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The influence of solid-phase concentration on the performance of electrorheological fluids in dynamic squeeze flow

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ABSTRACT

The yield stress of electrorheological (ER) fluids increases by orders of magnitude when electric field is applied across them. In the absence of the field, ER fluids behave as Newtonian fluids. This paper is concerned with an experimental investigation to determine the rheological performance of ER fluids, consisting of a dielectric liquid carrier with a range of solid-phase concentration. The ER fluid was contained in a squeeze cell, which during motion subjects the fluid to both compressive and tensile loading. The results were analysed in terms of the capacity for the transmission of imposed forces across the fluid and showed a great dependence on the applied D.C voltage and the weight fraction of the dispersed solid-phase. In addition, the implications of the results to vibration control, where the ER fluid is employed in an engine mount, are discussed.

1. Introduction

Winslow [1] was credited with the first observation of the ER effect after his investigations into the application of electrical fields across oil dispersions of certain powders such as silica, and he was also the first to suggest industrial applications based on this phenomena. Since these early days and in particular during the last two decades, there has been much activity directed towards the design and development of ER devices. One such promising application is the variable damper for use in vibration control [2]. The first practical application of ER fluids in vibration control was reported in 1978 [3] in which a valve-operated vibration damper was described. Recently, the area of vibration control has seen a surge in the number of reported investigations involving ER fluids particularly in engine mounts [4,5], primary shock absorbers [6,7] and rotor support systems [8,9] in addition to adaptive structures [10,11].

The majority of ER fluid damping devices have employed the fluid in either flow or shear mode of operation in which the fluid is deformed in a direction orthogonal to the chains, and where the gap between the electrodes remains constant. An alternative arrangement, called squeeze mode, in which the fluid is subjected to oscillatory compression and subsequent tensile stresses (resulting in a variable fluid layer thickness) has been identified and investigated [12]. It was quoted that tensile/compressive forces are greater than those available in shear typically by a factor of ten [13]. This increased fluid strength prompted systematic studies by the author and others to exploit the mechanical and electrical properties of ER fluids in squeeze [14–16]. However, a survey paper [17] provides a more substantial overview of the classification of the modes of operation of ER fluids and their potential applications in vibration control.

In parallel with device investigation, during the last two decades, numerous studies have been carried out aimed at improving the mechanical and electrical characteristics of ER fluids. For example, the influence of the shape and configuration of the particulates [18,19] and their electrical properties [20,21] in addition to the solid-phase size [22,23] on the magnitude of the ER effect were assessed. Also, the effect of the dielectric properties of the base oil [24] on the performance of ER fluids was investigated.

In order to obtain a clearer understanding of the mechanisms, which control ER fluid strength, it is necessary to understand the role of solid-phase concentration. This paper is concerned with the assessment of ER fluids in dynamic squeeze flow and the influence of the solid-phase weight fraction on their rheological performance. The relevance of this work in the application to vibration control in a short-stroke damper is discussed.

2. Experimental arrangement

2.1. Experimental facility

The experimental rig (Fig. 1) consists of a Ling Dynamic Systems electromagnetic shaker (Model No. V450), which is capable of

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