Design of a 1 DOF MEMS motion stage for a parallel plane geometry rheometer

Yong-Sik Kim, Nicholas G. Dagalakis, Chiara Ferraris, and Svetlana Avramov-Zamurovic

Abstract— **Rotational rheometers are used to measure paste properties, but the test would take too long to be useful for quality control (QC) on the job site. In this paper, a new type of rheometer is proposed based on a one degree of freedom (DOF) micro-electro-mechanical systems (MEMS)-based motion stage. Preliminary data will be presented to show the capability of the system to measure the viscoelastic properties of a paste. The parallel plate geometry rheometer consists of two plates, which move relative to each other to apply a strain to the material to be tested. From the stress measured and the strain applied, the rheological characteristics of the material can be calculated. The new device consists of an electrothermal actuator and a motion plate. For the rheological measurements, the device is designed to generate the shear stress up to 60 Pa and maintain its stiffness to less than 44 N/m. With these features, the device uses a square plate of 1.5 mm x 1.5 mm to provide enough area for a few micro-liter level volumes. The motion of the square plate is monitored by a capacitive sensor at the end of the oscillating plate which has a resolution of 1.06 μm. When a reference cementitious paste, Standard Reference Material (SRM)-2492, is placed between the oscillating plate of the presented motion stage and a fixed plate, the reduction in the displacement of the oscillating plate is monitored showing that the presented motion stage is reasonably designed to detect the response of the reference cementitious paste.**

Index Terms— **MEMS, motion stage, electrothermal actuator, rheology, cement paste.**

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I. Introduction

RHEOLOGICAL measurements of viscoelastic materials, especially cement pastes, are critical to obtain desirable material properties in civil engineering and related applications [1]. Concrete is the main material used in infrastructure construction (bridges, buildings...) and is composed of cement, water, sand, aggregate, and chemical additives. The rheological properties of concrete are related to the relative amounts of the components used especially to the rheological properties of the cement paste. The cement paste is composed of cement, water, and chemical additives. Cement could also be a blend of Portland cement and other fine powders such as fly ash and limestones. Thus a fast measurement method of the rheological properties of the cement paste would allow the engineer to optimize the concrete composition [2].

Rotational rheometer designs used to measure properties of cementitious materials from concrete [3, 4] to cement paste include parallel plates or concentric cylinders [5]. The principle of a rotational rheometer is to shear the material between two surfaces, by rotating one surface at a controlled speed and measuring the resulting torque. If the gap between the shearing surfaces is small enough, there are analytical equations to calculate the viscosity of the material. The rotation surface could rotate at a constant speed or oscillate at various frequencies [6, 7]. In this paper, the oscillatory method will be used.