Numerical study of the lubrication and scuffing of piston rings: Application to Hybrid Internal Combustion Engines.

Introduction

The piston ring – cylinder liner contact is the most complex Tribological system in an internal combustion engine: it serves as an interface between the combustion chamber and the lubricant reservoir (lower engine).
This contact greatly determines the engine performance in terms of petrol consumption and polluting emissions.
Scuffing is a failure mode characterized by a rapid and important surface degradation. It is caused by a lubricant failure, leading to a catastrophic local heat generation.
The multiplication of the start and stop, inherent to a hybrid engine, increase the scuffing risk. Stopped, the piston rings will no longer be replenished with fresh oil, while the engine is hot. At the re-start, the combination of little available oil and high temperature (low oil viscosity) will favor scuffing.

Objective

In the literature, scuffing is studied from many different points of view. Historically, scuffing is analysed from a surface temperature point of view, for applications like gear teeth.

The surface temperature increase of the contacting bodies is determined through the dissipated power: normal force * friction coefficient * sliding speed. Incorporating additives in the lubricant and the use of surface coatings have allowed significant performance improvements with respect to scuffing.

Experiments show that scuffing only occurs after a sufficiently long time, corresponding to a period in which the surface micro-geometry was progressively removed. Modelling this wear and its consequences on lubrication is a possible approach to allow one to quantify the conditions that lead to scuffing.

To locally describe the start of scuffing, several researchers have tried to model the surface temperature at the roughness scale. The highest temperatures are generated during the metal-to-metal contact in the mixed lubrication regime, however, the existing models that describe these contacts do not benefit from universal approval.

A study from a “starved lubrication” point of view (insufficient lubricant available) is little used. We think that there are two principle factors at the scale of the engine: the overall oil starvation level due to the ring geometry / operating conditions and a local starvation level due to a non-equal distribution of oil. The dissipated power, the starting point for every thermal calculation, suffers from very complex physics: the mixed lubrication regime, with lubricant shearing and direct metal-to-metal contact.

Organisation

Step 1: Measurement of surface micro-geometry

Measurements of the surface micro-geometry will constitute a first step in order to describe the contact (geometry) evolution from normal to partial scuffing and full scuffing. This is an essential step to understand the surface geometry evolution.

Step 2: Analysis and understanding of the phenomena

It is important, in a second step, to analyse the contact between rings/piston/liner in the light of scuffing. Which phenomena initialise scuffing? Which geometrical parameters play a role? Etc… Complimentary friction tests can be carried out on real surfaces.

Etape 3 : Modelling

Once the phenomena that influence scuffing listed, a simulation model has to be established, in order to predict the scuffing risk. This model will be centered around the amount of available lubricant (3rd ring) and the flash temperature below the first ring. These two phenomena depend strongly on the surface roughness. Two approaches are envisaged:

- Generate a predictive tool that predicts scuffing risk for a given application (Geometry, operating conditions, application (hybrid engines)).
- Generate a qualitative tool that links the scuffing risk to an overall failure model.

Further info

This ciffre thesis is jointly proposed by the LaMCoS laboratory and PSA: for further information

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