Performance Brake Systems

CANADIAN CARBON CERAMICS

MadHatterBrakes

TECHNICAL NOTE 7.0 (Rev. A)

Cooling Effects on Vane Geometry – Focus on Pillar vs Curved Vane Design and the Number & Orientation of Structures.

Background

This technical note is a summary review of a research paper by Dr. Yuping He et al, Faculty of Engineering and Applied Science, University of Ontario Institute of Technology, Oshawa, Ontario, Canada. The article was originally published in *"Transactions of the Canadian Society for Mechanical Engineering"* in June 2008. While this Technical Note is a summary of the findings, the full paper can be read at:

https://www.researchgate.net/publication/295265524_Effects_of_brake_disc_geometrical_parameters_and_configurations_on_automotive_braking_thermal_performace

Dr. He and his team evaluated the thermal performance of two (2) primary types of vane designs: the "Pillar/Post" design and the "Curved Vane" design. Analysis was done evaluating both the geometry and orientation of the structures, as well as the affect of increasing the number of structures in both designs. This analysis was done using Computational Fluid Dynamics (CFD) software. The paper also cites many interesting historical studies around this topic, for further reading.

Figure 1: Pillar & Curved Vane Designs Being Studied

Summary of Findings

1. Heat dissipation directly off the face of the friction plates, accounts for 2/3's of the total convective heat transfer. The remaining 1/3 comes from cooling via the internal vanes. Thus, a somewhat significant improvement in the vane cooling design (for instance; +20%), would result in an overall cooling efficiency improvement of only +7%. The metallography of the grey iron material, its' molecular structure and heat transfer coefficient properties is the most significant determination of heat dissipation.
2. Heat dissipation off of the curved vane rotor geometry is 25% greater than for pillar design from speeds between 24 & 64 km/hr. As speed increases, this gap diminishes in a linear fashion.
3. For pillar geometry, the optimum number of pillars is 224 structures. Beyond this number, the pillars begin to obstruct air flow and cooling is diminished.
4. For traditional curved vane design (as shown in Figure 1), the optimum number of vanes is 64. Beyond this, the vanes begin to obstruct air flow and heat dissipation is diminished.
5. Increasing the physical size of the pillars or the width of the vanes, increases the heat transfer rate in a somewhat linear fashion. This is assumed due to basic increases in the surface areas contacting the air, as well as increased thermal mass dissipation. These structural increases must be weighed against the increased mass of the rotor.
6. Curved vane geometry offers significantly better heat transfer than pillar designs, in all test parameters. At speeds approximating 55km/hr, 110km/hr and 150km/hr, the curved vane design is +55%, +46% and +39% better at heat transfer, respectively. Taking into account that only 1/3 of the total heat dissipation is via internal heat transfer, the total "real-world" improvement between a curved vane design and pillar design is +18%, +15% and +13% respectively – which is still significant.

Conclusions

Curved vanes offer a significant improvement over pillar design, in every configuration. In more recent years, manufactures have introduced new and more complicated curved-vane geometry, to improve heat transfer at an incremental level. Some of the more promising designs utilize air-foil designs to shape and increase the air flow, entrance and exit changes to optimize pressure zones, and additional shaping to the curved vanes to increase turbulence, surface area and air flow without dramatically increasing the material (mass) used in the vane designs.

PBS believes that while these improvements are positive, we must keep in mind that 2/3's (66%) of the overall heat dissipation occurs off of the friction disc surfaces. More research needs to focus on advanced materials which offer similar or better coefficients of friction and improved heat transfer over HT150/HT250 grey iron, yet do not increase the manufacturing costs dramatically. Carbon Ceramic rotors offer significant improvements over grey iron, however manufacturing costs need to be reduced by 70%+ for wide market adoption.