# PhD in Mechanical Engineering

**Research Title:** Improvement of mechanical systems efficiency by means of nano-coatings and lubricants functionalised with nano-additives

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<th>Funded by</th>
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<td>Design and experimentation of mechanical drive components and thermography - JTECH</td>
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**Context of the research activity**

Nowadays it is widely agreed that the reduction of energy losses in mechanical systems is of crucial importance. This requirement responds to the need of higher environmental compatibility and sustainability in many industrial applications. A key factor in the development of mechanical systems of tomorrow is thus the abatement of any source of undesired frictional and wear effects affecting the mechanical efficiency.

In many industrial applications lubrication is a fundamental mean to protect surfaces from wear and to extend their fatigue life. Nevertheless, a share of energy loss is to be attributed to viscous effects related to the hydrodynamic and elastohydrodynamic contact conditions. This is the case of many components and couplings for power generation, power transfer systems and hydraulic systems, for examples geared and spline couplings, bearings, cam-follower actuators, ball-screw systems, cylinder-liner couplings, hydraulics and pneumatics linear actuators, etc... Many efforts were made in recent years toward the tribology optimization of such devices.

In this context, new ways towards the goal of optimisation an energy savings are still to be investigated. Innovative graphene nano-layers and high lubricity ultra-thin hard layer (like DLC and other ceramics) can...
reduce the EHL coefficient of friction, as may reduce wettability of metallic surfaces and thus viscous adhesion. Moreover, possible benefits may come from the use of oils and greases functionalised with innovative graphene fillers in traditional layout.

Lubrication is not always present anyway. Many industrial applications involve dry contacts in which even stronger detrimental tribological effects come out. The second goal of this PhD project is to study the beneficial influence of covering active surfaces of components with innovative 2D materials like molecular films of graphene and thin ceramic (like the ones in above) to improve these applications.

Referring to the above quoted tribological applications, the main problem to deal with is that related to the real life of materials and components, in terms of damage entity and distribution. In this kind of applications, wear phenomena and corresponding material losses are the main causes of damage. For as concerns high performance lubricants, the need to reduce the coefficient of friction has to go hand in hand with the decreasing of the damage entity and the corresponding increasing in durability.

Also in case of dry contacts, as in components coated by innovative active surfaces, the main goal is to keep effective over time the tribological performance.

To verify how these new lubrication techniques may improve the fatigue life of materials and components in terms of surface damage reducing, a wide experimental activity has to be planned and carried on.

If on one side experimental equipment and dedicated test bench are mostly available, on the other side the real difficulty lies in quantifying the surface damage. The only established method available in literature is that related to measure the material loss, so it may be a good challenge to identify different techniques to investigate surface damage phenomena, as an example thermography.

Since the eighties, thermographic techniques, in the so called passive form (no external source is required), have been utilised to analyse fatigue phenomena. For as concerns the detection of surface and sub-surface defects, the passive thermography may only provide a qualitative information, being impossible in that manner to perform a deeper investigation.

On the contrary, in active techniques, additional to thermal camera, an excitation source is required for the purpose of stimulating the thermal evolution inside the object while heating or cooling.

Nowadays, active thermography is considered the most practiced approach for non-destructive inspection of surface and sub-surface defects in conductive materials. This technique may allow a quantitative
detection of defects by means of the reconstruction of measured temperature maps and the corresponding data processing.

Objectives

This PhD project aims at developing an innovative and challenging research into the field of tribology and applied to the design and performance improvement of mechanical systems. It aims at investigating two new ways towards the goal of optimisation an energy losses reduction:

1) Evaluating the benefits in the EHL friction reduction by insulating metallic surface with innovative graphene nano-layers and high lubricity ultra-thin hard layer (like DLC and other ceramics). Preventing the direct contact between the lubricant and the metallic substrate may reduce indeed wettability and thus viscous adhesion and friction.

2) Evaluating the possible benefits in terms of friction and wear reduction coming from the use of oils and greases functionalised with innovative graphene flakes fillers in traditional mechanical layout.

3) Setting up a new method based on the active thermography to quantitatively determine the wear damage in materials and components.

4) Using that method to analyse and compare the results coming from the experimental campaign.

Skills and competencies for the development of the activity

- Experience in experimental tribology
- Experience in EHL
- Experience of work in a company in the field of Tribology
- Machine design knowledges
- Attitude to problem solving