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OPTIMIZATION OF THE CLEANING PERFORMANCE OF THE DOCTOR BLADE – ROLLER TRIBOSYSTEM DURING PAPER PRODUCTION

TRACK OR CATEGORY

Practical Lubrication Practices, ID: 1258481

AUTHORS AND INSTITUTIONS

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INTRODUCTION

In the paper production, scraping blades – referred to as *doctor* – are placed in contact with rollers during wet pressing in order to keep the roller's surface clean [1]. As a consequence of the contact between the cylindrical surface and the blade, the blade wears off and needs to be replaced periodically. The cleaning performance of the blade requires a certain contact force between the blade tip and the cylinder surface. However, a too large contact force increases energy consumption and wear, which shortens the lifetime of the blade and increases the number of stop maintenances of the machine for replacing the blade. The aim of this work is to achieve an optimum cleaning performance, while simultaneously wear of the doctor blade is minimized, thus increasing the blade lifetime and reducing energy consumption. There are different effects influencing the cleaning performance, such as design of the blade bracket, technology and choice of materials of the blade, presence of rinsing water, type of contaminations, etc. So far, the optimum process conditions have been improved on a trial-and-error basis.

Our hypothesis is that – under presence of rinsing water and for that study not considering other optimisation measures – optimum conditions occur under "weak" hydrodynamic conditions. Friction force and wear can be substantially reduced, whereas the cleaning efficiency can be maintained as long as the film thickness is kept smaller than the minimum diameter of particles to be removed.

MODELLING CONCEPT

The basic principles of the model are classical hydrodynamic lubrication [2] and elastic-beam theory of conventional Euler-Bernoulli type. This is applied by considering the doctor blade as a pad bearing sliding over the roller surface, so that the induced normal and friction force can be calculated by employing the Reynolds equation. During idealised working conditions, the blade runs with its contact length parallel to the roller surface, where through dynamic or external perturbations like slight deviations from concentricity, surface waviness, vibrations, etc. [3], a small aperture angle δ can be created (Fig. 1). In this case, the lubrication regime of the tribosystem changes from mixed to hydrodynamic lubrication.

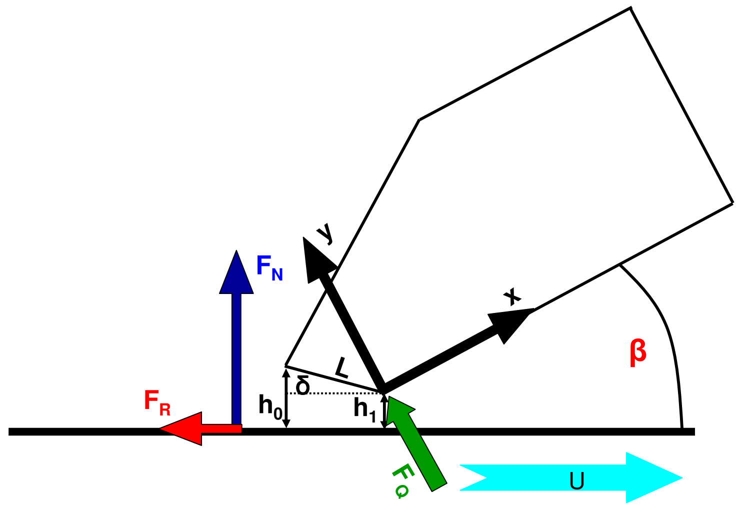

Figure 1. Schematic representation of the blade tip.

Based on the equilibrium conditions at the blade tip between hydrodynamic and contact forces, one obtains two non-dimensional groups, namely the wedge parameter *K* and the Sommerfeld number *So* as a function of *K*, that involve the physical key parameters.

$$K = \frac{h_0 - h_1}{h_1} \tag{1}$$

$$So = \frac{1}{K}\left(\ln(K+1) - \frac{2K}{K+2}\right) \tag{2}$$

The optimum condition is considered in the spirit of a minimal hydrodynamically exerted load and, therefore, calculated by imposing the onset of hydrodynamic sliding conditions:

$$\frac{So}{K} = \frac{h_1^3}{36U\eta L^3}\frac{Ed^3}{l^2\cos\beta} = \frac{1}{12} \tag{3}$$

where h_1 is the pad exit gap width between the blade and the roller and η is the fluid viscosity; U is the roller velocity; E is the Young's Modulus of the blade, L is the blade pad length, and l and d are the blade length and thickness, respectively; β denotes the positioning angle. The onset of the hydrodynamic contact regime depends on the blade pad length L. The relationship between the pad length L, the blade length l and the positioning angle β as the blade wears off is taken into account by using geometrical calculations.

RESULTS

In equation (3), the minimum pad exit gap width h_1 is selected as the diameter of the smallest particle contamination to be removed. De facto, its lowest value is limited by the sum of the average roughness of the blade and the roller, which in practice means an unavoidable leakage. The other parameters are selected according to typical realistic operating conditions. Under these conditions, an unworn blade operates in the mixed lubrication regime (Fig. 2). Due to the fact that the contact length gets longer during operation due to wear, becomes the slope So/K smaller, what causes a transition into the hydrodynamic regime. The most favourable friction conditions occur at the transition between mixed and hydrodynamic lubrication, i.e. for So/K = 1/12. In mixed lubrication, the cleaning efficiency is not impaired but higher wear and friction (i.e. energy consumption) have to be assumed. On the other hand, in the hydrodynamic regime, the cleaning performance is negatively influenced by a higher gap between blade and roller. The transition between both lubrication regimes can be modified by the selection of several geometrical, material and process parameters. For instance, a thicker, a shorter or a more rigid blade will remain longer in the mixed lubrication regime.

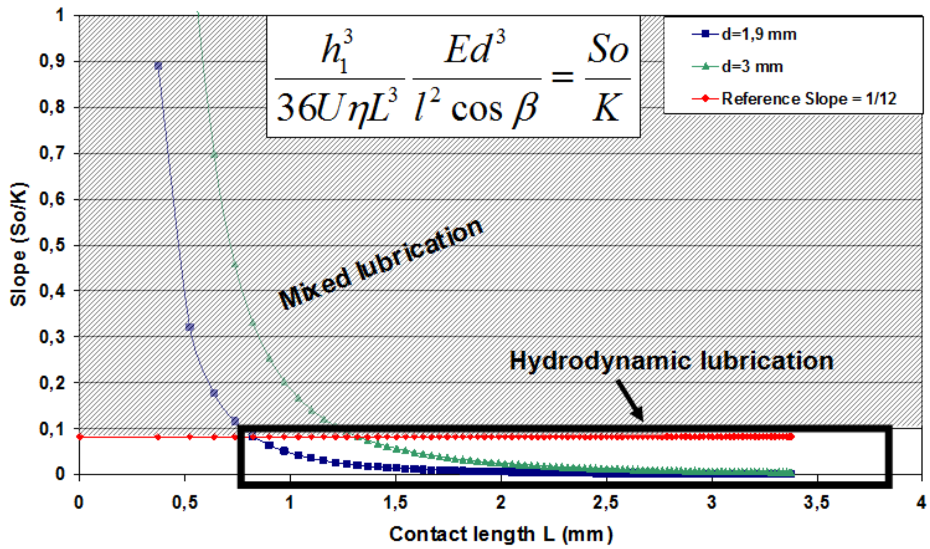

Figure 2. Slope *So/K* as function of the contact length *L* for two different blade thickness *d*

CONCLUSIONS

During the paper production, the tip of the doctor blade is in contact with the roller surface in order to remove impurities and keep the roller's surface clean. In case of worn blades, the contact length runs parallel to roller surface and hydrodynamic conditions can occur, mainly due to external perturbations, such as vibrations or sticky particles. Under such conditions, the system can be modelled by considering the doctor blade as a pad bearing, which is allowed to bend according to beam theory. The limiting value for occurrence of hydrodynamic effects is determined by the value *So/K* = 1/12. The proposed model allows for a systematic improvement of the cleaning efficiency, by targeted changes of the process parameters. For instance, a blade with a higher thickness remains longer in mixed lubrication, which means that hydrodynamic effects do not occur until a more pronounce wear condition. This is unfavourable for energy consumption and wear, but a better cleaning efficiency is expected.

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KEYWORDS

Applied Tribology: Paper Manufacturing, Components: Paper Machines, Hydrodynamics: Hydrodynamic Lubrication (General).