Mechanisms of Magneto- and Electro-Rheology: Recent Progress and Unresolved Issues

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Abstract:
An electrorheological fluid (ERF) (magnetorheological fluid - MRF) is a particulate suspension which shows a dramatic increase in flow resistance upon application of an external electric (magnetic) field. In both systems, the fundamental physical process is believed to be that the field induces polarization of each particle with respect to the carrier material, and the resulting interparticle forces cause elongated aggregates of particles to form in the field direction. While recent years have witnessed the appearance of several applications using these tunable flow properties, optimal use of this technology is still hindered by our incomplete understanding of the underlying mechanisms. This paper surveys our current understanding of several of the key issues governing the rheological behavior of MRF and ERF, with particular focus on recent progress made in important areas such as the behavior under high fields, sedimentation, temperature dependence, effect of wall surface conditions, and advances made in developing practical modelling strategies.

Zusammenfassung:
Eine elektrorheologische Flüssigkeit (ERF) (magnetorheologische Flüssigkeit - MRF) ist eine Teilchensuspension, welche ein dramatisches Ansteigen des Fliesswiderstandes bei Einschalten eines externen elektrischen (magnetischen) Feldes zeigt. Man geht davon aus, dass für beide Systeme die durch das Feld induzierte Polarisation der Partikel gegenüber der Matrixflüssigkeit zur Partikelausrichtung und dass die Kräfte zwischen den Partikeln zur Bildung von Aggregaten in Feldrichtung führen. Während in den vergangenen Jahren verschiedene Anwendungen der so einstellbaren Fliesseigenschaften entstanden sind, ist der technische Einsatz immer noch durch ein unvollständiges Verständnis der grundelegenden Mechanismen behindert. Diese Publikation gibt einen Überblick über unser momentanes Verständnis verschiedener Schlüsselfragen in der Beschreibung von MRF und ERF. Im Speziellen werden jüngste Fortschritte auf den Gebieten der Sedimentation, des Verhaltens unter starken Feldern, der Temperaturabhängigkeit, des Einfluss der Oberflächeneingenschaften der Wand und der Modellierung vorgestellt.

Résumé:
Un fluide électro-rhéologique (ERF) (magnéto-rhéologique – MRF) est une suspension de particules qui présente une augmentation dramatique de sa résistance à l'écoulement lorsque un champ externe électrique (magnétique) est appliqué. Dans les deux systèmes, le phénomène physique fondamental semble être que le champ induit une polarisation de chaque particule respectivement au materiau transporteur, et les forces inter particules résultantes induisent la formation d'aggrégats de particules dans la direction du champ. Tandis que ces dernières années ont vu l'apparition de plusieurs applications utilisant ces propriétés d'écoulement contrôlable, l'usage optimisé de cette technologie est encore retardé par notre compréhension incomplète des mécanismes qui en sont à la base. Ce papier rend compte de notre compréhension actuelle de plusieurs des questions essentielles qui gouvernent le comportement rhéologique des MRF et ERF, et met en particulier l'accent sur les récents progrès accomplis dans des domaines importants tels que le comportement sous champ intense, la sédimentation, la dépendance thermique, l'effet des conditions de surfaces, et les dernières avancées dans le développement des stratégies de modélisations pratiques.

Key words: Electrorheological fluid, magnetorheological fluid, yield stress, polarization

1 INTRODUCTION

Recently, there has much interest in electrorheological fluids (ERFs) and magnetorheological fluids (MRFs) which are "smart materials" with rheological properties that can be dramatically but reversibly altered by externally applied electric or magnetic fields respectively. The tunable flow properties of these particulate suspensions offer many potential applications, such as adjustable vibration damping devices, clutches and control valves. This field-induced increase in flow resistance is often referred to as the "electrorheological effect" or "ER effect" ("magnetorheological effect" or "MR effect" for the magnetic systems). There has been considerable activity worldwide in both industry and academe towards gaining an understanding of the fundamental mechanisms behind the ER or MR effects, in order to facilitate the development of optimal

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