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Interfacial properties of oil-in-water emulsions designed to be used as metalworking fluids

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Abstract

The creaming stability and wetting behaviour of oil-in-water (O/W) emulsions, designed to be used as metalworking fluids, were evaluated. The influence of the emulsifier type and its concentration on emulsion properties (droplet size distribution, zeta potential, creaming stability, and contact angle or work of adhesion) was studied. O/W emulsions were prepared with 3% (w/w) base oil content and three different emulsifiers (anionic, non-ionic and cationic surfactants). The base oil was a mixture of a synthetic poly-α-olefin and a trimethylol propane trioleate ester, and emulsifier concentrations were close to and above their critical micelle concentrations (CMC). Experimental results show that emulsifier concentration plays a key role on the properties studied. The O/W emulsion characterisation leads to relationships between interfacial properties and lubricating behaviour, which seems to be controlled by the interactions between the oil droplets and metal surfaces.

Keywords: Oil-in-water emulsions; Creaming stability; Contact angle; Work of adhesion; Metalworking fluids

1. Introduction

One important industrial application of oil-in-water (O/W) emulsions is as metalworking fluids (MWFs) in metal processing operations such as rolling, cutting or drilling. MWF emulsions work as lubricants and coolants, i.e. the oil reduces the friction between the rubbing surfaces whereas the aqueous phase dissipates the heat generated in the contact. Furthermore, MWFs provide chip removal, inhibit corrosion and increase fire resistance. They also improve performance of machining operations, increasing tool life and yielding better surface finishing.

The major limitation of MWFs is that they lose their lubricating properties with time because of their exposure to high temperatures and stresses in mechanical operations and ultimately need to be replaced. As a result, large volumes of oily wastewater are periodically generated which have to be treated before discharge. Currently the trend is to optimise the MWF formulation so that the emulsion will fulfil the lubrication and cooling requirements, while allowing environmental friendly treatment to be used. The formulation should take into account the regeneration of the emulsion, to extend its operating life, and the reuse or recycle of its components. In previous works, the formulated emulsions used in this study were tested to evaluate their film-forming ability in elastohydrodynamic contacts and their lubricating performance under extreme pressure conditions [1,2]. Lubricating ability of O/W emulsions has been traditionally linked to their interfacial properties, particularly to their creaming stability. Furthermore, in the treatment of O/W emulsions by ultrafiltration and vacuum evaporation [3,4] parameters such as droplet size or zeta potential have a significant influence on the operation performance.

Information on the interfacial properties of MWFs from their formulation to their disposal is required, in order to interpret their behaviour. Among the most relevant are creaming stability and wetting behaviour, both closely related to MWF's tribological performance [1,2]: an efficient MWF must show homogeneity of its physico-chemical properties, i.e., must be stable, and it must also wet tool and piece surfaces. However, the effect of physico-chemical properties on the emulsion lubricating performance is not apparent and it is desirable to establish a relationship between interfacial characteristics and tribological properties.

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