Friction Reducing Effect of Macro Textures in the Piston-Ring Cylinder-Liner Contact

Maximilian Zimmer[1)*], Sorin-Cristian Vladescu[1)] Lars Mattson[2)], Mark Fowell[2)], Tom Reddyhoff[1)],

[1)]Tribology Group, Imperial College London, [2)] Volvo Group Trucks Technology, Göteborg, Sweden
*Corresponding author: max-zimmer@live.de

Extensive research has been conducted on the friction reducing effects of surface texture in tribological contacts however there is little understanding about the underling mechanisms and few textures have been shown to be effective in the hydrodynamic regime. Herein, we put forward a new texture-induced, friction reduction mechanism which is demonstrated experimentally and validated theoretically. The mechanism involves macro-scale texture which acts to reduce both the sheared contact area and the load support associated with the lubricant film, with the former dominating. This mechanism functions in the hydrodynamic regime and has significant implications for piston-liner and journal bearing contacts.

Keywords: Surface-Texture, Piston-Ring, Friction, Macro-Texture

1. Introduction

The application of surface textures in the piston-ring cylinder-liner contact (PRCLC) has been shown to be an effective method of reducing contact friction and improving internal combustion (IC) engine efficiency. While past research has focused on reducing friction at the stroke reversals [1], in the middle, where large power-loss occurs, previously developed micro-textures are detrimental. This study aims to experimentally test the friction reducing effects of larger-scale macro textures in the middle of a piston stroke and demonstrate the underlying "Area-Reduction" mechanism.

2. Methods

2.1. Experimental

To experimentally test the friction reducing effect of macro textures, a custom reciprocating rig was employed to simulate the PRCLC using a ring sample in combination with both a textured (Figure 1) and untextured cylinder-liner samples.

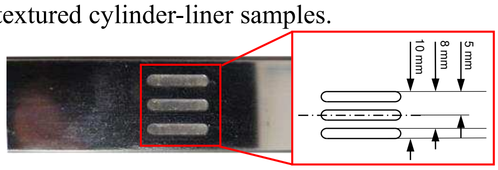

Figure 1: Macro texture applied onto a steel cylinder-liner sample using CNC milling.

2.2. 1D Analytical Modelling

To demonstrate the friction reducing mechanism, a 1D analytical model was developed based on Reynolds Equation and a mass-conserving cavitation analogy:

$$\frac{\partial}{\partial x}\left\{h^3 \frac{\partial P}{\partial x}\right\} = 6U\eta \frac{dh^3}{dx} \quad (1)$$

$$F = A_r\left[\int_{-x}^{0} L_c(x)\left(\frac{U\eta}{h}\right)dx + L\int_{0}^{x}\left(\frac{\partial h}{\partial x}\frac{P}{2} + \frac{U\eta}{h}\right)dx\right] \quad (2)$$

Based on the hypothesis that macro-textures reduce friction due to a lower shear surface-area, the texture is implemented based on the area-reduction ratio (A_r).

2.3. Results

Experimental results show friction reduction of up to 35% in the textured region at mid stroke. Numerical results support the experimental findings validating the "Area Reduction" mechanism hypothesis.

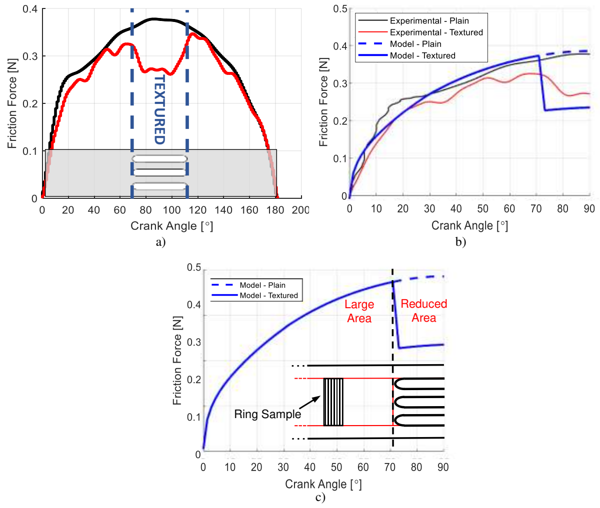

Figure 2: Comparing friction response from experiment (a) to modelling (b). "Area Reduction" mechanism (c).

3. Discussion

Experimental results have shown significant reductions in friction in the hydrodynamic mid-section of the stroke where previous textures increased friction. This opens previously unexplored opportunity for friction reduction in IC engines particularly as substantial power-loss occurs at mid-stroke.

Model results show that the observed reductions are due to a reduced shear area, whereby the pocketed regions do not contribute shear-friction. This is because of the pocket depth being orders of magnitude greater than the minimum lubricant film thickness. Having identified the main tribological mechanism behind these friction reductions will allow us to optimise textures and maximize their friction reducing benefits.

4. References

[1] Vladescu, S et al., "The Effects of Surface Texture in Reciprocating Contact – An Experimental Study" Tribology International, 82, 02, 2015