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Multiscale analysis of lubricant-surface combinations for reduced frictional losses within high performance automotive transmissions [Abstract]

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MULTISCALE ANALYSIS OF LUBRICANT-SURFACE COMBINATIONS FOR REDUCED FRICTIONAL LOSSES WITHIN HIGH-PERFORMANCE AUTOMOTIVE TRANSMISSIONS

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Parasitic energy losses during energy conversion and transmission have significant adverse economic and environmental implications within the four main energy consuming sectors of economy; Transport, Manufacturing, Power Generation and Residential. Energy loss from contacts between components accounts for approximately 23% of the global energy consumption^[1]. This presents the tribology (science of friction, lubrication and wear) community with a significant challenge, whilst advancement of the underpinning science provides an opportunity to effectively address environmental emissions, energy efficiency, product reliability and durability, resulting in significant economic savings over both short- and long-term projections.

This research unlocks opportunities for developing modern tribological technologies by understanding the fundamental physics at nanoscale to reduce frictional losses, specifically within high-performance automotive transmissions. However, the underlying scientific methodology, techniques, analysis and research developments are generic and can be expanded to a wide range of components and contacts to impact other sectors and reduce energy consumption through a track to road concept^[2] and therefore, a having a much larger scale of impact. My PhD research, commencing in October 2016, is a joint EPSRC and industry sponsored Doctoral Training Program with duration of three and a half years and aims to investigate the formation of low shear strength ultra-thin adsorbed tribo-films at the conjunctural surfaces within high-performance transmissions. My research utilises the state-of-the-art concept of treating lubricant-surface interactions as a system. The increased demand for reduced emissions and improved energy efficiency has resulted in components that experience harsher operating conditions. This has resulted in a demand for designing of surfaces with advanced coatings and extra-low viscosity lubricants with sophisticated additive packages in tandem, and no longer in isolation, to ensure that true optimisation is achieved. Thus, my research focus is to understanding fundamental mechanisms for reducing frictional losses while improving operational stability and reliability simultaneously. The research encompasses a variety of lubricant-surface system properties such as lubricant formulation, tribofilm chemistry, contact mechanics, surface topography, surface coatings and wear characteristics.

One of the novelties within my research is the development of a combined experimental and analytical test procedure for characterisation and assessment of the critical parameters in lubricant-surface system across the physics of scales in a sequential manor. For instance, the performance of Diamond-Like-Carbon (DLC) thin coatings in combination with a fully formulated transmission lubricant is evaluated in comparison to steel tribopair. Boundary active lubricant additives are adsorbed onto the surface through precise tribometric experiments under representative contact conditions and regime of lubrication, whilst their frictional performance, at microscale, was assessed. The composition of the adsorbed tribofilm is characterised through X-ray Photoelectron Spectroscopy technique to determine the nature of lubricant additives' interactions with the DLC coating. The nanoscale interfacial boundary shear strength coefficient is then assessed with the use of Atomic Force Microscope in Lateral Force Microscopy mode. In addition, I developed a novel approach using fractal surface analysis to provide scale-independent surface topography characterisation. The research I have completed using the combined analytical and experimental method for benchmarking and characterising frictional performance of lubricant-surface performance allows for greater accuracy within predictive models of system power loss and energy efficiency. Furthermore, the tribofilm analysis has shown increased understanding and more informed design of lubricant-surface systems to maximise the performance and efficiency. More importantly, the results also were able to explain underlying physics behind the improved performance of DLC coating against more traditional steel samples in this application area. Furthermore, the understanding of the contact theory is key to understand the structural integrity, friction and wear of the system over the physics of scales given a precompetitive advantage of the cutting edge.

[1] Holmberg, K. & Erdemir, A. Friction (2017) 5: 263. <https://doi.org/10.1007/s40544-017-0183-5>

[2] Mourier, L., Crofts, P., Motta, M., Forastiero, G., Salino, P.: Engine Tribology: From F1 Performance on Track to Energy Efficiency on road, World Tribology Congress, 2013, pp. 1–4