shown in Figure 2 [6].

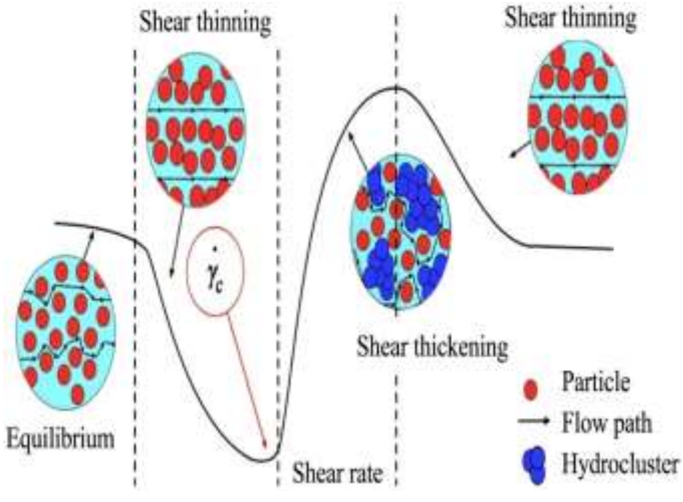

Figure 2: The shear thickening fluid behavior [7].

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Figure 2 represents the general scheme of STF, which consists of three regions: The first region represents the occurrence of shear thinning that is evident at shear rates that are less than the critical shear rate γc, the second region represents the shear thickening that occurs between the critical shear γc and the greatest shear, and the last region is the occurrence of shear thinning.

II. FACTORS AFFECTING ON SHEAR THICKENING FLUIDS:

Shear thickening behavior is affected by many factors related to the dispersed medium, including volume fraction, particle size, shape and dispersion, and also depends on the properties of the continuous medium.

A. The volume fraction of the added particles has a great effect on the appearance of the shear thickening behaviour, as by increasing the volume fraction, the critical shear rate appears in a closer area, which means an increase in viscosity, as shown by Figure 3 and 4.

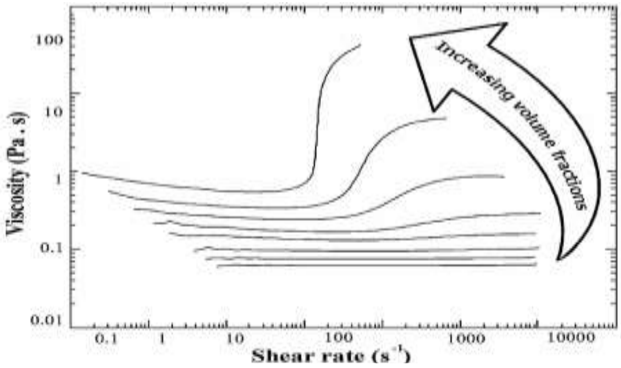

Figure 3: Shear rate/Viscosity curve as a function of different volume fraction[8].

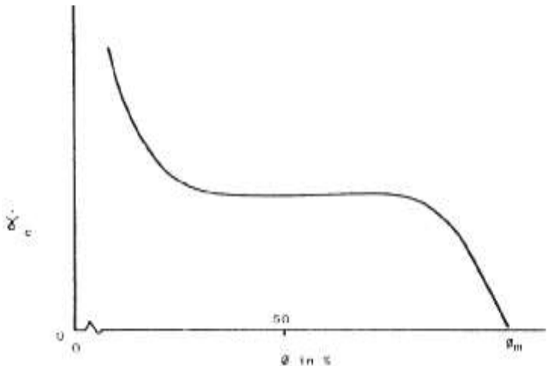

Figure 4: Critical shear rate onset dependence on the volume fraction[9].

B. Particles size: particle size has an opposite effect on shear thickening, as the larger the particle size, the less shear thickening appears, as shown in Figure 4 [10].

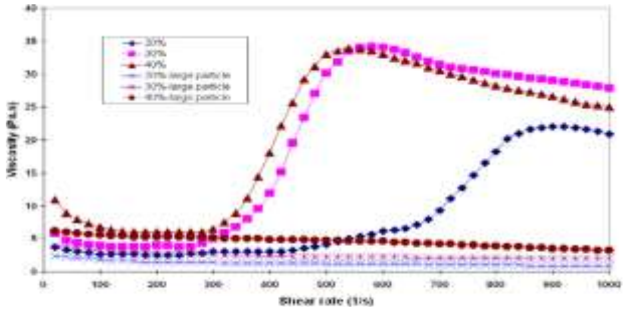

Figure 4: Particle size effect on the shear thickening behavior[10].

C. The particles size distribution: The blocks that consist of different sizes of particles are more compact in that the small particles fill the spaces between the large particles. when shear stress is applied, the small particles act as a lubricant for the flow of large particles and thus lead to a decrease in the viscosity of the fluid, as shown by Figure 5 and 6 [11].

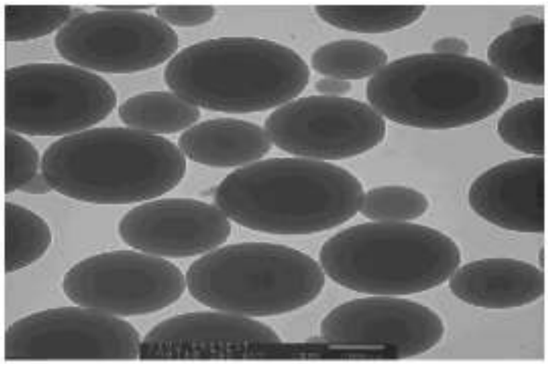

Figure 5: SEM image of large and small particles in shear thickening fluid[12].

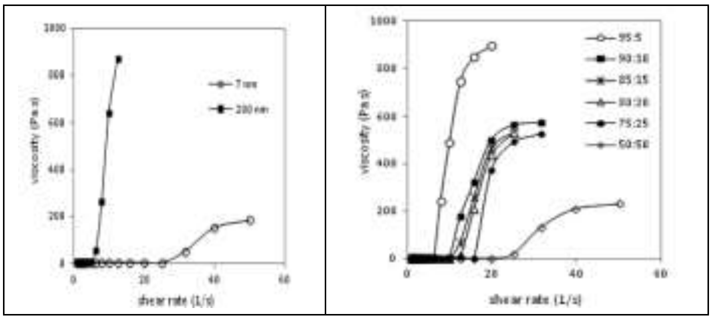

Figure 6: The effect of particle diameter (left) and particle size distribution (right) on the shear thickening behavior [13].

D. The shape of the particles: The particle shape has a great effect on the shear thickening behavior. Studies have shown that the rod-shaped particles are more effective than the plate because the rod arranges itself in the direction of flow. Spherical particles produce higher viscosity because they disperse higher energy, as shown by figure 7 [11].

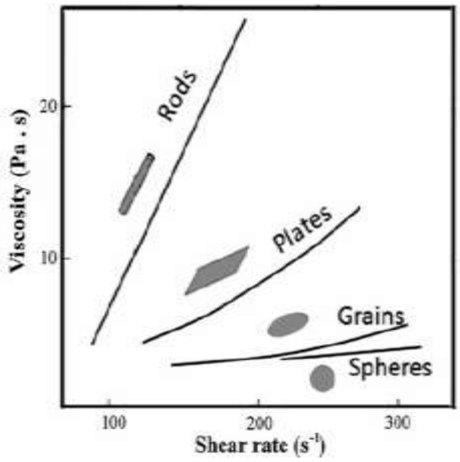

Figure 7: The effect of different shape of particles on the viscosity/shear rate behavior[14]and [4].

E. Attractive forces between particles: The attraction between particles has an important effect to obtain the required rheological properties, as the forces must be stable between particles. To get shear thickening there should be no attraction between the particles as shown by figure 8 [11].

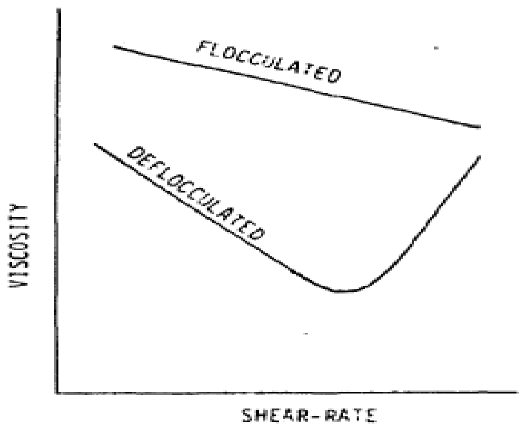

Figure 8: The chemical induction effect on the shear thickening behavior, (flocculated-no interaction between the particles/shear thinning), and (deflocculated- there are an interaction between the particles/shear thickening)[14]and [4].

III. Application of Shear Thickening Fluids:

These liquids have many different applications from industrial applications to medical applications, as the use of these liquids in a specific application depends on the materials used in terms of the type of particles as well as the type of polymer. In this section, some of the important application are listed.

A. Shock absorbers and suspension systems, which consist of an insulating fluid and polar particles called ER fluids, are affected by an electric field. Magnetic particles can be used and MR fluids are known to be affected by the magnetic field[15].

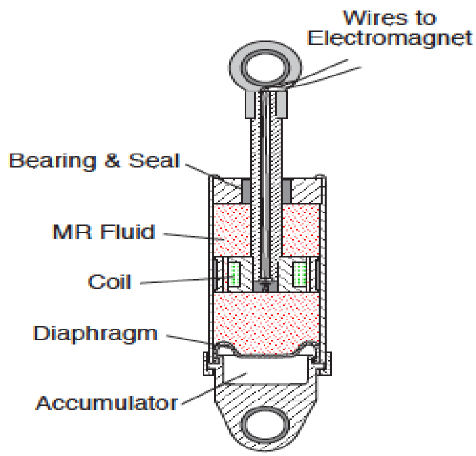

Figure 9: Shock absorber system for automotive[15].

B. Shear thickening fluids are used for the purpose of protection against sudden shock to the screens of devices, especially smart devices, and automotives (paint, and mirrors) where the surface of the screen is covered with this type of material[16].

C. Shear thickening fluid is used for the purpose of smoothing surfaces, especially complex surfaces, as it is an easy, fast and low cost method. SiC particles are characterized by high hardness and strength, which are used for the cleaning and smoothing of rust and oxidized objects, as in figure 10 [17].

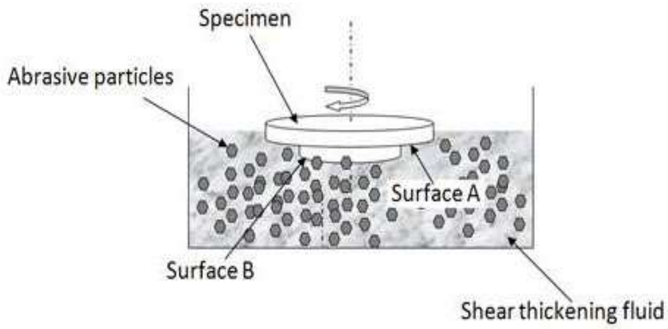

Figure 10: Shear thickening fluid and SiC particles for polishing and cleaning[17].

D. Shear thickening fluids are used in oil extraction operations during drilling to prevent an explosion in the well when the drill reaches a gap containing gases at high pressure[18].

E. The most common and widely used application is in the field of armor industry to protect people from stabbing and bullets, where layers of Kevlar or aramid fibers are used and covered with Shear thickening fluid, thus providing protection, ease of movement and low cost. As the number of layers used is less in the case of Shear thickening fluid as in figure 11[19].
Personal protection of the body from dangers and injuries is an important need for people, especially soldiers and policemen, to protect them from attacks and attacks that they may encounter in their daily work [14].

This led to the manufacture of clothing or covers that are resistant to these conditions to protect them from any attacks and attacks that may lead to their death. These protective clothing are called shields and are defined as any cover used to protect the body from any danger, external influence or violent strike. Animal skins, natural fibres, cotton, silk and iron have been used as shields throughout history[20], [21].

The shields used today should not only be stabbing resistant, but rather bulletproof. It is made of metal, ceramic and solid polymeric panels with several layers to provide adequate protection. The problem with these armors is the weight as well as the restriction of movement, so the use of nano-liquids known as liquid armor that adopts the shear thickening behavior has been resorted to[22], [23].

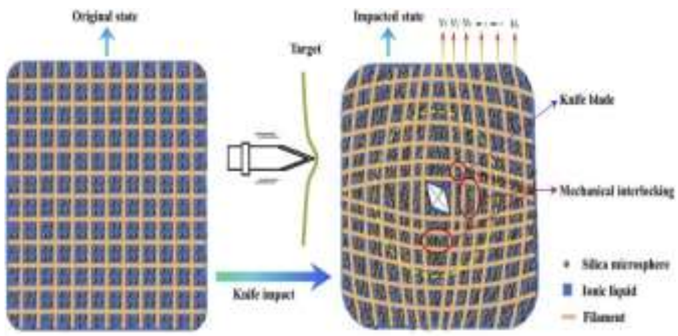

Figure 11: Kevlar woven fibers and shear thickening fluid for body armor[24].

IV. CONCLUSION;

This review paper discussed the shear thickening fluids because it’s a new type of materials that have properties of different materials. Its shown that under specific shear rate the material will behave like shear thinning and after the shear rate increase and exceeds critical shear rate the material will show the solid like behavior shear thickening behavior. In addition, its shown that there are several factors effect on the behavior of this material such as volume fraction, particle size and its distribution, particle shape, and attraction forces, some factors make this behavior appear at low shear rates while other factors make it appear at high shear rates. In addition, it's found that there are several applications of these material, the kind of application depends on the dispersed particle type.

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