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► **To cite this version:**

Tovignon Devo, Didier Joly, Arnaud Beaurain, Éric Deletombe, Yannick Desplanques. Study and characterization of wear and heat phenomena, for metallic and composites aircrafts' structural materials, during emergency landings.. 17th LACCEI, Jul 2019, MONTEGO BAY, Jamaica. 10.18687/LACCEI2019.1.1.504 . hal-02393400

HAL Id: hal-02393400

<https://hal.science/hal-02393400>

Submitted on 4 Dec 2019

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Study and characterization of wear and heat phenomena, for metallic and composites aircrafts' structural materials, during emergency landings.

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Abstract – Aviation is one of the safest public transport means today. To reach such a performance, aircraft safety mainly relies on experience feedbacks and a set of constantly evolving rules which concern the flying products and operations. This also works for emergency landings or crash situations wherein the aircraft “belly” is directly in contact with the runway (Figure 1).

For this purpose, a four years research project (PHYSAFE) funded by the French DGAC started in August 2015. Part of the research aims at experimentally studying and characterizing various phenomena which may have a noticeable influence on aircraft passengers’ safety in case of emergency landing or crash. Among these experimental studies, the development of test means and facilities to characterize the dynamic wear behavior of aircraft primary structure materials once in contact with the ground was selected as being of common interest for aircraft and rotorcraft airframes.

The part of the PhD work to be presented is notably focusing on the study and characterization of wear and heat phenomena, for metallic and composites aircraft structural materials (reference materials: Au2024, T700/M21) during emergency landing situations. It aims at estimating (through “pin on disc” tests [1]) the main phenomena and principles to be taken into account for an experimental protocol (test bench, specimens, instrumentation, etc.) dedicated to the study of wear and heat of materials in representative conditions, followed by a first comparison of metallic and composite reference materials performances.

The methodology set up to partially answer the studied problematic, starts with pin-on-disc tests using a concrete pad and discs made of aluminum or composite material. The preliminary experimental design permits to observe the results of interactions between concrete and the materials like in an aircraft fuselage.

A first identification of the tribological systems representing the studied contact, aims at defining the first bodies and the third body produced within the studied contacts. Once the tribological mechanisms identified (by post mortem and in-situ analysis), an estimated dissipated energy may be linked to those mechanisms through the writing of material and energy balances [2,3].

A future step of the work would concern the study of possible similitude rules (through non-dimensional numbers establishment relying on the Vaschy-Buckingham’s theorem [4]), for a selection of identified wear and abrasion mechanisms, to check the possible extrapolation of experiments at a laboratory scale at full-scale level.

Keyword: wear, friction, tribology, experiments, emergency landing.

Digital Object Identifier (DOI):

<http://dx.doi.org/10.18687/LACCEI2019.1.1.504>

ISBN: 978-0-9993443-6-1 ISSN: 2414-6390



Fig. 1 LOT Boeing 767 from Newark to Warsaw Emergency Landing with no landing gear (Getty Images).

I. TRIBOLOGICAL SYSTEM & PRELIMINARY TESTS

A. Tribological system

In the studied problem, a tribological system can be defined including two first bodies (fuselage and runway), defining the contacting materials and surfaces, and a third body produced by the interactions of the two first bodies. Furthermore, the tribological system includes also the working system, here the whole aircraft and the landing area, defining the load and the sliding conditions, one of the main parameters been the stiffness.

B. Preliminary tests

The objective of the study is to design a reduced scale experiment to study the crash situation in a laboratory. However, it remains important to identify and understand tribological mechanisms that occur within the contact between an aircraft body and a concrete runway, which are up to now completely unknown. Therefore, preliminary pin-on-disc tests were realized using a concrete pad (as the runway material) and an Al2024 aluminum alloy disc (or a T700/M21 carbon fiber reinforced polymer composite.) The parameters chosen for the tests are presented in Table 1.

II. MATERIAL & ENERGY BALANCES

Having defined the tribological triplet, one may write a material balance (1) to characterize the wear of the 2 first bodies (disc, pad). For each first body, the wear would here represent the loss and possibly gain of materials during the contact then, considering the third body, one can obtain:

$$M^{i \text{fst body}}(t) = M_{\text{initial}}^{i \text{fst body}} + \Delta M_{\text{lost or gain}}^{i \text{fst body}}(t) \quad (1)$$

$$\sum \Delta M_{\text{lost or gain}}^{i \text{fst body}}(t) = \sum (Q_s + Q_r - Q_e - Q_w) \Delta t \quad (2)$$

where Q_j represent incoming and outgoing flows of the third body into the contact.

Considering the thermodynamics first principle, assuming that the contribution of the potential energy is negligible compared to the other energies' contribution, the following energy balance may be written:

$$\delta Q = dEc - dU - \delta W_{Fext} \quad (3)$$

Where dU is the "internal energy" which is dissipated by tribological mechanisms (abrasion, oxidation, etc.) The works to be presented are dedicated to the study of these mechanisms i.e. identification, modelling, and quantification according to the tests conditions. In situ (infrared) and post-mortem (SEM, optical microscopy) analysis were used to support this study (Figure 2).

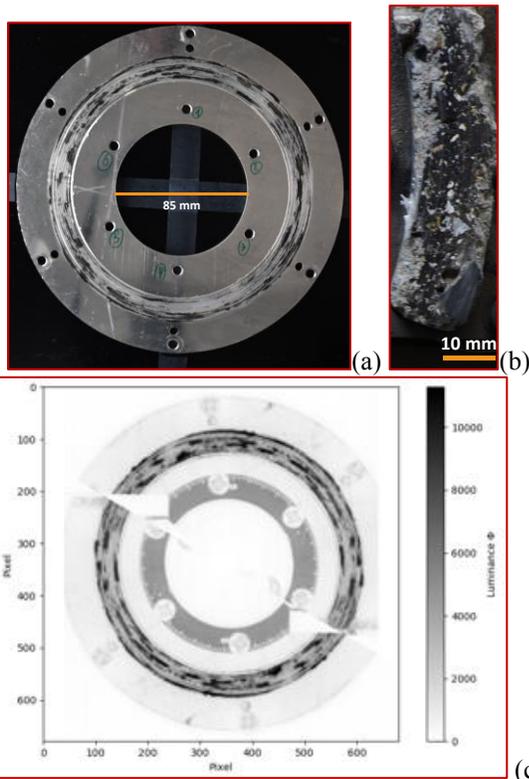


Fig. 2 Post-mortem aluminum disc (a) Post mortem concrete pad (b) IR image of the disc within the test (here at $t = 17$ seconds) (c)

III. ANALYSIS OF RESULTS

As described previously, a third body is produced within the contact and as different tests were carried with different parameters, it is interesting to identify its chemical and mechanical nature. That is to say to characterize its flow and determine if its production may reduce the wear or the load-bearing area.

Therefore, it was observed by SEM (Figure 3) revealing different phases present on the disc. The elements Si and Ca present in the concrete were detected upon the (Al) disc, as the main part of the third body (Figure 4).

Material used	Thickness of the disc (mm)	Thickness of the pad (mm)	Rotation speed (rpm)	Charge (kN)	Duration (s)
Al2024/T3	1.4	8	2000	1	20
	1.6	11	2000	0.5	20
	3	11	1000	1	20
	3.5	10	2000	0.5	50
	3.65	11	2000	1	20
T700/M21	4	10	1000	0.1	20
	4	10	1000	0.5	20

Table 1 Parameters of the preliminary tests realized

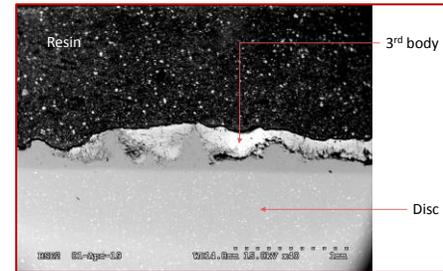


Fig. 3 BSE post-mortem radial section analysis of a part of the surface of the disc/pad contact

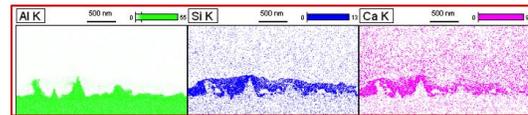


Fig. 4 EDS post-mortem radial section analysis of a part of the surface of the disc/pad contact

ACKNOWLEDGMENT

The authors thank A. Mège-Revil (Lecturer) and D. Najjar (Professor) for assistance with SEM analysis to be presented at the conference. The authors gratefully acknowledge the french DGAC that supports the PHYSAFE project, the European Union with European Regional Development Fund, the French State and the Hauts-de-France Region Council that support ELSAT 2020 project.

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