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Reduction of friction using electrospun polymer composite microbeads emulsified in mineral oil

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Abstract

Tribological properties of electrospun polymer-based microbeads dispersed in mineral oil were investigated. Microbeads composed of polyvinypyrrolidone, zinc oxide and multi-walled carbon nanotubes (MWCNTs) were generated using an electrospinning apparatus. The influence of various electrospinning parameters such as voltage, injection rate and concentration were investigated. The friction reducing ability of microbeads enhanced lubricants were evaluated using a reciprocating tribometer system. In the tribometer, a hemispherical ruby counter surface was slid against an aluminum 6061 workpiece in the presence of a mineral oil-based lubricant. Friction was reduced by 13% to 27% when the composite microbeads were emulsified in the base mineral oil.

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1. Introduction

The reduction of friction and wear on functional surfaces is important for many engineering, and technological applications [1, 2]. Reducing friction through fluid lubrication in mechanical systems, such as automotive, turbines, compressors and engines, can reduce energy losses, improve durability and increase efficiency by minimizing the effects of friction and wear [3,4]. A further reduction in friction can often be achieved by adding micro and nano particles to the base lubricant [4,5,6,7,8]. Studies typically show an optimal size, composition, and concentration of the additive particle when they are used to reduce friction. However, these parameters are highly variant and depend

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on the mechanical system examined, and therefore that the influence of particle additives on lubrication is poorly understood.

Sources have found that an addition of as little as 0.1 % volume of nanoparticles can improve tribological properties [9]. Due to agglomeration and precipitation concerns, the concentration of any additives must be optimized and controlled [10]. Rolling effects, mending effects, protective films, increased load-carrying capacity, reduced real contact area and third-body effects are some of the mechanisms that have been proposed to explain the friction reduction witnessed while using nano and micro particles as additives [5,10]. The lubrication technique of those particles is to create a tribofilm to prevent the direct contact between the reciprocating surfaces [11,12,13]. Another interesting technique is the use of carbon spheres [5], in this case the carbon spheres show a rolling motion effect acting as a nanoscale ball bearing.

There are various ways of synthesizing particles, including electrodeposition [14] and freeze-thawing cycles [15]. However, many of the current synthesis techniques may have highly negative environmental impacts [16], and thus are not desirable pathways for nanoparticle synthesis. Alternatively, electrospinning has recently emerged as a simple fabrication method, primarily, for polymer-based nanofibers [17]. Electrospinning is a process for preparing nano- to micro-scale materials by accelerating a jet of charged solution into an electric field. The electric field is generated by a high voltage power supply that is attached to a syringe needle tip and a grounded collector. Electrostatic charges generated at the needle tip result in the formation of a Taylor cone, and the ejection of a single fluid jet from the apex [18]. The single jet is then solidified within the electric field, and thinned into nanofibers if the ejection rate and electric field are balanced. The generated materials are then randomly deposited on the collector. Understanding different applications and optimizing the processing parameters accordingly is vital in electrospinning processes. Microbeads can also be generated from electrospinning [19]. The microbeads are typically generated with lower polymer concentrations and lower applied voltages. The method is economical and can be scaled up for industrial purposes. The resulting compound can be manipulated in a variety of ways to attain the desired structural composition and morphology [20].

It has been reported that the addition of fillers, such as multi-wall carbon nanotubes (MWCNTs) and metallic oxides in polymer microbeads, increases load-carrying capacity in oils [21] and therefore reduces real contact area [5,22]. In this study, electrospun polymer microbeads are added to a fluid lubricant (mineral oil) to reduce friction. The various parameters influencing the size and shape of the microbeads are analyzed. Mineral oil lubricated sliding friction experiments, where a ruby hemisphere sliding against a flat surface in a custom designed reciprocating tribometer system, are analyzed. The reduction of friction with the microbead enhanced lubricant is evaluated against base mineral oil. The effects are dependent on the concentration and type of microbead introduced into the base mineral oil.

Nomenclature

wt%	mass percentage of
DI	deionized
ZnO	zinc oxide
DMF	dimethylformamide
PVP	polyvinylpyrrolidone
MWCNTs	multi-wall carbon nanotubes

2. Experiments

The following section describes the synthesis procedure of PVP and PVP-based composite microbeads. The optimization of various parameters influencing the size and shape of the microbeads are explored. Subsequently, the influence of these microbeads as additives in mineral oil and their ability to lubricate a sliding contact are explored. Friction tests involving these microbead enhanced oils will be evaluated using a home-built reciprocating tribometer.