Taiho Kogyo Tribology Research Foundation

Main report

Name: Sorin-Cristian Vladescu / Tom Reddyhoff

Theme: Advanced Laser Surface Texturing for Improving Engine Efficiency

1. Progress and result of the research

The proposed research specifically aimed at providing a bridge between lab-based test results and improved automobile performance, while replying to four fundamental tribological questions; for each of these questions a thorough study was performed, assessing the underlying mechanisms for both textured and non-textured specimens.

i) How can surface texture simultaneously alleviate starvation?

The occurrence of cavitation – reversal – starvation in reciprocating contacts was investigated using the newly built tribometer. This occurs at the extremities of the stroke when reversal causes the cavitated exit to the contact become the inlet and hence deprives it of oil. The result is starvation for up to 5% of the stroke length, depending on the lubricant's viscosity. It was observed that pockets act to bring oil into the cavitated region aiding lubricant entrainment and hence reducing friction (Fig. 1)

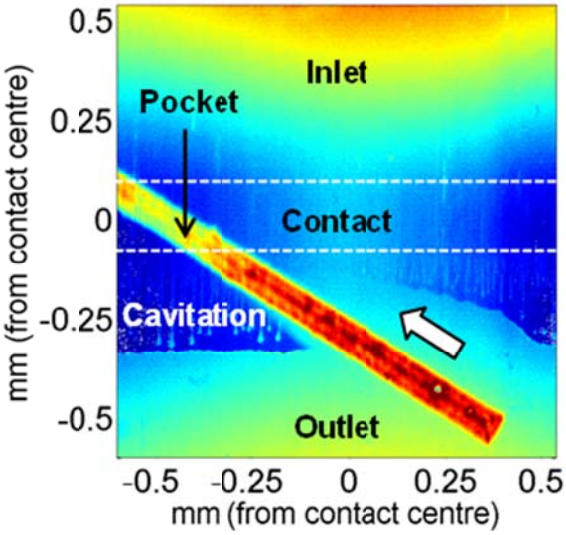

Fig. 1 - In-situ fluorescence map of oil distribution

ii) What are the mechanisms by which laser produced surface texture enhances film formation?

The friction reduction mechanisms identified were summarized in [1] as follows:

For non-textured surfaces functioning under starved conditions, the volume of lubricant is pushed to the extremities of the wear track by the reciprocating motion of the contact; this results in increased friction and increased oil consumption. Surface texture acts to alleviate this issue, each pocket carrying lubricant from the contact's inlet to the outlet; sub-ambient pressure in the cavitated region sucks the oil out and deposits it on the liner surface. This results in an even distribution of lubricant along the reciprocating stroke and consequently in friction reductions of up to 33% compared to the non-texture reference (Fig. 2).

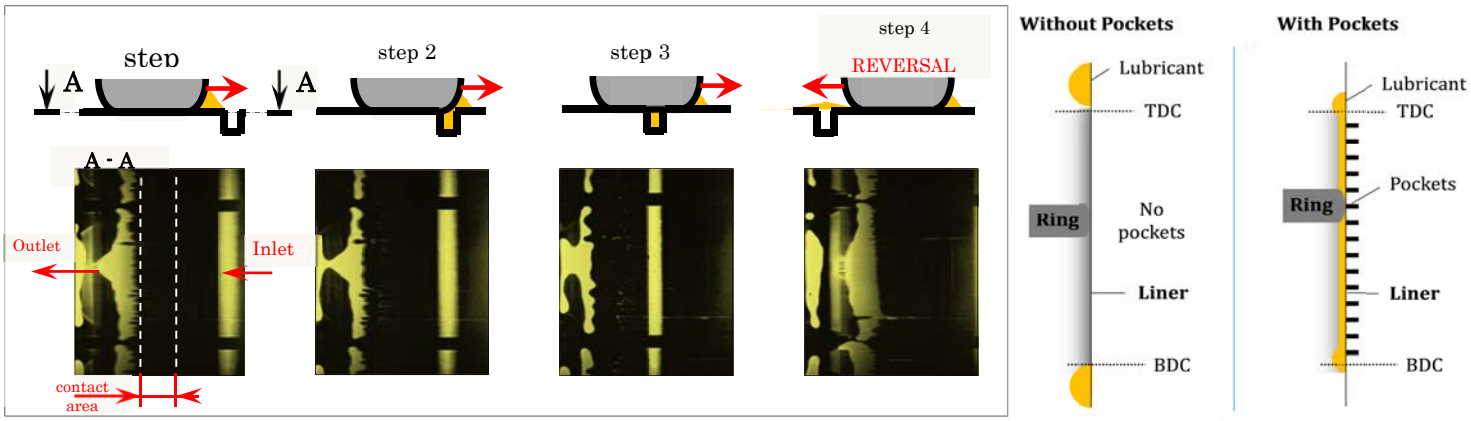

Fig 2 - Schematic representation of a pocket passing through a starved contact.

By filling the cavitated region with oil to flood the contact following reversal, the same mechanism described above acts to reduce wear at both TDC and BDC.

Finally, during the entrainment of pockets oriented normal to the direction of sliding, cavitation bubbles were observed within each pocket, which supports the mechanism of inlet suction, previously identified by Olver and Fowell.

iii) Can optimal, intelligent geometry be found for each application?

A series of tests were performed to identify the criteria for optimum pocket depth, breadth, and density. The implication for practical IC engine texturing was summerised in [2], concluding that texture geometry positioning should vary according to the alternating lubrication regimes along the piston stroke.

iv) Can texture lubrication mechanisms be modelled and optimized for immediate transfer into practice?

The two members of the project designed novel experiments which provide data for validation of advanced predictive tools currently being developed in collaboration with the University of Sao Paolo and University of Bari, under the guidance of Professor Daniele Dini. Key activities include: (1) Model cavitation observed experimentally using mass conserving algorithms; (2) Implement robust algorithms to deal with complex deforming geometries; (3) Capture realistic rough surface friction and flow around asperities.

Regarding the proposed collaboration with Yokohama National University, aimed at combining our texturing methods with their vibration control research, Dr. Vladescu is currently filling an application for a *JSPS International Fellowship for Research in Japan* aimed at undergoing the proposed research topic under the guidance of Professor Ken Nakano. The proposed starting date for the 6 months long fellowship is April 2019.

2. Subjects remain to be solved in future/Subjects required further investigation

A recent study performed in collaboration with Prof Spikes has shown significant

differences in friction as a function of component (bearing) operating temperature in IC engines. We aim to continue our work investigating the impact of laser surface texturing on bearings' temperature, as well as to explore the inter-dependencies between textured surfaces, polymer coatings and surface super-finishing. The study will be performed employing base oils with new smart-rheologic, boundary film forming additives.

3. Plan and past presentation or publication of your research results

These novel results, obtained partly using the resources provided through this grant, were recently published in Tribology International and Tribology Transactions, of course acknowledging the support of the Taiho Kogyo Tribology Research Foundation. A series three other journal papers are currently under submission (we plan to have at least one of the three papers published in the Tribology Online, the online journal published by the Japanese Society of Tribologists). The five studies are listed below:

[1]. "Looking into a laser textured piston ring-liner contact"
S.-C. Vlădescu[1*], A. Ciniero[1], K. Tufail[2], A. Gangopadhyay[3], T. Reddyhoff[1]
1 Imperial College London, 2 Ford Motor Company UK, 3 Ford Motor Company USA
Tribology International 115 (2017) 140-153

[2]. "Parametric study of surface texture in reciprocating linear bearings"
S.-C. Vlădescu[1*], K. Tufail[2], A. Gangopadhyay[3], T. Reddyhoff[1]
1 Imperial College London, 2 Ford Motor Company UK, 3 Ford Motor Company USA
Tribology Transactions (2017) 1-10, DOI: 10.1080/10402004.2017.1363930

[3]. "Optimising friction reduction by varying the space between pockets and adjusting the piston ring radius in a laser textured ring-liner contact"
S.-C. Vlădescu[1*], K. Tufail[2], A. Gangopadhyay[3], T. Reddyhoff[1]
1 Imperial College London, 2 Ford Motor Company UK, 3 Ford Motor Company USA
(to be submitted, Tribology Online)

[4]. "Experimental Study of Surface Texture Applied to Journal Bearing Shells"
S.-C. Vlădescu[1*], M. Fowell[2], T. Reddyhoff[1]
1 Imperial College London, 2 Volvo Group Truck Technology
(to be submitted, Tribology International)

[5]. "Understanding how laser surface texture functions – an overview"
S.-C. Vlădescu[1*], T. Reddyhoff[1]
1 Imperial College London, (to be submitted, Tribology International)

The recent results were presented at the World 6th Tribology Congress, WTC 2017, Beijing, where the members of the research project had a series of three presentations:

1 - "*Visualising cavitation in a piston ring-liner type contact to understand surface texture behaviour*"
Sorin-Cristian VLADESCU, Khizer TUFAIL, Arup GANGOPADHYAY, Tom REDDYHOFF
Track 2: Wear & Surface Engineering

2 - "*Enhanced piston-liner friction reduction through surface texturing*"
Tom REDDYHOFF, Sorin VLADESCU
Imperial College London, UK
Track6: Engine and Transmission Tribology

3 - "*A combined experimental and modelling investigation of laser microtextured surfaces with focus on piston ring - cylinder liner contacts*"
Francisco PROFITO, Sorin-Cristian VLĂDESCU, Thomas REDDYHOFF, Daniele DINI
Track6: Engine and Transmission Tribology

The results will also be presented at the 2018 STLE Tribology Frontiers Conference, co-sponsored by the Tribology Division of the ASME, which will be held October 28-31, 2018, at the Drake Hotel in downtown Chicago, Illinois, USA.

Title: "*Visualising Cavitation in a Piston Ring-liner Type Contact to Understand Surface Texture Behaviour"*
Current Category: Topic 12 - In-situ Tribometry
Session Abreviation: 2B - In Situ Tribology II
Scheduled for: 11:00 AM to 11:20 AM

Finally, as mentioned in Section 1, Dr Vladescu is currently applying for a short term postdoctoral fellowship in Japan, with the proposed starting date 1st of April 2019. If successful, Dr Vladescu would be honored to have an oral presentation at the TTRF headquarter in Toyota-City, detailing to the TTRF Board of Directors the progress and results achieved throughout this research project.