Influence of Processing and Storage on the Shear Thickening Properties of Highly Concentrated Monodisperse Silica Particles in Polyethylene Glycol

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Abstract:
The shear thickening behavior of concentrated suspensions can be exploited to dissipate energy during impact or shear loading. To preserve the consistency of the thickening behavior in practical applications, particle concentration, and dispersion should be kept within very close bounds over time. In this article, we analyze the influence of the processing methods and storage conditions on the rheological properties of shear thickening fluids (STF) based on monodisperse suspensions of silica particles in polyethylene glycol. Particle dispersion linked to processing method and time strongly influences the value of the critical shear rate and storage in contact with air and humidity is responsible for a change in particle concentration. Encapsulating the suspensions in silicone is proposed as a solution to preserve their rheological properties over time.

Zusammenfassung:
Das dilatante Verhalten konzentrierter Suspensionen kann ausgenutzt werden, um die beim Aufprall oder bei Scherbelastung auftretenden Energien abzubauen. Für praktische Anwendungen ist ein zuverlässiges dilatantes Verhalten nötig. Dies erfordert eine über die Zeit nahezu konstante Partikelkonzentration und Partikeldispersion. In diesem Artikel untersuchen wir den Einfluss der Herstellungsmethode und Lagerungsbedingungen auf die rheologischen Eigenschaften von dilatanten Fluiden, basierend auf monodispersen Suspensionen von Siliciumdioxid-Teilchen in Polyethylenglykol. Die Dispersion der Partikel, abhängig von der Herstellungsmethode, als auch die Zeit beeinflussen den Wert der kritischen Scherrate. Die Lagerung in Kontakt mit Luft und Feuchtigkeit ist verantwortlich für eine Änderung der Partikelkonzentration. Als eine Lösung für die Bewahrung der rheologischen Eigenschaften über einen längeren Zeitraum wird die Einkapselung der Suspensionen in Silikon vorgeschlagen.

Résumé:
Les propriétés rhéoépaississantes des suspensions concentrées peuvent être exploitées pour dissiper de l'énergie lors d'un impact ou d'un chargement en cisaillement. Pour préserver la reproductibilité du rhéoépaississement dans des applications pratiques, la concentration en particules et la dispersion doivent être maintenues dans une gamme très étroite au cours du temps. Dans cet article, nous analysons l'influence des méthodes de mise en oeuvre et de conditionnement des suspensions rhéoépaississantes (SRE) monodisperses de silice dans du polyéthylène glycol sur leur propriétés rhéologiques. La dispersion des particules est fortement liée à la méthode et au temps de mélange et influence fortement la valeur du seuil critique de taux de cisaillement; de plus, le conditionnement en contact avec l'air et l'humidité entraîne une variation de concentration. Encapsuler les suspensions dans une silicone est proposé comme solution pour préserver les propriétés rhéologiques de ces suspensions au cours du temps.

Key words: shear thickening fluids, STF, concentrated colloidal suspensions, processing, storage, encapsulation

1 INTRODUCTION

Silica particles dispersed in polar solvents of low molecular weight form non-flocculated suspensions [1, 2]. When highly concentrated, these suspensions present discontinuous shear thickening properties and dilate during the viscosity increase [3–5]. At a given level of stress and above a critical shear rate, the viscosity of these fluids increases by several orders of magnitude. This shear thickening phenomenon is instantaneous and reversible. It has been widely investigated in terms of rheological properties [6–10] and many promising applications have been proposed. They all rely on the large energy absorp-

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size. It is thus necessary to introduce a strict protocol for STF manufacturing and conservation. Sonication is the fastest way to disperse the particles inside the STF for rheological tests. Furthermore, unlike with mechanical mixing, there is no risk to induce shear thickening during processing using sonication. The dispersion of the particles inside the fluid is then maintained by the presence of the electrostatic and Brownian forces. In contact with air and humidity the shear thickening properties deteriorate over time. Two different solutions to preserve the rheological properties are thus proposed storage at temperature under -24° C and encapsulation inside a material with good barrier properties to water and air. The encapsulation of the STF inside a containing material seems the most efficient way to preserve its rheological properties, because it also provides a "solid framework" to the STF that facilitates its integration for a damping application.

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