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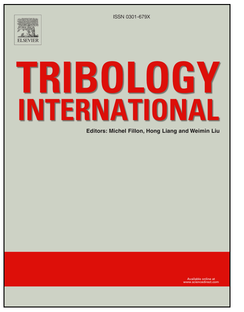

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Zhongnan Wang, Derek G. Chetwynd, Ken Mao

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Friction Characteristics of Polymers Applicable to Small-scale Devices

Zhongnan Wang*, Derek G Chetwynd, Ken Mao

School of Engineering, University of Warwick, Coventry, CV4 7AL, UK

ABSTRACT:

A review of the critical features of a published micro-tribometer design, which was intended to improve on the dynamic response of typical commercial instruments, leads to its use with a modified technique. Data post-processing is introduced to partially compensate for some potential systematic errors. This approach is demonstrated by a preliminary study of the coefficient of friction (CoF) in sub-mm length reciprocating sliding motion for samples of polytetrafluoroethylene (PTFE) and an R11 acrylic formulation made by micro-stereo-lithography, with an SiO_2-coated silicon wafer used as a control sample. Testing covered normal loads in the region of 10 mN to 60 mN, at scan frequencies up to 9 Hz, corresponding to sliding speeds in the broad region of 1 mm s^{-1}. While the control samples closely adhered to Amonton's laws over all the test parameter ranges, the CoFs of the two polymers showed contrasting patterns of dependence on sliding speed and repetition rate. Such results have implications for how polymers might be used effectively in future designs for small mechanical systems. They indicate a clear need for further development of the testing methods and large-scale studies of tribological behaviour and its underlying mechanisms under the specified micro-scale conditions.

Keywords: Polymer, Reciprocating, Micro-scale friction, Small-scale devices

1. Introduction

There are continuing drives towards greater miniaturization, covering small macroscopic devices as well as true micro-electromechanical systems (MEMS), across many engineering disciplines, ranging from aerospace to medical implants. This, in turn, increases concerns over tribological behaviour when the contact area and normal load (or applied force) become very small in production devices that involve sliding motion[1,2,3]; it is, for example, widely reported that Amonton's laws tend to describe observed behaviour less well in the sub-N load regime[4,5]. Designers presumably wish to exploit new 3D microfabrication techniques (to meet increasing requirements to create high-aspect-ratio microstructures) and high-precision types of additive manufacture (AM, also called direct digital manufacturing, DDM), most notably micro-stereolithography (MSL). These techniques bring the prospects, or even consequent necessity, of using new materials, but a lack of good data on properties known to be representative in the intended operational regime has caused wide concerns and inhibited progress.

MSL almost always uses the additive layer-by-layer method, which shares the same principles with earlier conventional stereolithography techniques to build complex high-resolution MEMS devices with the engineering materials such as silicon substrates, ceramics, metals, and especially polymers and composites for applications within various industrial fields[6]. The basic material for these process routes is a polymer resin. There is great scope for adding micro-or nano-powders to produce composites with specifically customized functions, e.g.: to give electrical or magnetic properties; to add, e.g., alumina for strength and stiffness; to add carbon for mechanical and sensor properties; *etc*. Currently, little is known about the surface and tribological properties of the

*corresponding author.

E-mail address: zhongnan.wang@warwick.ac.uk