Shear Thickening Mechanism

Subjects: Mechanics

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Shear thickening fluid (STF) is a dense colloidal suspension of nanoparticles in a carrier fluid in which the viscosity increases dramatically with a rise in shear rate. Due to the excellent energy absorption and energy dissipation of STF, there is a desire to employ STFs in a variety of impact applications.

shear thickening fluids viscosity particles

1. Introduction

Shear thickening fluid (STF) is a non-Newtonian fluid that exhibits an abrupt increase in viscosity by a few orders of magnitude with increasing shear rate ^{[1][2][3]}. STF behaves as a solid-like material under applied stress due to increasing viscosity, and when the loading is removed from the medium, the STF turns to the initial liquid state. Due to the excellent energy absorption and energy dissipation characteristics of STF, it has been widely used in the Li-ion batteries ^[4], wearable devices ^[5], triboelectric nanogenerator (TENG) ^[6], protective structures ^{[7][8]} and some novel applications ^{[9][10][11]}.

STF consists of a carrier liquid and colloidal particles ^{[12][13]}. The particles are generally selected from a number of groups of particles which include silica, polymethyl methacrylate, calcium carbonate, cornstarch, synthetically and naturally occurring minerals, polymers or a mixture of them. Many carrier fluids such as water, ethylene glycol (EG) and poly ethylene glycol (PEG) have been investigated ^[14]. The common particles and carrier fluids of STFs are summarized in **Table 1**.

Carrier Fluids	Additives	Reference
EG	_	[2]
Glycerine-water		[<u>15]</u>
PEG	_	[<u>16]</u>
PEG		[<u>17</u>]
Ethyl alcohol and PPG		[<u>18]</u>
PEG	Polyvinyl alcohol	[<u>19</u>]
	Carrier Fluids EG Glycerine–water PEG Ethyl alcohol and PPG PEG	Carrier FluidsAdditivesEG—Glycerine-water—PEG—PEG—Ethyl alcohol and PPG—PEGPelyvinyl alcohol

Table 1. The compositions of STFs.

Particles	Carrier Fluids	Additives	Reference
	Water	_	[20]
	Ionic liquids	_	[21]
	EG	PEG	[22]
	PEG	Graphene	[23]
	Ethanol and PEG	Silane coupling agent	[24]
Fumed silica	PEG	SiC	[25]
		SiC nanowires	[<u>26</u>]
		Carbon nanotubes	[27]
	EG	_	[28]
	PEG	Clay nanoparticles	[22]
Cornstarch	Water	_	[<u>29</u>]
	CsCl in demineralized water	_	[<u>29</u>]
Styrene/acrylate	EG	_	[<u>30</u>]
(Poly)Styrene-acrylonitrile (PSAN)	EG	_	[<u>31</u>]
Polyvinyl chloride (PVC)	Dioctyl phthalate	_	[<u>31</u>]
Precipitated calcium carbonate	PEG	_	[<u>32]</u>
ZrO ₂	Mineral oil	_	[<u>33</u>]
Soda-lime glass spheres	Water	_	[<u>33</u>]
Glass spheres	Mineral oil	_	[<u>33</u>]
Polystyrene (PS)	PEG	_	[<u>34</u>]
Nano-silica and calcium	PEG and ethanol	_	[35]
Kaolin clay particles	Glycerol	_	[36]

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(passively viscosity switching fluids). J. Rheol. 1991, 35, 999–1034. According to the rheological properties of STF, they can be divided into two categories: continuous shear thicken fluid (csZ) un Wois Continuous shear; the Roming: (DSP), STPH offsetsen below in his koning use, be with the shear in the shear is the shear in the shear is th the Notalitian, thickening-the writtomian hids coast yoon stelled yest alle slotten flowestich blood - Dewidery. Filmidat her chiriction

coelling tige and experiments. Brown et al. [39] gave a good overview on phenomenology and

mechanisms of shear thickening and discussed the relations to jamming systems. They proposed different 4. Liu, K.; Cheng, C.-F.; Zhou, L.; Zou, F.; Liang, W.; Wang, M.; Zhu, Y. A Shear thickening fluid mechanisms and models to explain the common physical properties and a phase diagram for shear thickening based impact resistant electrolyte for safe Li-ion batteries. J. Power Sources 2019, 423, 297–304. behavior. The rheological properties of STF are affected by many factors, including particle volume fraction, particle spleid, Mitio, hardels particles interactions, Whangness, Balughiness, 9paticle use, Ssizliangetrivities of particle, modification of Karlae, hastering, provide the state of the state of the state of the state and subaffalting new. More Recently of the state of the state and subaffalting new.

Beike resistance performance of STF. impregnated to improve the impact resistance of textile, different STFs were prepared for the high operformance with in GRM posites in States of the high operformance with in GRM posites in States of the high operformance with in GRM posites in States of the high operformance with in GRM posites in States of the high operformance with in GRM posites in States of the high operformance with in GRM posites in States of the high operformance with the high operformance with the field of the high operformance with the GRM provides and the STFs' contribution on improving the impact, 7 Liu, H. Fu, K. Zhu, H. Yang, B. The acoustic property and impact behaviour of 3D printed builds and stab resistance performance were investigated by many researchers in Mechanistic problems due structures filled with shear thickening fluids. Smart Mater. Struct. 2021, 31, 015026.

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Hoffman ^[31] first proposed the order-disorder transition theory that the shear thickening phenomenon was 11. Fehrenbach, J.; Hall, E.; Gibbon, L.; Smith, T.; Amiri, A., Ulven, C. Impact Resistant Flax Fiber concurrent with the transition from order to less ordered flow of particles. Different diffraction patterns were found Fabrics Using Shear Thickening Fluid. J. Compos. Sci. 2023, 7, 31. before and after shear thickening, as shown in **Figure 1**a. Subsequently, he found that the nanoparticles in the STF 12re Glyereb Arde Mound the Artice Pare and the transition for the first state of the bister to bistore additives and the state of the bistore additives additives and the state of the bistore additives add

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3. Hydro-Clustering Theory

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