How to Cut and Clean Properly: Balancing Wear and Performance in Knife-Die and Scraping Systems

Manel Rodríguez Ripoll[1]*, Balazs Jakab[1], Stefan Krenn[1], Bernhard Scheichl[2,3]
[1]AC2T research GmbH (Austrian Centre of Competence for Tribology), Wiener Neustadt, Austria
[2]Austrian Tribology Society, Wiener Neustadt, Austria
[3]TU Wien, Vienna, Austria
*manel.rodriguez.ripoll@ac2t.at

Introduction

Many industrial applications rely on the use of sharp rigid materials pressed against a surface to keep it clean of solid impurities or to precisely cut an extruded material. Examples:

- Doctor blade-press roll system in the paper industry
- Knife-die plate system in polymer pelletizing

Delicate equilibrium between the press force required for effective cleaning by scraping or cutting and the wear imparted to the components:

- Too low pressing force hampers process quality
- Unnecessarily high pressing force leads to higher energy consumption and increased wear

No procedure exists for guiding the selection of cleaning or cutting parameters How to find the optimum process conditions?

Model: Hydrodynamic lubrication

Pad bearing: $F_N = \frac{6U\eta L^2}{h_1^2} So$

Beam deflection: $F_Q = \frac{Ed^3\delta}{6l^2}$,

Equilibrium: $F_Q = F_N \cos\beta$

➔ $So = \frac{h_1^3}{36U\eta L^3}\frac{Ed^3}{l^2\cos\beta}K$, with $K = \frac{h_0 - h_1}{h_1}$

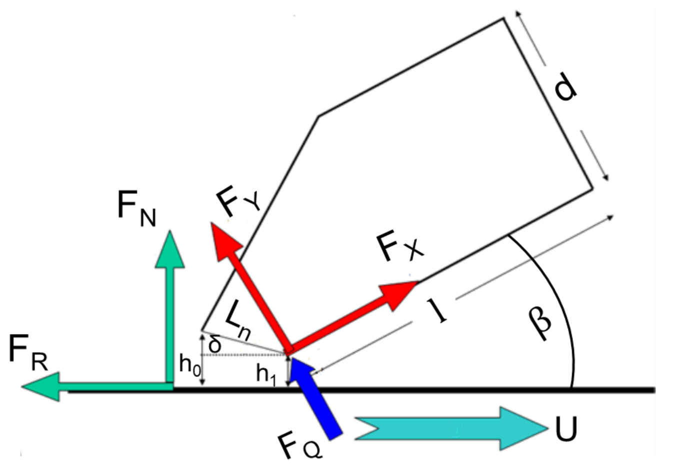

Fig. 1: Schematic of a sliding pad bearing.

Optimum conditions: Onset of purely hydrodynamic conditions [1] in limit K→0

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

Application to the paper industry

The goal is to achieve an optimum cleaning performance while simultaneously minimizing wear of the doctor blade for increasing blade lifetime, reducing energy consumption and enlarging the maintenance intervals.

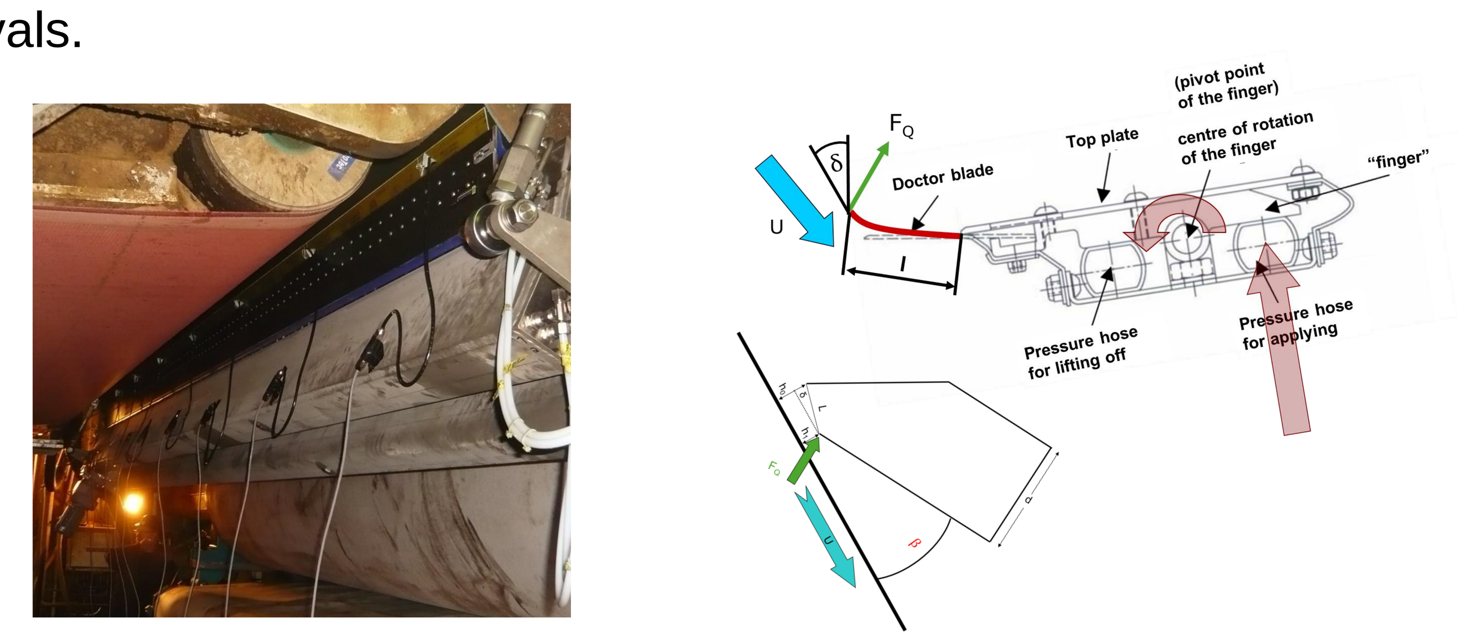

Fig. 2: Doctor blade-press role in a paper factory (left) and schematic representation of the contact situation (right).

Initially a sharp blade operates under mixed lubrication conditions, i.e. slope of So/K > 1/12. With increasing wear, the contact length *L* increases until it switches to hydrodynamic conditions. A blade with a higher thickness *d* operates longer under mixed lubrication [2].

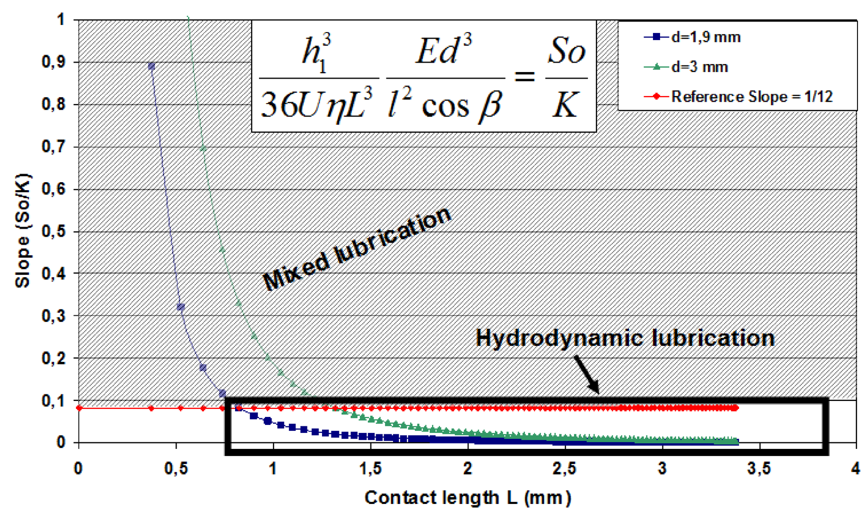

Fig. 3: Transition from mixed to hydrodynamic lubrication for increasing contact length L due to wear.

Application to polymer pelletizing

In polymer pelletizing, the cutting precision is determined by the proximity of the knife tip to the polymer extruder. By controlling parameters such as the geometry of the knife, press force, and operating velocity, we can achieve a reliable balance between wear and performance.

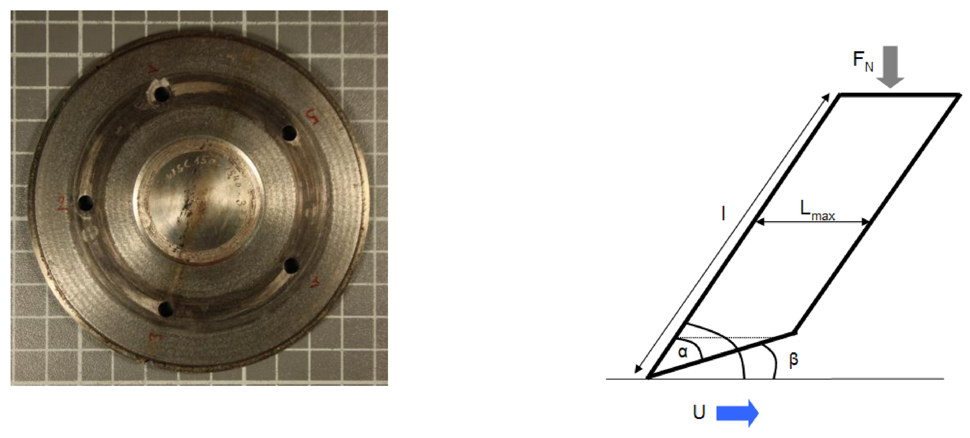

Fig. 4: Perforated die plate use for polymer pelletizing (left) [3]. Through this component, molten polymer is extruded before being cut into pellets by rotating knives. Schematic representation of a rotating knife (right).

Rotating knives also show a transition from initial mixed lubrication into hydrodynamic lubrication for increasing wear. However, the knife length *l* decreases for increasing wear, thus increasing So/K. For certain conditions, the knife can remain in mixed lubrication or even experience a transition from mixed to hydrodynamic lubrication and back to mixed lubrication.

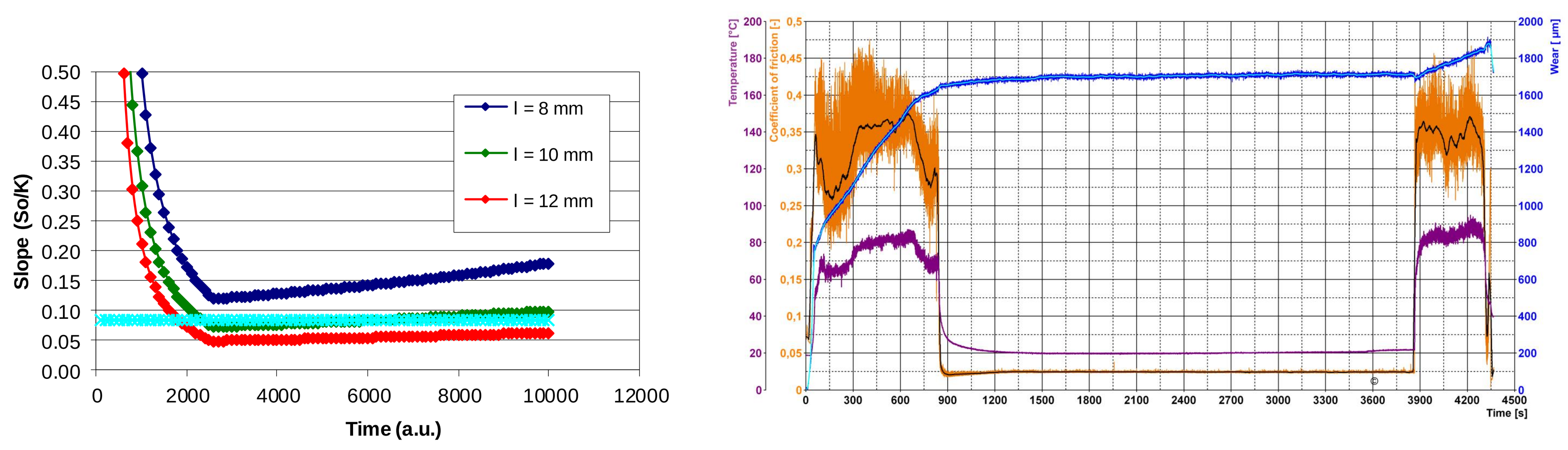

Fig. 5: Transitions in lubrication regime for increasing contact length L due to wear as function of the knife free length l (left). Note the transition mixed-hydrodynamic-mixed experienced by l = 10 mm. Wear and friction measured using a knife-on-disk tribometer showing similar transitons (right)

Conclusions

- Our model predictions successfully identify transitions between hydrodynamic and mixed lubrication regimes in water-lubricated experiments performed using blade-on-disk and knife-on-disk setups.
- By controlling parameters such as the geometry of the blade/knife, press force, and operating velocity, we can achieve a reliable balance between wear and performance.
- These appealing findings provide a robust framework for enhancing efficiency and durability in industrial cutting and cleaning applications.

Literature

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