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# Use and understanding of the new abrasion test bench for the study of emergency landing with retracted landing gear

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## Abstract

In the event of an aircraft performing an emergency landing without deployed landing gear, the aircraft's underside may skid along the runway for several hundred meters. This extended skid gives rise to various physical phenomena, including wear and heat generation within the structural components of the aircraft's underside. Unchecked, these phenomena could compromise the integrity of the structure, posing a significant threat to passenger safety. In response to these challenges, ONERA, in collaboration with the Mechanics, Multiphysics and Multiscale Laboratory, has directed its efforts towards characterizing the tribological behaviour of aeronautical structures under extreme conditions through the PHYSAFE project, which was launched by the French Civil Aviation Authority (DGAC).

Tribology, the science of friction, wear, and lubrication between bodies in contact and relative motion, is complex, involving an array of physicochemical phenomena. Traditionally, wear characterization has relied on a tribological system consisting of two contacting solids, a third body (debris or reaction products), and the surrounding environment. The wear behaviour of such a system is governed by its tribological circuit, which is sensitive to each component's properties. During contact, most of the dissipated energy manifests as heat, potentially altering material properties through thermodynamic reactions like oxidation (as per Quin's theory). This thermal effect complicates the formulation of an accurate energy balance, as highlighted by Uetz and Fohl.

Despite existing standards for tribological system characterization, none specifically address emergency landings with retracted landing gear. Laboratory tribological tests must also account for representativeness at larger scales, a challenge that can be approached by using dimensionless numbers, such as the Reynolds number in fluid mechanics. Kline suggests that experiments are similar when their respective dimensionless numbers match across different setups. In recent years, Deletombe et al., working with the Mechanics, Multiphysics and Multiscale Laboratory, have developed a prototype abrasion bench specifically tailored for emergency landing scenarios.

This prototype was completed and installed at ONERA's Lille facility in early 2024. It allows for experiments involving spiral trajectories, facilitating controlled contact between a surface representative of an aircraft and a "clean" runway surface, free from debris or aircraft material remnants. The objective of this study is to introduce this novel abrasion test bench, detail its operational principles, and present findings from initial testing.

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The prototype comprises two main components: a "runway" represented by a rotating disk driven by a brushless motor, capable of reaching 2,700 rpm; and an "aircraft" component embodied by a test specimen made from the material under investigation. The disks, which can measure up to 400mm in diameter, enable the test piece to achieve speeds approaching 60 m/s, typical of civil aircraft during runway contact. Constructed from gabbro, a rock with concrete-like properties but greater resistance to ensure operational safety and prevent disk explosion, these disks provide a robust testing platform. A six-axis robot arm, equipped with a three-axis load cell and a heavy mass, is employed to bring the "aircraft" test specimen into contact with the rotating disk. The robot's control system allows for precise positioning of the test piece at various radius on the disk, enabling both circular and spiral trajectories that simulate different contact scenarios. With adjustable arm speeds ranging from 0.025mm/s to 320mm/s, a wide array of trajectories can be realized, facilitating comprehensive material testing under diverse conditions.

The prototype's versatility in executing various trajectories, thanks to precise disc and robot controls, has enabled the study of different materials in multiple configurations. Among these are aluminum 2024Ti53 and two advanced materials from Pyromeral: Tactylit and Pyrosic. In addition to the load cell, which measures normal and frictional forces, an optical displacement sensor was used to measure sample wear during the experiments. A high-speed infrared camera assesses surface temperature increases of the tested materials, with data corroborated by thermocouples affixed to each specimen's surface. A visible camera captures real-time degradation of the samples upon contact with the disk. Preliminary results on circular trajectories highlight a difference in wear behaviour between contact at an inner radius and an outer radius (at the same speed seen by the test specimen), with more significant wear at the edge of the disk than its center, leading to a higher macroscopic friction coefficient in the first case. These initial tests have allowed the familiarization with this new abrasion prototype. The comparison of circular and spiral tests is the next step in this research.