Experimental and numerical analysis of high-speed dynamic seals: Application to e-mobility

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Context and objective

The energy transition in France is characterised by a growing commitment to electrifying transport, an imperative driven by the need to reduce greenhouse gas emissions and to meet the commitments made under the Paris Agreement. This trend reflects a critical challenge for environmental sustainability, with the development of electric vehicles (EVs) emerging as a key element of this transformation.

The possibility of offering a more environmentally friendly alternative, such as the electric vehicle compared to the internal combustion vehicle, is heavily dependent on the efficiency of the propulsion systems (electric motor and transmission system). For manufacturers, this translates into a need for compactness in the electric motor while ensuring the needed power, which can be achieved by increasing rotational speeds, currently around 15,000 rpm, and which are expected to approach 30,000 rpm in the near future.

This technical evolution imposes strict requirements in terms of design and manufacturing of powertrains, particularly concerning dynamic sealing systems. Indeed, to improve the efficiency of electric motors, it is essential to ensure effective cooling, achieved by the circulation of a cooling fluid between the stator and rotor, which requires the use of dynamic sealing. Dynamic sealing is also necessary at the gearbox level, where the gears must be lubricated. Overall, the solutions adopted must not only ensure perfect sealing to prevent leaks but also minimise frictional resistance. At the same time, it is crucial to increase their lifespan and minimise wear that could compromise reliability. As a reminder, the failure of a sealing costing only a few euros can lead to the destruction of the motor.

The goal of the Ph.D. Thesis is therefore to advance the understanding of dynamic sealing technologies for electric motors and gearboxes in new electric vehicle propulsion systems. The main challenges are to **ensure effective sealing at high speeds**, while **minimising friction losses and wear**, thus ensuring the reliability of the propulsion systems and, consequently, the electric vehicle.

A secondary problematic to consider is the potential impact of accidental electrical sparks at the interfaces of sealing systems. These discharges can not only alter the sealing and lubrication properties but also lead to premature wear, thereby compromising the proper functioning of the motors and the overall safety of the vehicle.

Project phases

The first phase of the study will be dedicated to a detailed literature review on dynamic sealing systems in the context of e-mobility. In particular, it will focus on: (1) refining the issues and objectives related to dynamic seals applied to electric vehicles (EVs); (2) cataloguing the various existing dynamic sealing technologies currently used in EVs; (3) outlining the scientific and technological barriers of other technologies that could potentially be used.

The second phase will mainly focus on the in-depth study of existing dynamic sealing technologies, both experimentally on a test rig in the laboratory, and numerically through the skills and resources available within the team. The experimental part will involve, among other things, adapting the test rig, conducting the tests, and post-processing the results. On the numerical side, the objective of this phase is to improve the numerical model based on the experimental analysis, particularly by incorporating multi-scale characteristics.

The third phase of the project will involve proposing improvements to existing dynamic sealing technologies or suggesting new technologies based on the findings made during the previous phase. This will be done through the use of the enhanced numerical model and by conducting additional tests on the adapted test rig.