THERMAL INVESTIGATIONS ON SCUFFING USING A TWIN-DISC MACHINE

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Context

Fig.1 Gear presenting scuffing traces

Scuffing is defined in the literature as "**gross damage characterized** by the formation of **local welds** between the sliding surfaces" [1]. This localized damage suddenly appears when the **frictional heat generated at the contact induces a critical temperature increase**.

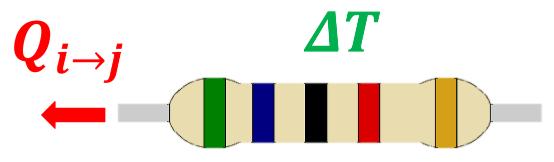
Numerous studies were conducted in order to establish a **scuffing criterion**. Some of them focus on the **power dissipation inside the contact** (product of the sliding speed and the load) [2] some others compare **the minimum film thickness of lubricant** separating the surfaces to the surface roughness [3,4]. In 1937 Blok introduced a **thermal scuffing criterion** [5]: each combination of base-stock lubricant and material has a characteristic scuffing temperature.

The present study proposes a **thermal model** based on **correlations between experimental tests** performed on a twin-disc machine and **numerical studies using the thermal network methodology** in order to better understand scuffing.

Thermal Network

The numerical study is based on a **thermal network analysis** of the twin-disc machine, which associates the heat generation due to power losses and the thermal dissipation. This analysis is derived from an **electrical analogy of Ohm's law** [Figure 2], and similar approaches applied to gearboxes have been successfully presented [6,7].

The twin-disc machine is divided into **discrete isothermal elements** also called "nodes", such as the housing, the shafts, the lubricant, the discs, etc.. These nodes are then **connected by characteristic thermal resistances**, which represent the different types of **heat transfer** (conduction, convection, radiation) [Figure 3].



$$\Delta T = R_{th} \times Q_{i \to j}$$

Fig.2 Thermal analogy of Ohm's law

The aim of this thermal network is to evaluate the temperature of different elements and more specifically the **bulk temperature of each disc**. In fact, as the Blok criterion sums the bulk temperature with the flash temperature, it should be relevant to determine these bulk temperatures with a greater accuracy instead of considering this to be equal to the oil injection temperature. Numerical results obtained with the thermal network model show that the **disc bulk temperature can be very different from the oil injection** one [Figure 4].

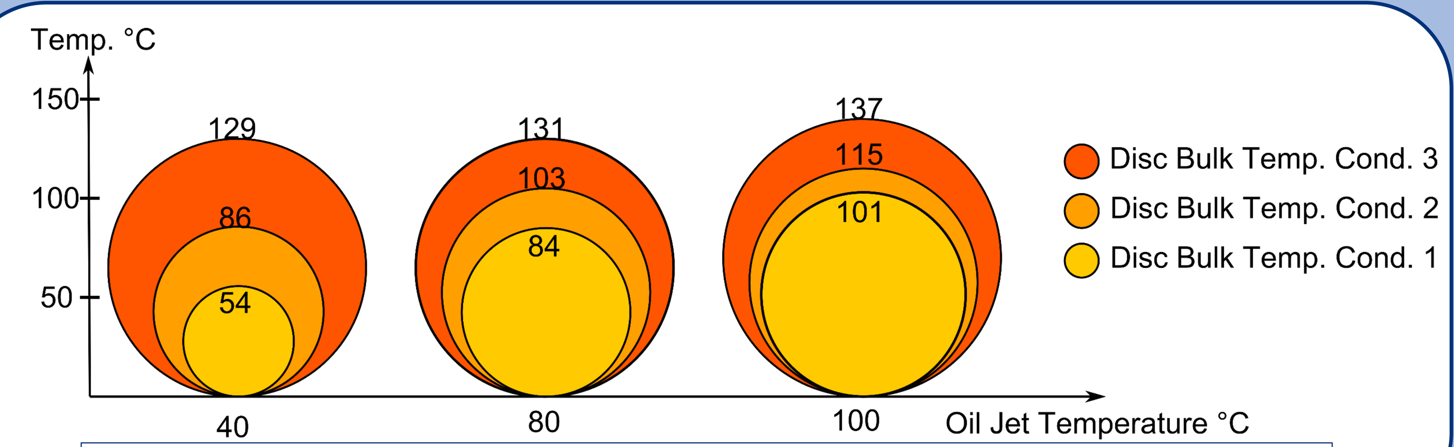


Fig.4 Disc Bulk Temperature in function of Oil injection temperature

Condition 1 : *Hertz pressure 1.1 GPa, Peripheral speed 20m/s, SRR 10%*
Condition 2 : *Hertz pressure 1.5 GPa, Peripheral speed 20m/s, SRR 10%*
Condition 3 : *Hertz pressure 1.8 GPa, Peripheral speed 20m/s, SRR 10%*

Thermal Network

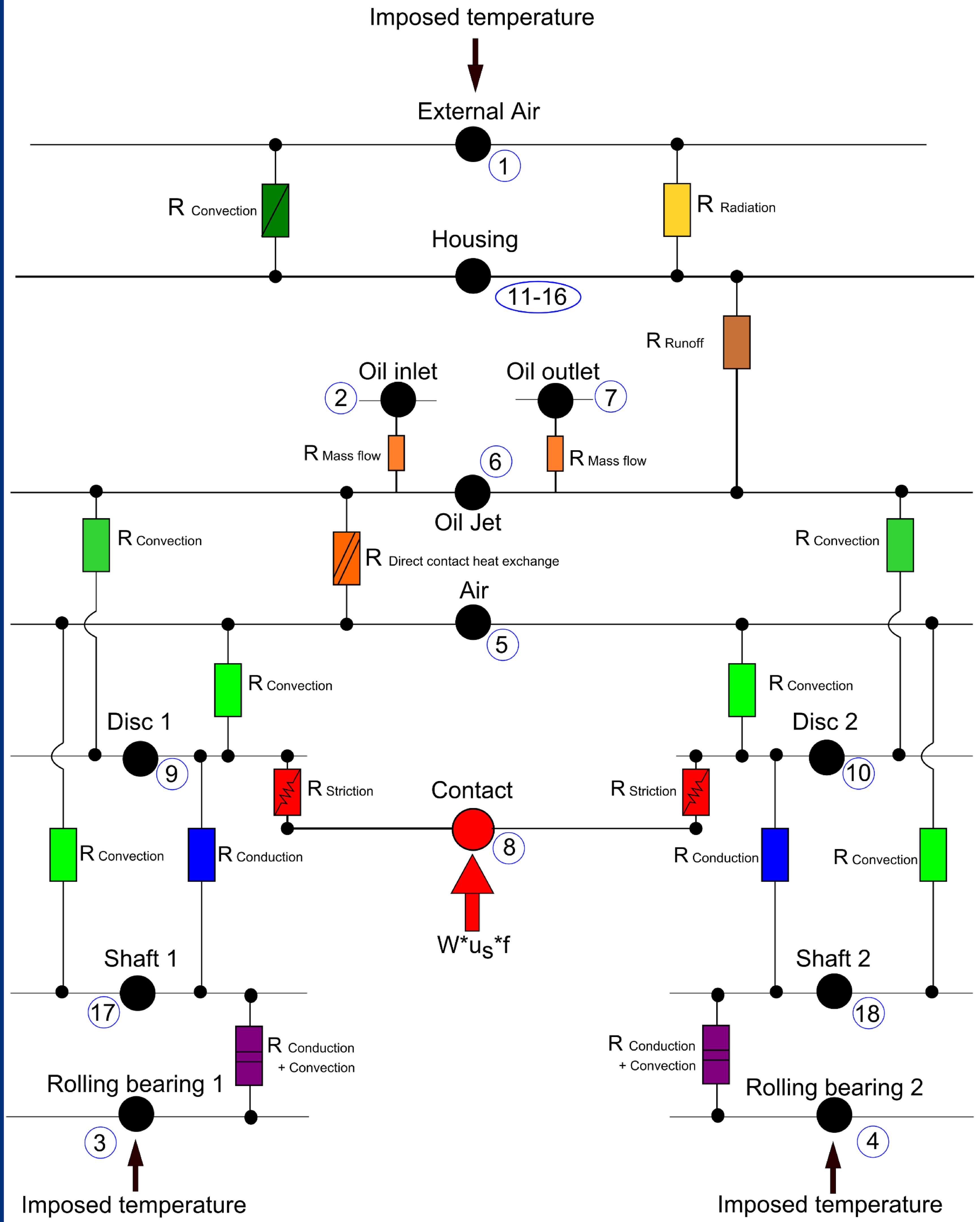


Fig.3 Thermal Network of the twin-disc machine

Twin-disc test rig and methodology

The twin-disc machine **simulates the contact conditions between gear teeth** (gear transmission) or between ring and rolling elements bearings. The machine is composed of **two discs independently driven** by motors in order to allow sliding conditions, and the load can be applied thanks to a pneumatic jack [Figure 5].

Specifications :

Hertz pressure:	0.1 - 4 GPa
Rolling speed:	2000 – 14000 rpm
Slide to roll ratio:	0 - 75 %
Oil temperature:	40 - 100°C
Ra:	0.05 - 0.4 µm
Material:	32CDV13 nitrided

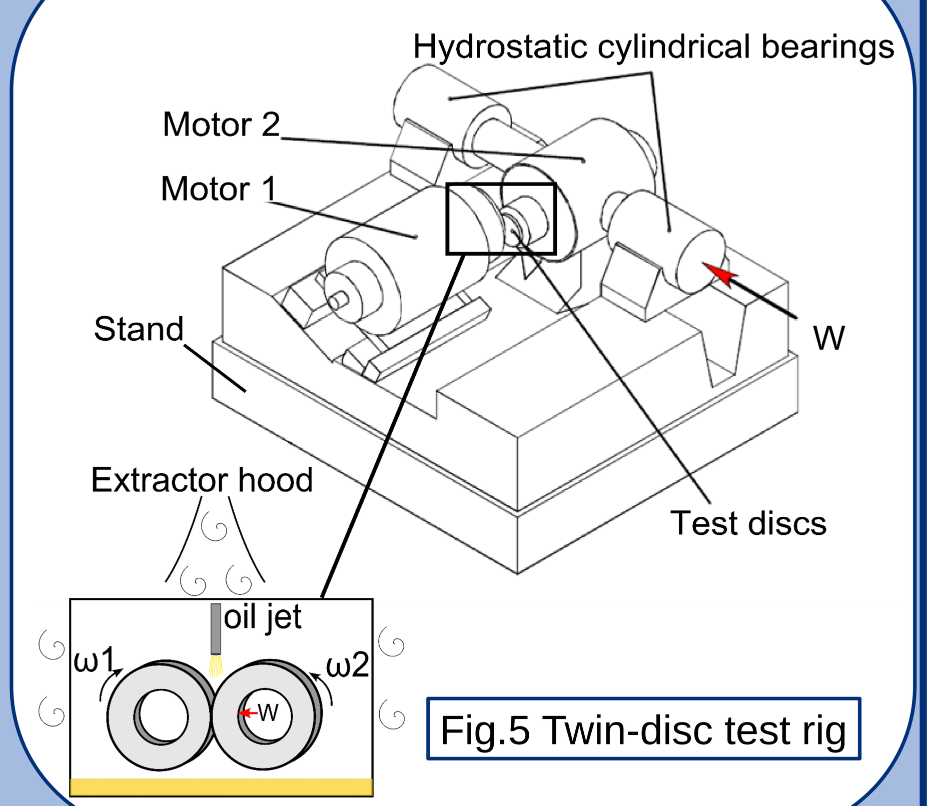


Fig.5 Twin-disc test rig

This test rig is designed to study the behavior of a given couple lubricant and disc material under different operating conditions and to perform traction curves and/or scuffing tests [8]. Numerous sensors have been placed on the twin-disc machine to measure the evolution of temperature and friction coefficient according to contact conditions in order to validate the thermal network.

Conclusion and future work

Fig.6 Discs presenting scuffing traces

- The literature review (e.g. standards) revealed that the oil injection temperature is sometimes used instead of the disc bulk temperature to calculate the scuffing temperature proposed by Blok. Calculations show important differences.
- Further tests have to be performed with the twin-disc machine :
  - to validate the thermal network.
  - to conclude onto the influence of element temperatures on scuffing.

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