Biomimetic Water Based Lubricant Development: Nanoencapsulation with Micelles and Liposomes

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This paper investigates the lubrication mechanism provided by micelles and liposomes with encapsulants within their core. Aqueous micellar and liposomal solutions including glycerol monostearate, sodium stearate and lecithin solutions were used as nanocapsules into which a range of additives were encapsulated. High frequency reciprocation tests on these solutions provided an understanding of their lubrication mechanisms. Nanocapsules enter the contact and are ruptured by high shear stresses allowing for the encapsulants within to be released. These encapsulants lubricate the contact and are cyclically replenished as more nanocapsules are entrained into the contact. This cyclical process provides a mechanism that minimises friction and wear within the contact.

Keywords: water based lubrication, biomimetic, nanoencapsulation, nanocapsules, sustainable

1. Introduction

The replacement of oil-based lubricants with sustainable water-based lubricants has been a long-standing unfulfilled ambition. The physical instabilities and poor wear performance associated with water-based lubricants has led to minimal adoption within mechanical systems [1]. This need for stability has led to the exploration of nanoencapsulation as a means to provide longevity and improved lubrication performance for water-based lubricants. Through encapsulating biodegradable, polymeric/biological additives within micelles a local lubrication system can be implemented to improve and sustain long-term lubrication. As additives adhered to the contacting surfaces gradually breakdown and wear away by shear, the release of further additives from sheared nanocapsules at the contact provide a replenishing source to continue lubrication. Such a novel mechanism would allow for the creation of a stable, effective and sustainable biolubricant for application in a variety of systems.

2. Methods

Experiments were performed to assess the benefits of nano-encapsulation for lubrication performance by comparing the friction and wear results obtained on solely micellar and liposomal solutions with solutions in which additives were encapsulated within the liposomes and micelles.
This lubrication performance was investigated using a high frequency reciprocating rig (HFRR, PCS Instruments, London, UK). Tests were performed on a stainless steel sliding pair at 25 ºC, at a load of 0.5N, a frequency of 10Hz and a stroke length of 1mm. Some results are shown in Figure 1, showing the evolution in time of the coefficient of friction for micelle solutions and distilled water.

The adsorption of the encapsulated additives was assessed by Fourier Transform Infrared Spectroscopy of the resulting wear marks.

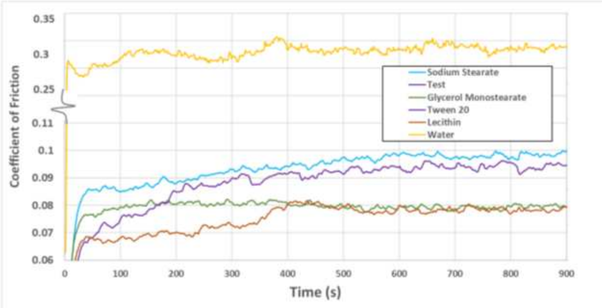

Figure 1: Coefficient of friction against time for HFRR test of micelle solutions compared to distilled water

3. Discussion

A strong reduction in both wear and coefficient of friction was seen with micellar and liposomal solutions compared to distilled water. This has, for example, led to a reduction in friction coefficient from 0.3 in distilled water to 0.08 in a glycerol monostearate micellar solution (Figure 1). This is reflective of many of the nanocapsule solutions. Solution age, synthesis temperature and solution concentration modifications lead to further effects that change lubrication behavior and alter lubricant performance within the contact region. The mechanisms behind the performance differences are explained through observational studies and FTIR in which an adsorption of additives is seen due to the replenishment mechanism.

This research demonstrates that the primary failings of past water-based lubricants have the potential to be overcome through the application of encapsulated micelles and liposomes. The lubrication mechanism achievable through this approach is both active and novel in its workings, and presents the viability of sustainable lubricants for industrial applications.

4. References

[1] Ahlroos T. et al. Biomimetic approach to water lubrication with biomolecular additives. Proc Inst Mech Eng Part J J Eng Tribol. 2011;225(10):1013–22.