Energy balance during the interaction between a blade and an abradable coating

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This paper addresses the industrial problem of blade-tip / abradable coating interaction in aircraft engine which may lead to blade failure. An energy balance at the rubbing contact is established through experimental analysis of interactions on a simplified test rig, coupled with inverse simulation models for heat flow estimation. The proposed method highlights the evolution of energy partition between the blade and the abradable coating according to the interaction condition.
Keywords: energy balance, blade/coating interaction,

1. Introduction

Aircraft manufacturers want to improve their engines to be more efficient, while reducing fuel consumption, emissions of pollutant gazes and noise levels. Improving performance therefore requires reducing the radial clearance at the top of the blade. Abradable coatings sprayed on the inner part of the casing are commonly used solutions in aeronautics. Their role is to guarantee the engine integrity in case of rotor-to-stator contact. Even in the presence of abradable coatings certain operating conditions can lead to divergent dynamic response of blades up to cracking or breaking [1]. The understanding of physical mechanisms during interaction must be done and is achieved by an energy balance, which is the aim of the paper.

2. Method

2.1. Experimentation
Short parabolic incursions of a titanium blade in an AlSi-Po abradable coating are performed on simplified test rig already used in [2] and shortly described on Figure 1.

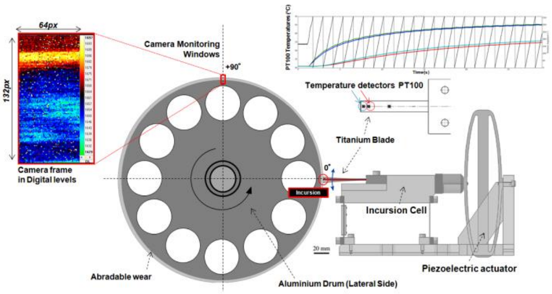

Figure 1: Schematization of the test rig and its instrumentation.

In order to achieve the energy balance and in addition to the force and displacement measurements, a rich instrumentation is added with the measurement of the blade heating (PT100 temperature sonde probe) and abradable coating heating (IR camera).

2.2. Equation of the energy balance
The energy balance equation may given by [3]:

$$\delta W^{abra} = \delta Q^{blade} + dE^{abra}_{p,micro} + dK^{abra}_{micro} + e^{abra}_{out} dm^{abra}_{out}$$

The mechanical work dissipated by friction is split into remaining terms:

- The amount of heat in the abradable coating: dK^{abra}_{micro}
- The amount of heat in the blade : δQ^{blade}
- Mechanical energies from reversible, irreversible and dissipative mechanism : $dE^{abra}_{p,micro}$
- Energy exchanges evacuated with abradable debris: $e^{abra}_{out} dm^{abra}_{out}$.

Quantities of energy dissipated in the form of heat is estimated throughout exploitation of temperature rises induced by the interaction using analytical [4] and numerical thermal model to determine the quantity of generated flux. The mechanical work is determined from the force and displacement measurement.

3. Discussion

Figure 2 presents the energy balance during a short incursion: 10% of mechanical work is used for the blade heating, 80% for the abradable coating heating and the rest is dissipated in debris and irreversible mechanism of the abradable coating.

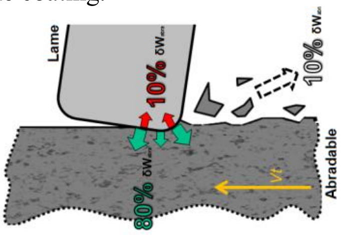

Figure 2: Result of the energy balance.

It also may be noticed that the instantaneous heat flux dissipated in the abradable coating is not constant during of the incursion. Future works may consider all generation, storage and energy loss that participate in the accommodation of the incursion. Wear mechanisms must be introduced in the completed energy balance.

4. References

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