Electronic Supplementary Material (ESI) for Soft Matter.

Electronic Supplementary Information

A lubrication replenishment theory for hydrogels

Elze Porte[a, b]*, Philippa Cann[a], Marc Masen[a]

[a] Tribology Group, Department of Mechanical Engineering, Imperial College London, SW7 2AZ, UK

now at: [b] Department of Mechanical Engineering and Materials Science, Yale University, New Haven, CT 06511, USA

*corresponding author: elze.porte@yale.edu

1. Fluorescent intensity maps

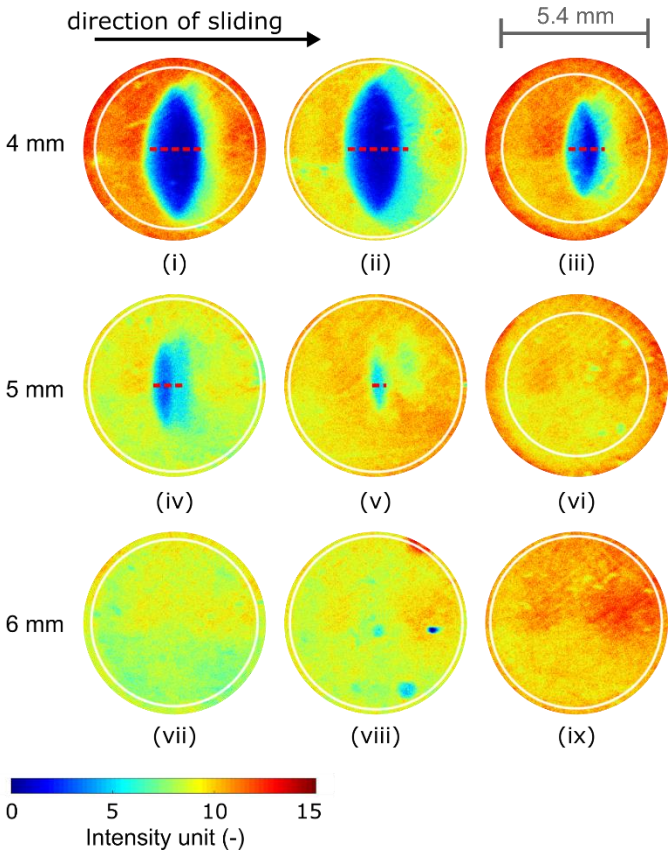

Fig. S1: Fluorescent intensity maps of the contact area for 4 mm (i-iii), 5 mm (iv-vi) and 6 mm (vii-ix) stroke lengths

Fig. S1(i-iii) show the measurements at 4 mm stroke length, Fig. S1(iv-vi) at 5 mm stroke length, and Fig. S1(vii-ix) at 6 mm stroke length. The images can be categorised into two groups: a group in which an area with low fluorescent intensity can be observed (Fig. S1(i-v)), and a group that shows a highly uniform fluorescent intensity throughout the contact (Fig. S1(vi-ix)). Although Fig. S1 shows some minor variations between identical tests, it clearly shows that the distinction between non-replenished and replenished images was largely dependent on the applied test conditions: all images for the 4 mm stroke length show a clear area with very low fluorescent intensity, whereas the 6 mm stroke lengths show uniform fluorescent intensity throughout the contact. The 5 mm stroke showed varying behaviour: one of these images could be categorized similar to the 6 mm stroke length as the fluorescent intensity was uniform in the contact, and the other two images resembled the 4 mm stroke length as a low intensity area is visible in the contact. The variability observed in the fluorescence results for a stroke of 5 mm was also observed in the friction results, with Fig. S1(v) and S1(vi) relating to relatively low friction and Fig. S1(iv) to a relatively high friction.

2. EHL film thickness

Isoviscous central film thickness:[1]

$$h = 4.18\frac{(U\eta)^{0.60}R'^{0.67}}{W^{0.13}E'^{0.47}} \quad \text{(S1)}$$

where h is the central film thickness, U the sliding speed, η the dynamic viscosity of water at room temperature, R' the radius of the glass lens, W the applied load, and E' the combined elastic modulus.

$U = 20\ mm/s$

$\eta \approx 1\ mPa \cdot s$

$R' = 15.7\ mm$

$W = 0.9\ N$

$E' = 2E^* = 2E/(1-\nu^2)$, assuming $\nu = 0.5$ and $E = 0.1\ MPa$ gives $E' = 0.27\ MPa$

Filling out in eqn (S1) gives an expected central film thickness of $h \approx 1\ \mu m$.

[1] M. Ratoi and H. A. Spikes, *Tribol. Trans.*, 1999, **42**, 479–486

3. Cartilage friction traces

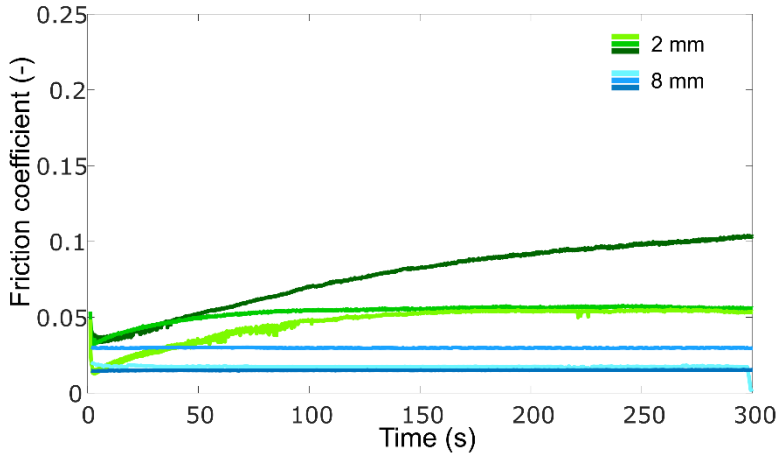

Fig. S2: Friction traces for individual experiments on bovine cartilage at 2 and 8 mm stroke lengths