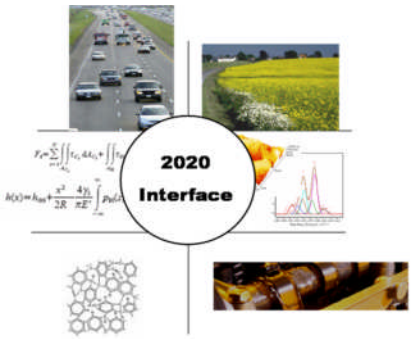

EC SEVENTH FRAMEWORK PROGRAMME

SST.2008.1.1.1 Clean and energy efficient gasoline and diesel powertrains

SMALL SCALE FOCUSED RESEARCH PROJECT:

Tailoring of tribological interfaces for clean and energy-efficient diesel and gasoline power trains

2020 Interface

Project No 234324

Periodic Report – Period 2

Publishable Summary

AUTHORS:

Professor Anne Neville: Coordinator

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Publishable Summary (max 4 pages)

Summary description of project context and objectives

Durability and friction control in internal combustion engines is currently delivered from a complex package of lubricant additives in a fully formulated engine oil. These oil additives, through tribochemical interaction with the surface, produce nanostructured composite, self-healing and smart tribofilms at the surface. 2020 Interface involves the design of the complete system; functionalised Diamond-like Carbon (DLC) coating and future generation lubricant to enable Europe's stretching targets in fuel economy and durability to be met. There has been much emphasis in research on designing new coatings technology such that the degree of complexity of surface systems has increased dramatically over the last decade. In boundary lubricated contacts, it is the interfacial nanostructured film, which results from tribochemical interactions between the surface and the lubricant additives, which dictates the system performance. No attempts have been made to incorporate "design" strategies into optimizing this interface and 2020 Interface tackles this through an interdisciplinary integrated experimental and theoretical approach. The benefits of this approach are accrued from substantial improved fuel economy (protection of natural resources), reduced emissions (protection of the environment) and improved durability (lower waste and maintenance). As the number of vehicles in the globe increases year on year without showing signs of reaching a plateau and the internal combustion engine remains the major platform for powertrain for the foreseeable future, the impact of this project will be large and long lasting. 2020 Interface brings together a world class consortium of 4 Universities, 1 research institute and 4 leading multinational companies from 8 EU countries together in complete supply chain to deliver fast track radical innovation in nanoscience through to a full set of novel lubrication technology platforms, for commercial applications in diesel and gasoline power-trains.

Partners involved:

Beneficiary number	Beneficiary Name	Beneficiary Short name	Country	Date enter project	Date exit project
1	University of Leeds	Leeds	United Kingdom	Dec 2009	
2	Faculdade de Ciências e Tecnologia da Universidade de Coimbra (FCTUC)	FCTUC	Portugal	Dec 2009	
3	University of Ljubljana	CTD-UL	Slovenia	Dec 2009	

4	University of Groningen	Groningen	The Netherlands	Dec 2009	
5	Jožef Stefan Institute	JSI	Slovenia	Dec 2009	
6	Sulzer Sorevi SAS	Sulzer		July 2010	
7	Lubrizol	Lubrizol	United Kingdom	Dec 2009	
8	Volvo Technology Corporation	Volvo	Sweden	Dec 2009	
9	SKF	SKF	The Netherlands	Dec 2009	

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Project website:

http://www.2020interface.eu/index.html

Objectives:
The hypothesis is:
It is possible, through intelligent interface design (tribofilm) to provide a step change in cleanliness, fuel economy and durability aligning with the aspirations of the lubricant manufacturers and OEMs and at the same time meeting imminent legislative changes.

The project objectives are

- To summarize the understanding of interfacial reactions and processes occurring at tribological interfaces between conventional materials and current lubricants and consolidate it to potential “use” in “new optimised powertrain systems”
- To select and define the required DLC coatings fundamental structure-property relationships in combination with the lubricant components, which will facilitate the development and “design” of optimized interfaces, and will provide ultra low friction, enhanced durability and clean powertrain operation

- To understand the interfacial mechanics, reaction kinetics and durability to enable a new approach to interface design
- To develop a "system" for which the laboratory and industrial scale testing and validation indicates clearly that the ERTRAC 2020 Vision for fuel reduction is achievable. Several tribofilm options will be tested, validated and compared.

Description of the work performed since the mid-term report and main results achieved so far

This second period (month 18-month 36) was focussed on further development of the coatings developed in WP3 (through WP 5) and also refinement of the oils supplied by Lubrizol to enhance the performance of the coatings. The tests would continue initially using laboratory based tribometers (WP 5) but would culminate in the component level and the engine tests of WP 6 where the translation of laboratory results into full scale testing occurs. All of this activity is presented in this report.

At the proposal stage the duration of the project was 36 months and so period 2 was to be the final report. However in late 2012 the request was made for a 6 month time only extension of the project to enable the engine and full scale tests to be finalised[1] and so this report is now a periodic report for the second of three periods.

The following achievements are noted in this period:

- Groningen has produced two types of coating, refined from WP 3 and referred to as Ti1G and Ti2G and these have formed the basis of the testing of Ti-doped coatings in this period.
- Sulzer has produced three coatings as part of the iterated coatings workpackage. These are HHS (a hydrogenated DLC) and Si1S and Si2S (two Si-doped DLCs). These coatings were fully characterised.
- FCTUC produced two levels of W doping (W1C and W2C as low and high levels respectively)
- Lubrizol adapted their oils from the previous results and produced 4 oils based on E6 (low SAPS) referred to as E6C1, E6C2, E6C3 and E6S. These new friction modified oils would then be assessed with the new coatings to test the hypotheses developed in the first 18 month period.
- Leeds has performance all the tribological tests (pin-on-disc and TE 77) on coatings developed in WP 5 and tribochemistry analysis as stated in WP4. The main findings were that the Si-doped coatings typically had higher frictions and much more tribochemical reactivity than the HHS and other metallic doped coatings. There was no systematic relationship between the modulus or hardness of the coatings and the

[1] The request for a time only extension was made on the basis that there had been delays due to technical difficulties in Lubrizol. The extension would allow for the appropriate final meetings and wrapping up of the project in 2013.

tribological/tribochemical behaviour. It was shown that the lubricant composition has a large impact on the coating performance, the friction in the tribocouple and the wear of the counter material in these sliding conditions. The coatings from WP3 (W-doped) and that had been refined in WP 5 survived all tests and were seen to be able to be successfully lubricated with these new lubricants.

- Ljubljana also conducted the same test matrix using the MTM machine. Results that are aligned with the findings in Leeds were found. Again the W-doped coatings survived these tests. The Si-doped coatings were shown again to be very reactive compared to the other doped coatings and the undoped coating. .
- Ab-initio chemical modelling has continued in this period. The reactivity (adsorption) of some model lubricants were theoretically calculated and the reactivity towards Si has been demonstrated.
- Mesoscopic modelling has been done in Leeds and is still ongoing. A 2D Matlab model has been completed with the pressure calculation from the 2D finite element model. Real measured mechanical properties of DLC have been input into the model and some predicted results were obtained.

Expected final results and their potential impact

- Much extended knowledge of optimised carbon (DLC) coatings for powertrain application, optimum lubricant formulation and tribochemistry.
    - We have extended the knowledge of tribochemistry considerably and this is being disseminated through scientific publications. The link between the laboratory tests in tribometers and the engine and component level tests is being demonstrated. The mechanisms of tribochemical reactions at DLC surfaces are being clarified for some conventional and next generation additives.
- Fuel economy and durability improvements in real engines; The above technical knowledge will be exploited in WP6 where full scale powertrain parts are tested. Impact on engine fuel economy and durability will ultimately impact on vehicle emissions. The preliminary results from tis WP look very promising and will be disseminated in the next period.
- Modelling framework; Chemical and mesoscopic modelling work together is able to determine the best sp_3/sp_2 ratio for DLC coatings and what mechanical properties are desired for DLC coating in order to have an optimised overall performance in engine and bearing applications. These two parts of the modelling work will help further industrial interface design. The results from the modelling part of the study although extremely idealistic are showing a good correlation with laboratory test results.

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