Analysis of an Automobile Disc Brake

H. Krishnan[1], T. Zhu[1], Y. Zeng[1]

[1]University of California Los Angeles, Los Angeles, CA, USA

Abstract

INTRODUCTION: Disc brakes systems are typically used in the automotive industry for stopping or decelerating vehicles by forcing brake pads onto the surface of the brake discs. The frictional heat developed during the braking action can cause brake failure, wear and thermal cracks. Brake discs usually have drilled holes on the surface and consist of different vane profiles which allow maximum airflow and cooling to quickly dissipate heat generated.The purpose of this study is to investigate the thermal and mechanical effect of a braking action on a ventilated carbon ceramic brake disc assembly - specifically of a Porsche 911 Carrera S model (Figure 1) and to determine the best vane profiles for maximum cooling and dissipation of heat. The study is further extended to determine the factor of safety for the optimal vane profile for the given material.

USE OF THE COMSOL MULTIPHYSICS® SOFTWARE: A coupled thermal, mechanical and fluid flow study have been conducted using the COMSOL® software to investigate the temperature and stress distribution on the brake disc. Mechanical simulation involves the clamping pressure and tangential frictional force developed during breaking. Fluid simulations involve the airflow within the brake disc assembly due to the motion of the vehicle and the thermal simulations include the frictional heat generated in the brake pad region, conduction of heat on the brake disc surface and heat transfer between the disc surface and external air due to both forced convection and radiation. Heat generated by friction during braking and the inlet/outlet pressures to simulate airflow within the brake disc assembly are both calculated separately. By simulating the brake disc assembly with various vane profiles, the optimal profile can be determined for maximum heat dissipation. The curve profile of the vane is characterized by the angles Φ〖,θ〗_1 and θ_2 as shown in Figure 2. Thermomechanical stress analysis is then carried out with the optimal vane profile to determine the factor of safety for the given configuration and material used.

RESULTS: The simulations clearly show how change in vane profile can affect the temperature (Figure 3) and stress distribution (Figure 4) within the assembly. Optimal design is obtained by sweeping all possible combination of parameters. From the simulation results, the final vane profile angles are determined to be Φ=15°, θ_1=20° andθ_2=10°. A factor of safety about 2.3 is calculated from the Von misses stresses.

CONCLUSION: The simulation study shows the effect of brake disc design on its temperature distribution. Optimizing the design by simply changing the vane profile can significantly improve the temperature dissipation within the brake disc and prevent failure

of ceramic brakes at high temperatures. Certain approximations have been used in this study such as using calculated average heat and fixing inlet and outlet pressure values for the vane profile. The simulation results can be dependent on the assumptions used such as heat flux and pressure inputs, physical parameters such as materials used and design of assembly and numerical parameters such as element size.

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Figures used in the abstract

Figure 1: Rendered assembly of Disc Brake

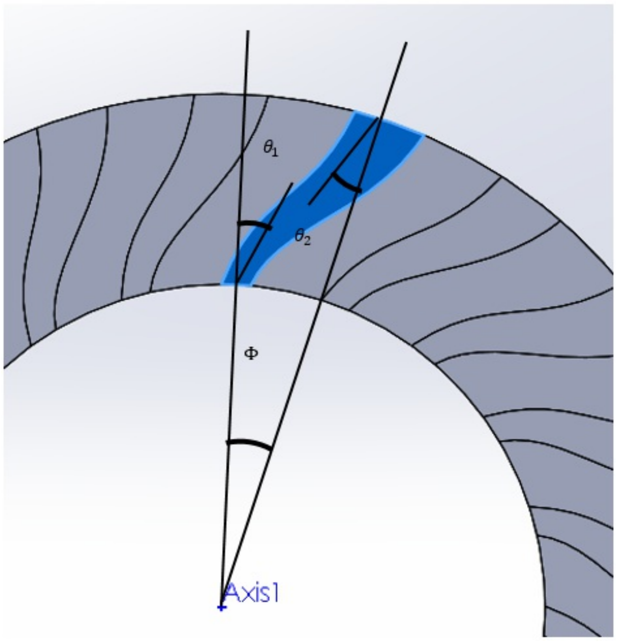

Figure 2: Vane curve profile

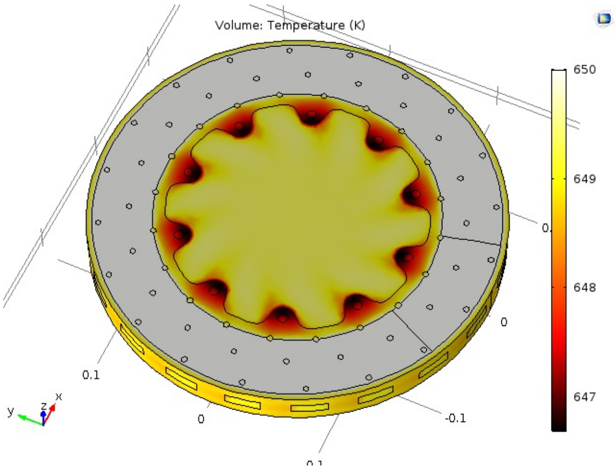

Figure 3: Temperature distribution within disc brake

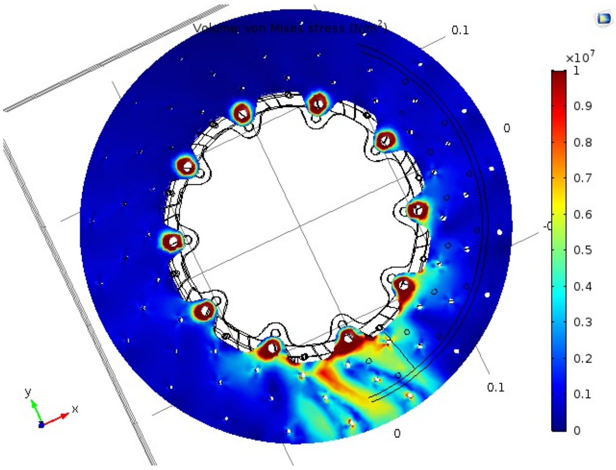

Figure 4: Stress distribution and radial expansion of disc brake