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THE USE OF A PILOT MILL FOR DEVELOPMENT OF LUBRICANTS FOR ALUMINUM HOT ROLLING

TRACK OR CATEGORY

6L, Non-Ferrous Metals II (Rolling)

AUTHORS AND INSTITUTIONS

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INTRODUCTION

In this presentation Quaker's new pilot mill is introduced. The mill is designed for, among others, aluminum hot and cold rolling. Trial protocols for aluminum rolling will be discussed, as well as some results. The pilot mill can be utilized to develop new lubricant concepts, study emulsion properties and investigate new raw materials. The pilot mill is also used for validation of existing laboratory (tribology) test methods.

Aluminum hot rolling pilot mill trials were carried out to investigate the effect of lubricant type and emulsion condition. Three different lubricants were trialed and roll forces compared. Trials were done with the fresh emulsion and with the emulsion after 1 week ageing. Furthermore, the effect of addition of a phosphorus-based extreme pressure additive to the (aged) emulsion was investigated. After the trials the surface texture was investigated with the electron microscope, allowing tentative conclusions on the lubrication mechanism.

MATERIALS AND METHODS

The Quaker pilot mill was commissioned in June 2016. It is a 4-high, backup roll-driven reversing pilot mill. Some specifications: main motor/tension reel power: 400/200 kW, max. roll force: 1200 kN, backup/work roll diameter: 400/165 mm, max. tension: 30 kN, max. rolling speed: 1200 m/min. Note that some of these values will be much lower for aluminum hot rolling. The strip width may vary between 100 and 200 mm. The mill is equipped with a recirculating emulsion system of 3.1 m^3.

The aluminum alloy for the trials was of type 5052 and the strip had a width of 200 mm. Prior to the hot rolling trials the coil was heated in a furnace at 480 °C (900 °F) for 4 hours. The coil was then transported to the pay-off reel and the trials commenced as soon as the coil temperature had reached a temperature of 400 °C (750 °F). The trials were conducted in a 3-pass schedule of which the details can be seen in table 1.

The emulsions were prepared one day before the trial, allowing overnight circulation at 50 °C (122 °F). The volume of emulsion was 2000 l, with an oil concentration of 4%. Prior to the trial the emulsion was used to heat up the work rolls while the mill was running idle.

	entry thickness (mm)	exit thickness (mm)	reduction (%)	back tension (MPa)	front tension (MPa)	speed (m/min)	typical entry temperature (°C / °F))
Pass 1	4.00	3.40	15.0	20	28	100	395 / 745
Pass 2	3.40	2.55	25.0	21	35	150	285 / 545
Pass 3	2.55	2.00	21.6	24	40	200	245 / 475

Table 1. Pass schedule for the trials.

RESULTS

For the current series, 15 pilot mill trials were carried out, with 3 different lubricants, fresh and aged emulsions and in some cases an extreme pressure additive was added to the aged emulsion. In figure 1 can be seen that the range of roll forces for these trials was higher than the reproducibility, which indicates that there are significant influences of lubricant and the condition of the emulsion.

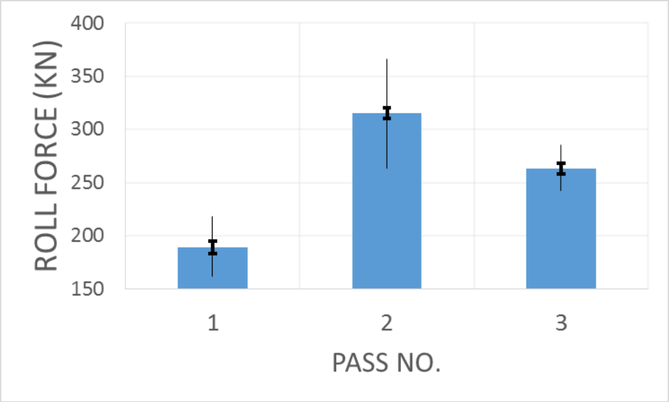

Figure 1. Average roll force of the 15 trials, with indicated the range of roll forces (non-capped bars) and the standard deviation of duplicate trials (thick capped bars).

In figure 2 can be seen there are significant differences in roll force and forward slip for the three lubricants. Emulsion 2 seems to be the better lubricant as it overall gives the lower roll forces and lower forward slip values. Emulsion properties were measured in the laboratory and it was found that the oil particle size for emulsion 2 was the highest and consequently the emulsion stability index the lowest (lower stability). This could be a reason for the higher level of lubrication for emulsion 2. Furthermore, pin on disc tribometer tests at 316 °C (710 °F) indicated a better performance of lubricant 2, i.e. a lower coefficient of friction.

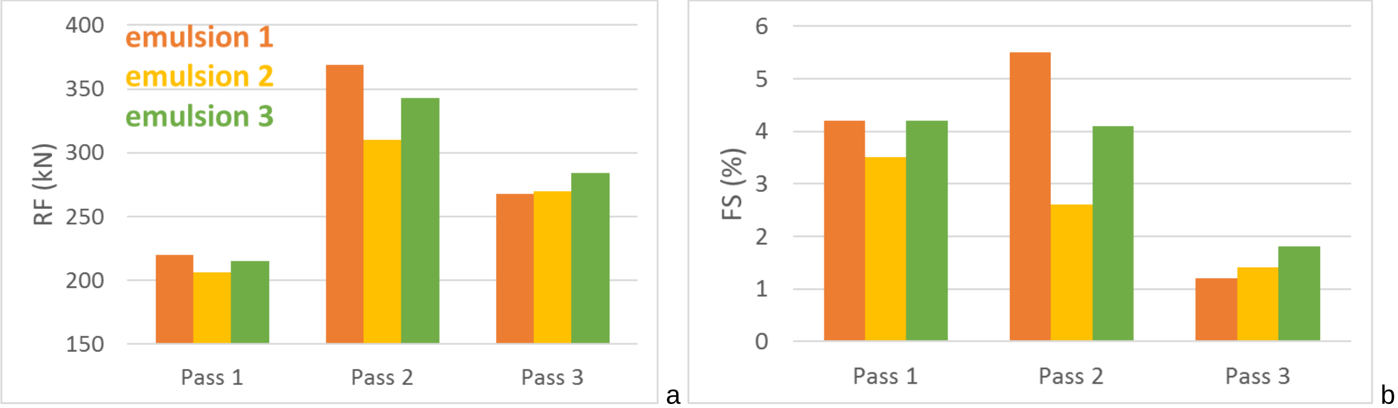

Figure 2. a) Roll force and b) forward slip for the fresh emulsions.

In figure 3 can be seen some representative graphs of the effect of 1 week's ageing (3a) and additivation of the aged emulsion with an extreme pressure additive (3b). Ageing significantly improves rolling performance. Note that an example is given for emulsion 3, but this behavior is displayed by all three emulsions. Emulsion analysis showed increased oil particle size after ageing, corroborating the improved rolling performance. Additivation of the aged emulsion 1 with an extreme pressure additive also causes an improvement in rolling performance, but this behavior is not displayed by all tested emulsions, notably when significant amounts of extreme pressure additives were already included in the product. The improvement seen in figure 3b was also seen in the pin on disc tribometer tests at 316 °C.

After the trials the rolled surface was investigated with the electron microscope (SEM). It can be seen in figure 4 that the surface, after pass 2, rolled with emulsion 1 contains significant scooping, while this feature is much weaker for the surface rolled with emulsion 2. Note that the roll force at pass 2 is significantly higher for emulsion 1. Tentatively, therefore, the scooping with emulsion 1 may be evidence for a particular type of lubrication mechanism dominating for emulsion 1. It is proposed that the lubrication mechanism in pass 2 with emulsion 1 involves a significant contribution from so-called wedging abrasive wear, while for emulsion 2 it involves more ploughing-type of abrasive wear. These mechanisms were described in reference [1]. Ploughing wear is encountered when sliding occurs mainly over interfacial layers, while wedging wear occurs when the interfacial shear stress is very high and sliding occurs within the bulk metal. The wedging and ploughing wear could thus also be described as resulting from ‘sticking friction’ and ‘sliding friction’. Whether the correlation between wedging wear and higher roll forces is also generally true needs further study.

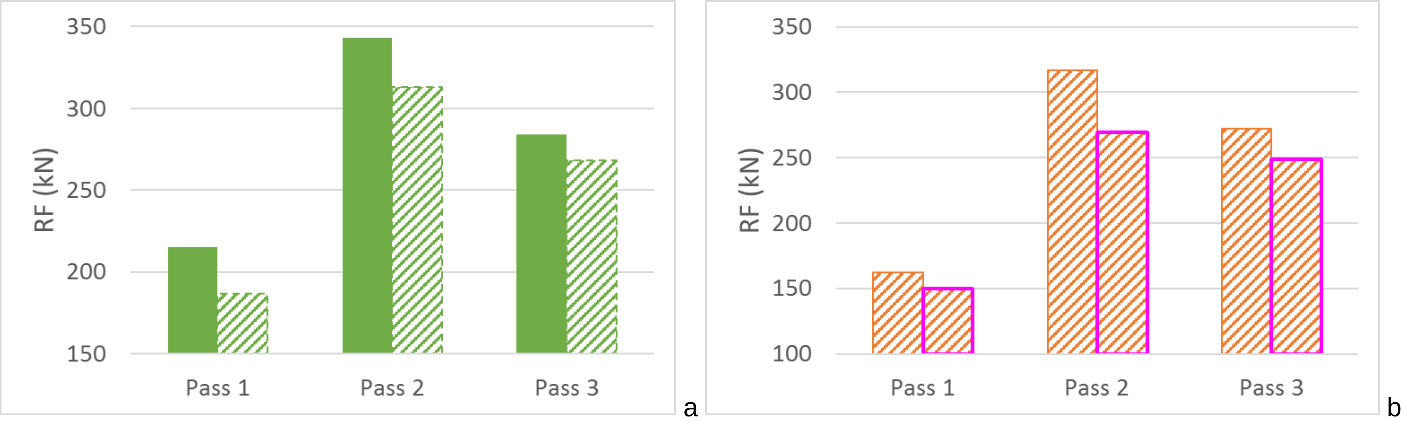

Figure 3. a) The effect of ageing of emulsion 3 (aged = hatched bar). b) The effect of additivation of the aged emulsion 1 with an extreme pressure additive (additivated = pink outline).

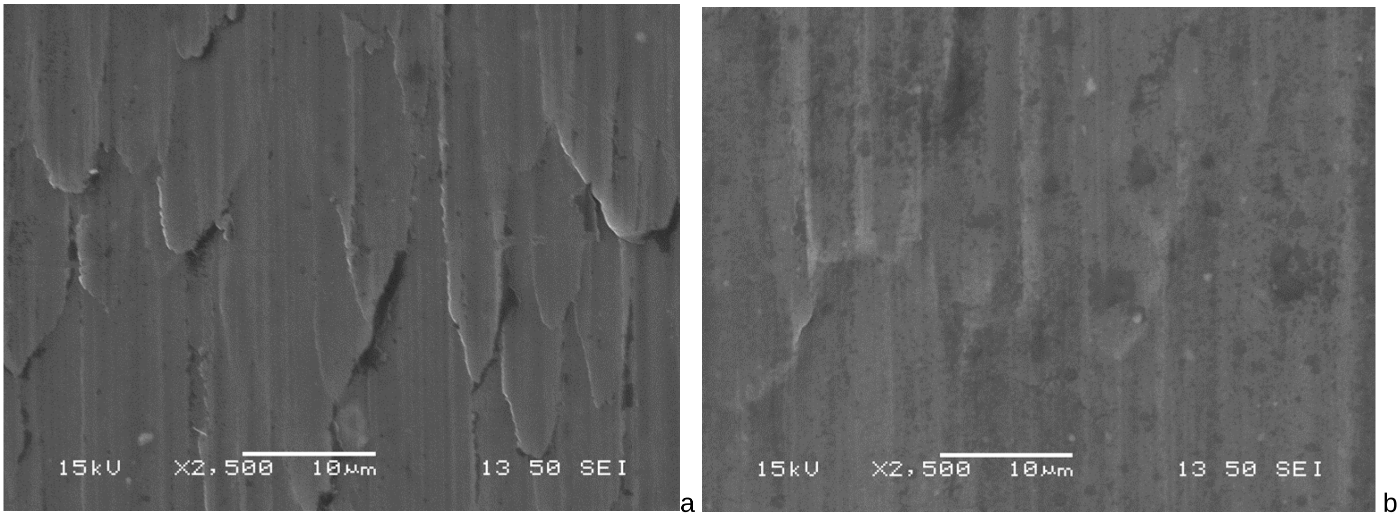

Figure 4. SEM micrographs of the surface texture after pass 2, for the fresh emulsions 1 (a) and 2 (b).

ACKNOWLEDGMENTS

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REFERENCES

[1] Hokkirigawa, K., Kato, K., 1988, “An experimental and theoretical investigation of ploughing, cutting and wedge formation during abrasive wear”, *Trib. Int.* **21**(1) pp 51-57.

KEYWORDS

Pilot mill trials, Aluminum hot rolling, Roll force, Emulsion composition and ageing, Surface texture, SEM, Ploughing and wedging abrasive wear, Sliding friction, Sticking friction.