Frictional Performance of Wire-Die Interface in Wire Drawing Process

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In wire drawing, lubrication conditions and frictional forces at the wire-die interface affect the quality of the produced wire as well as the total energy consumed in the drawing process. High pressures, high sliding speeds and the use of rather unconventional lubricants and material pairs lead to complex and poorly understood tribological interactions in the wire-die contact. This work aims to provide new insights into the tribology and frictional behaviour of the wire-die interface.

Keywords: Wire Drawing, Friction, Emulsion, Soap, Film thickness

1. Introduction

Steel wire is a crucial part in surprisingly many engineering products, from car tyres, oil platform anchorage ropes, concrete reinforcement, bicycle wheel spokes, to champagne corks. Given the quantities of wire produced, optimising the wire production process has a potential to offer huge economic and environmental benefits. Wire drawing is the most widely used process in steel wire production. This is the process of reducing the cross-sectional area of a wire by pulling it through a series of conical dies. At the wire-die interface the wire is subjected to significant frictional forces which directly affect the wire quality and die life and lead to high energy consumption.

Despite its obvious significance to potential energy savings and product improvements, the tribology of the wire-die contact is seldom studied and surprisingly poorly understood. One reason for this is that the tribological conditions in the wire-die interface are complex: high sliding speeds of up to 20 m/s, high pressures, large plastic deformation, uncommon material pairs and the use of emulsions and soaps as lubricants. Literature on the topic is limited and mainly focuses on liquid lubricants used in wet-wire drawing, for example [1]. Dry-wire drawing which relies on solid soaps as lubricant has received even less attention, with existing literature identifying the complex rheology of wire drawing soaps, exhibiting plastic behaviour at low temperatures and viscous non-Newtonian at higher temperatures, as one of the obstacles to better understanding of tribological performance of wire-die contact [2].

This work studies the film thickness and friction between the wire and the die during the drawing process using lab tribometers and custom wire drawing set-ups.

2. Methods

A ball-on-disc tribometer (PCS ETM) capable of producing loads of 1600 N, equivalent to contact pressures of ~6 GPa in WC on steel contacts, and any slide roll ratio from pure rolling to pure sliding, is used to measure friction over a range of speeds and temperatures at pressures representative of a real wire drawing process.

Tungsten carbide ball specimens, mimicking the die material, are tested against discs made of different low carbon steels that are typically used for wires. Tests employed two dry wire drawing soap formulations, calcium and a sodium stearate, as well as wet wire drawing emulsions. The influence of soap grain size, previously suggested to be of significance [3], was also investigated through suitable sieving of soap samples prior to testing.

In order to be able to test with soaps, the ETM set-up included a 'scoop' to push the powdered soap into the ball track, similar to that used in previous grease research on the same type of tribometer [4]. The rig is illustrated in Figure 1. Ball and disc surfaces are inspected post test using various surface analysis techniques to measure wear and presence of chemical compounds in the track.

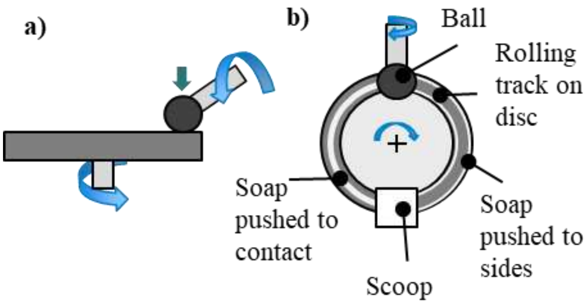

Figure 1: a) Schematic illustration of ball-on-disc tribometer and b) test set-up with a 'scoop'.

Additional tests were conducted on an actual wire drawing rig to measure process energy consumption, and hence infer wire-die friction forces, over a range of operating conditions.

3. Results and Discussion

ETM results are presented to examine the influence of contact pressure, lubricant formulation and temperature on friction in wire-die contact. These are then related to observations made on the real wire drawing rig and discussed in terms of lubricant rheology and the expected film thickness at various test conditions.

4. References

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