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Coupled study hydrodynamic and thermal behaviour of a ventilated disc brake

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Abstract: Optimization ventilated disc brake requires a thorough knowledge of the hydrodynamics of the air flow through the ventilation ducts of the disk to determine the design to facilitate the evacuation of heat by friction pads engaging the disc.
In this work we present the results of numerical simulation giving behaviors coupled hydrodynamic and thermal cooling air on the one hand, and the thermal behavior of unsteady ventilated disc, on the other hand.

Key words: hydrodynamic, thermal, disc brake.

1. Introduction

Wide consultation literature on previous experimental work on the thermomechanical behavior of disc brakes [2,3,7], we found that studies on this subject are limited to the knowledge of the distribution of temperatures only at the disc surface. As for numerical work [5,6,8,9,10], they are often based on simplifying assumptions and limited to the study of hypothetical scenarios braking and relate to conventional braking systems.

In this work, we propose to determine the temperature distribution in the disk as well as in the surrounding air. For this purpose, we coupled calculations in the subdomains corresponding disk on the one hand, and the air is flowing in the grooves is at the outer sides of the disc, on the other hand.

The results are presented in the particular case of a braking stop duration t_f = 1.72 s with constant deceleration 8m/s^2 from an initial speed of 50km / h.

2. Mathematical formulation

Our system study is a ventilated disc brake consisting of two plates connected by twenty six solid ribs forming between them twenty six ventilation channels.

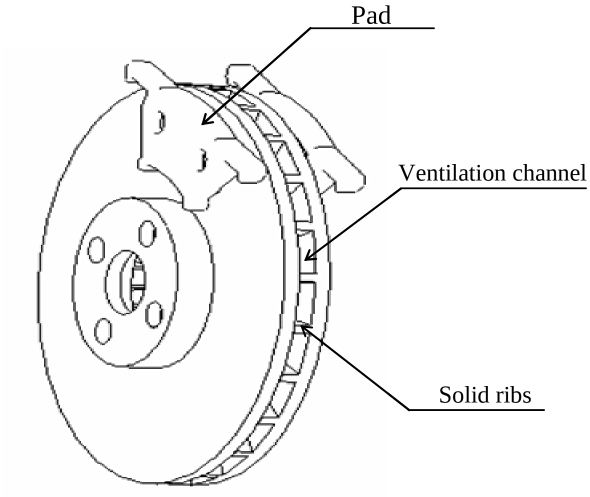

Fig. 1 device studied

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The equations describing the flow of air in the channel and heat transfer resulting in turbulent flows are derived from the Reynolds decomposition of hydrodynamic and thermal variables followed by taking the time-averaged Navier-Stokes and instant energy equations. The closure of these equations is performed by a first-order k-ε turbulence model.

- Thermal energy equation relating fluid

$$\frac{\partial T}{\partial t} + \mathrm{div}\left(\vec{\mathbf{V}}\, T - \frac{2\, d_e^2}{\pi\, Pe}(1+\lambda_t)\, \mathrm{gra}\vec{\mathrm{d}}T \right) = 0$$

3- Results and interpretations

3.1- Velocity field

Reasoning by symmetry, the calculation of hydrodynamic behavior is undertaken in a single channel speeds varying, step by step, from the initial velocity to zero velocit. The velocity field in its entirety is then reproduced by periodicity in the 26 ventilation channels dug in the disk, in order to calculate the temperature field in the whole disc. The target deceleration is constant, there is then a linear variation in the speed.

Figure 2 shows the spatial distribution of the resultant component of radial and tangential velocity to the inside of the ventilation channels, at the median plane of the disc. From this figure reproduced at the moment when the Reynolds number is equal to 50000, it is seen that air enters the cooling fin to undergo centrifugation effect of disc rotation. This flow is for pumping the heat source is at the contact pad-disc and propagates by conduction in the disc. It can be seen the formation of a small recirculation to the output of the flutes.

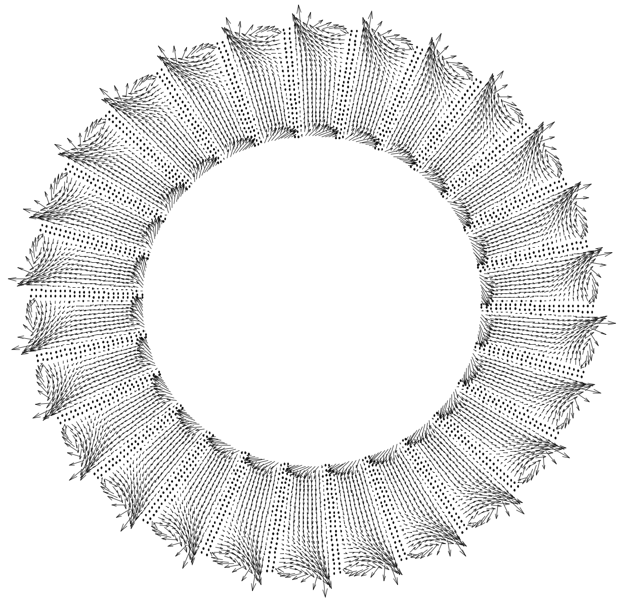

Fig. 2 Velocity fields in the median plane of the disc

3.2- Temperature field in the disc and its environment

Figure 3 shows the temperature distribution of the disk on its contact surface on the left, and the temperature distribution of the air at the periphery of the disc. We note that at the beginning of braking, figure (3-a), the hottest zone is concentrated in the area of contact with the pad. Outside the contact area, the surface swept by the pad already undergoes a start of heating, while the surface not scanned remains at a temperature approximately equal to ambient temperature. At this plane occupying the surface of the disc, the supply air is at a temperature much lower than those of the disc.

Following the change over time in figures 3-a, 3-b and 3-c, we note that the area swept by the pad heats up more and more sensitive. Meanwhile, the temperature distribution on the surface of the disc tends to become uniform. Thus, at the end of the braking operation, fig (3-c), the temperature in this area is almost homogeneous. In contrast, the air surrounding the large radius of the disk undergoes only slight heating and remains at a temperature very close to that of ambient air.

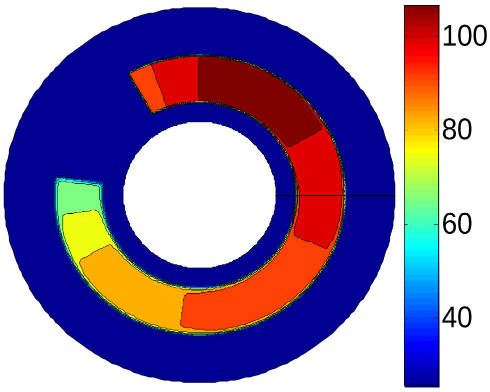

Fig. 3-a: t=0.1 s

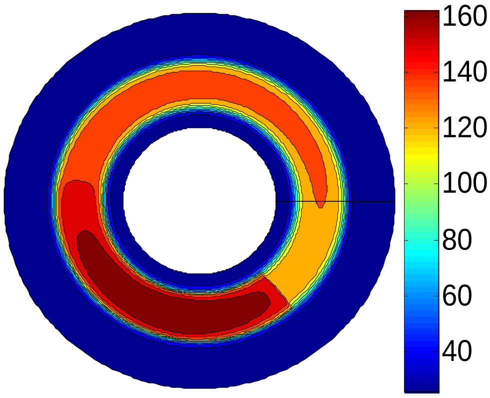

Fig. 3-b: t=1 s

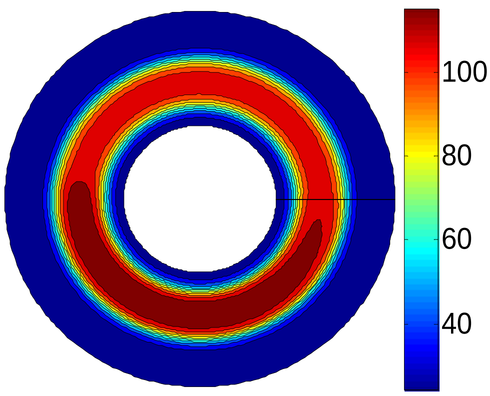

Fig. 3-c: t=1.72

Fig. 3 Evolution over time of the temperature in a plane intersecting the contact surface left

The distributions of temperature over time on the contact surface on the right (the side of the hub), are shown in figures (4-a) to (4c). Although, we note from observation, from these figures, that the contact surface, side hub, warms slightly more than the other side of the disc. This is quite normal because this area is enclosed by the hub, while the other surface is in direct contact with the ambient air from the outside environment.

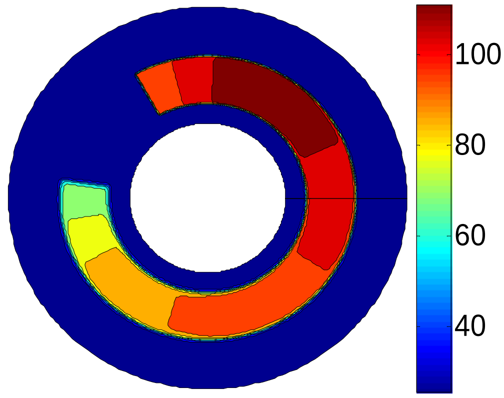

Fig. 4-a: t=0.1 s

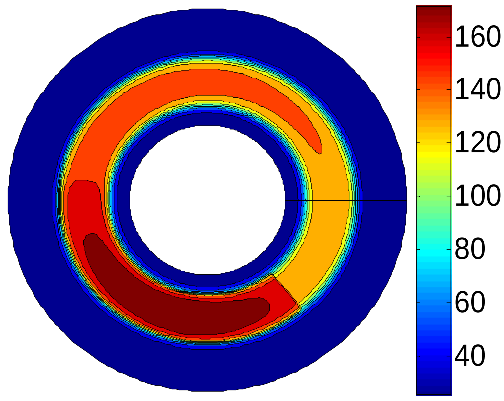

Fig. 4-b: t=1 s

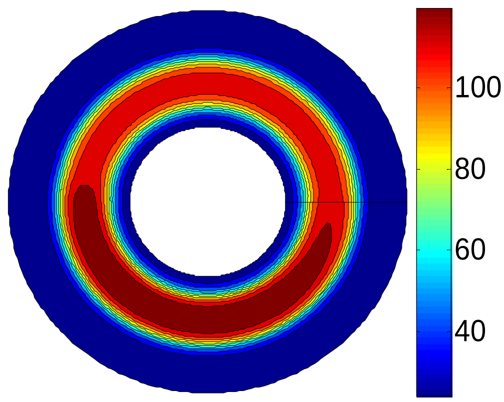

Fig. 4-c: t=1.72 s

Fig. 4 Evolution over time of the temperature in a plane intersecting the straight contact surface

4- Computer code validation

The figure 5 shows the temperature field at time t=3.287s, calculated by our code for a braking stop duration t_f= 4.274 s from an initial speed of 100 km / h. The figure shows the temperature field at the same time and for the same braking conditions given by Gao and al. There is a great resemblance quantitative level and qualitative shape of the isotherms at temperature values between the two figures which constitutes a validation of our thermal calculation code.

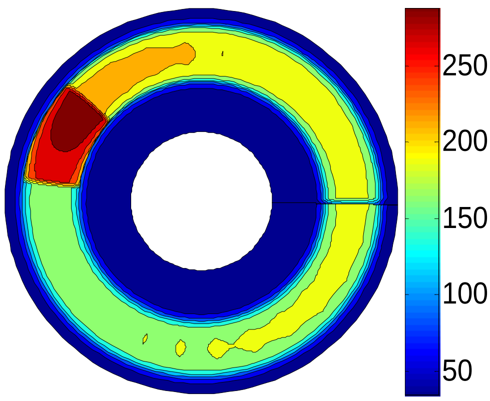

Fig. 5 Temperature field at time t = 3.287s calculated by our code

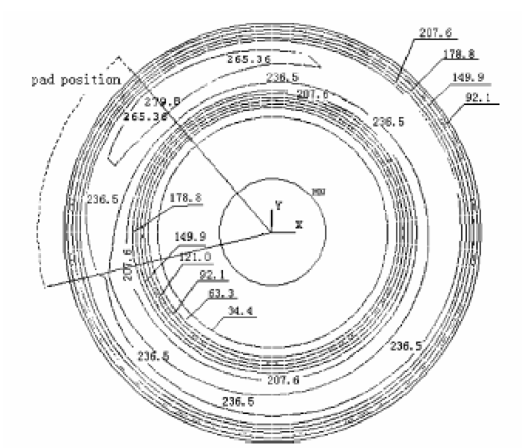

Fig. 6 Temperature field at time t = 3.287 s calculated by Gao et al

5- CONCLUSION

In the general context of the development of local knowledge of heat transfer phenomenon in ventilated disc brake, we have built a computer code with the following performances:

- the laminar flow simulation, transitional and turbulent in the ventilation ducts of the disc brake,

- simulating the thermal behavior of the unsteady disc brake,

- modeling taking into account the friction of the pad against the movable disc, developing a new technique called "Sliding Boundary Condition" which allowed us to take into account the spatial and temporal variability of heat flux generated by friction and update its value in function of the speed and braking scenario,

- Visualization of unsteady temperature fields which comply following scenarios braking whatsoever.

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