

COEFFICIENT OF FRICTION AND PERMANENT CHANGES IN A BRAKE DISC

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Abstract

The thermal performance of the brake system directly affects its safety and component lifespan, as the heat generated during braking can lead to material degradation, reduced friction coefficient, and permanent changes in the brake disc. This study presents the design and computational analysis of a passive convective cooling system for an automotive brake disc, aimed at improving heat dissipation without increasing system complexity. Coupled computational fluid dynamics and heat transfer models were used to compare a conventional brake system with the proposed system, evaluating temperature gradients and airflow under real conditions. Results show a significant reduction in brake system temperature, confirming that passive forced convection is a viable solution for enhancing thermal performance. Additionally, this approach promotes environmental sustainability by extending component lifespan, reducing material waste, and lowering brake dust emissions through minimized thermal degradation of friction materials.

Introduction

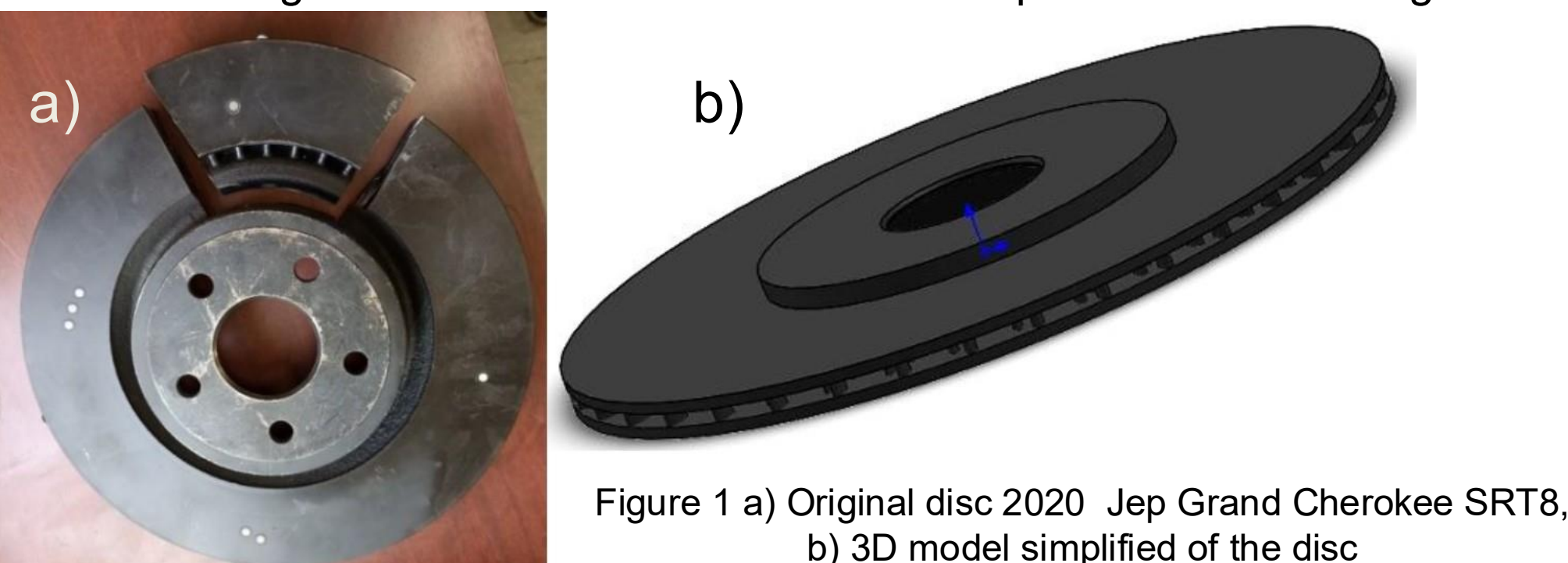
The braking system (BS) is essential for vehicle safety, converting kinetic energy into heat through friction. In disc brakes, the generated heat can cause microstructural changes, modify the friction coefficient, and accelerate material degradation, reducing performance under severe conditions. Repetitive braking may lead to brake fade, characterized by decreased efficiency at high temperatures [1, 2]. Previous studies have explored vehicle-induced airflow as a passive cooling mechanism, highlighting the role of convective heat transfer in rotor temperature distribution. Computational fluid dynamics (CFD) enables the optimization of these strategies without extensive experimental testing. However, thermal overload remains a challenge affecting durability and costs. Thus, this work proposes a passive cooling system to redirect airflow toward the brake disc and pad, aiming to reduce temperature peaks, improve heat dissipation, and extend component lifespan [3, 4].

Statement of the Problem

Thermal management of braking systems has become increasingly important, especially in high-performance applications where airflow is used to improve heat dissipation. In sport utility vehicles (SUVs), the greater vehicle mass and frequent full-load operation increase braking energy demands, making front brake discs more susceptible to overheating. Repeated exposure to high temperatures can cause microstructural damage, reduce the disc-pad friction coefficient, and decrease braking efficiency, which compromises vehicle safety. In addition, thermal degradation accelerates wear, shortens component lifespan, and increases maintenance costs, making periodic inspections essential for ensuring braking system reliability.

Material and methods

The methodology involved the direct geometric characterization of a brake disc through controlled physical sectioning, allowing the measurement of its main dimensions and internal features. These data were used to develop a detailed CAD model capable of accurately representing the real component (Figure 1). The model was then implemented in COMSOL Multiphysics® to perform a coupled analysis of fluid flow and heat transfer. Based on the obtained temperature and velocity fields, the system was analyzed to identify critical regions, and a passive cooling system was designed and optimized to improve airflow distribution and heat dissipation, considering both thermal performance and manufacturing constraints. For this purpose, an original brake disc from a 2020 Jeep Grand Cherokee SRT8 was used (Figure 1). It was disassembled and subsequently sectioned in a controlled manner to expose its internal structure. This procedure allowed for the identification and measurement of geometric parameters, including the internal and external diameters, the total thickness, the arrangement and dimensions of the structural pillars, as well as the intermediate spaces that form the internal ventilation channels. The information obtained was used as the basis for reconstructing the CAD model used in the subsequent simulation stages.



Based on the resulting temperature and velocity fields, a passive cooling system was designed to redirect airflow toward critical heat accumulation regions. The system geometry was defined considering manufacturing feasibility and commercial availability constraints, such as standard automotive pipe dimensions and the available space within the vehicle as shown in Figure 2.

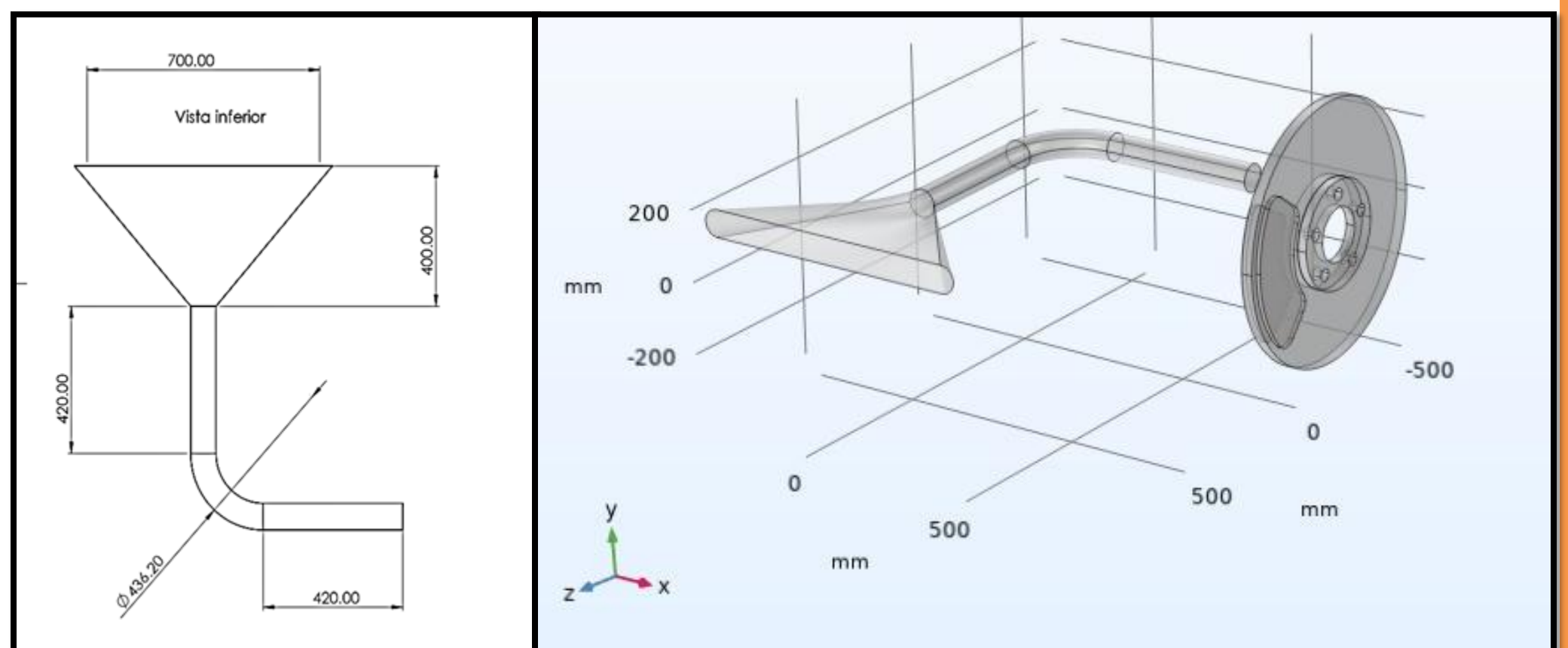


Figure 2. a) Preliminary design of the cooling system (the dimensions are in mm), b) Cooling system coupled to the original brake system

Results

The presence of streamlined with reduced turbulent energy loss enables more efficient air circulation around the disc. Figure 3 illustrates improved heat dissipation during braking. Consequently, the system exhibits enhanced cooling performance due to the increased convective capacity of the flow.

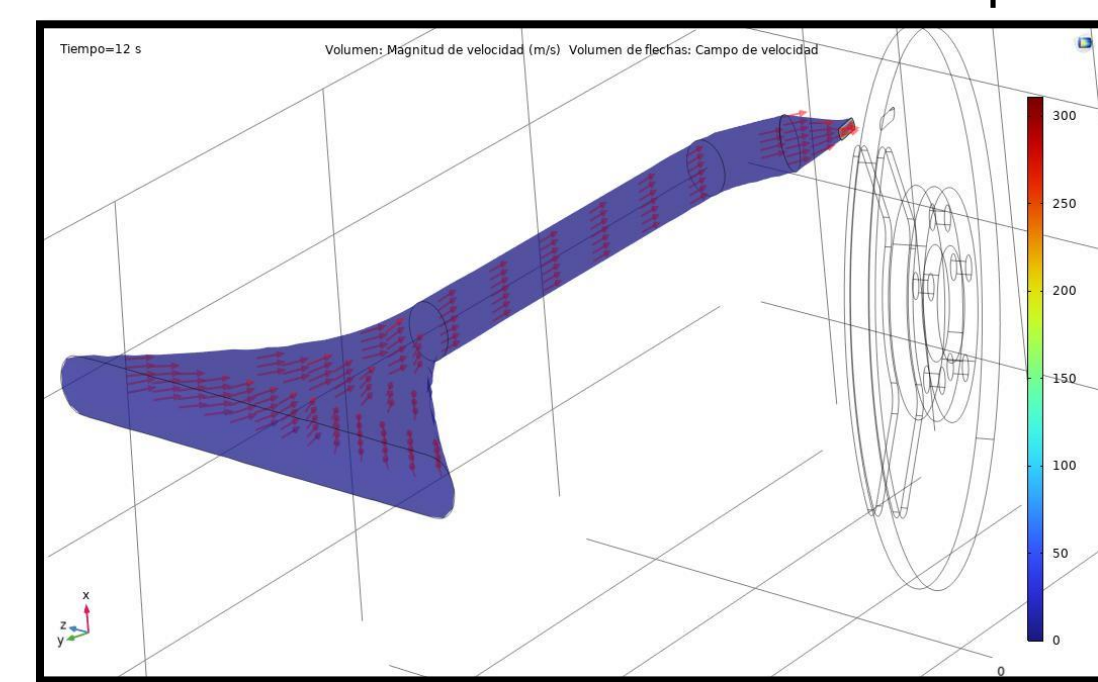


Figure 3. Velocity vectors of the cooling system coupled to the braking system

Conclusions

CFD analysis enabled the comparison of three configurations: an uncooled disc, a preliminary cooling system, and an optimized system. Results (Figure 4) showed a progressive improvement from the uncooled to the optimized case, with enhanced airflow stability, reduced vorticity, and increased heat dissipation. The uncooled disc reached temperatures above 100 °C, while the preliminary system significantly reduced peak temperatures, and the optimized design achieved a more uniform thermal distribution, minimizing hot spots and improving overall thermal performance.

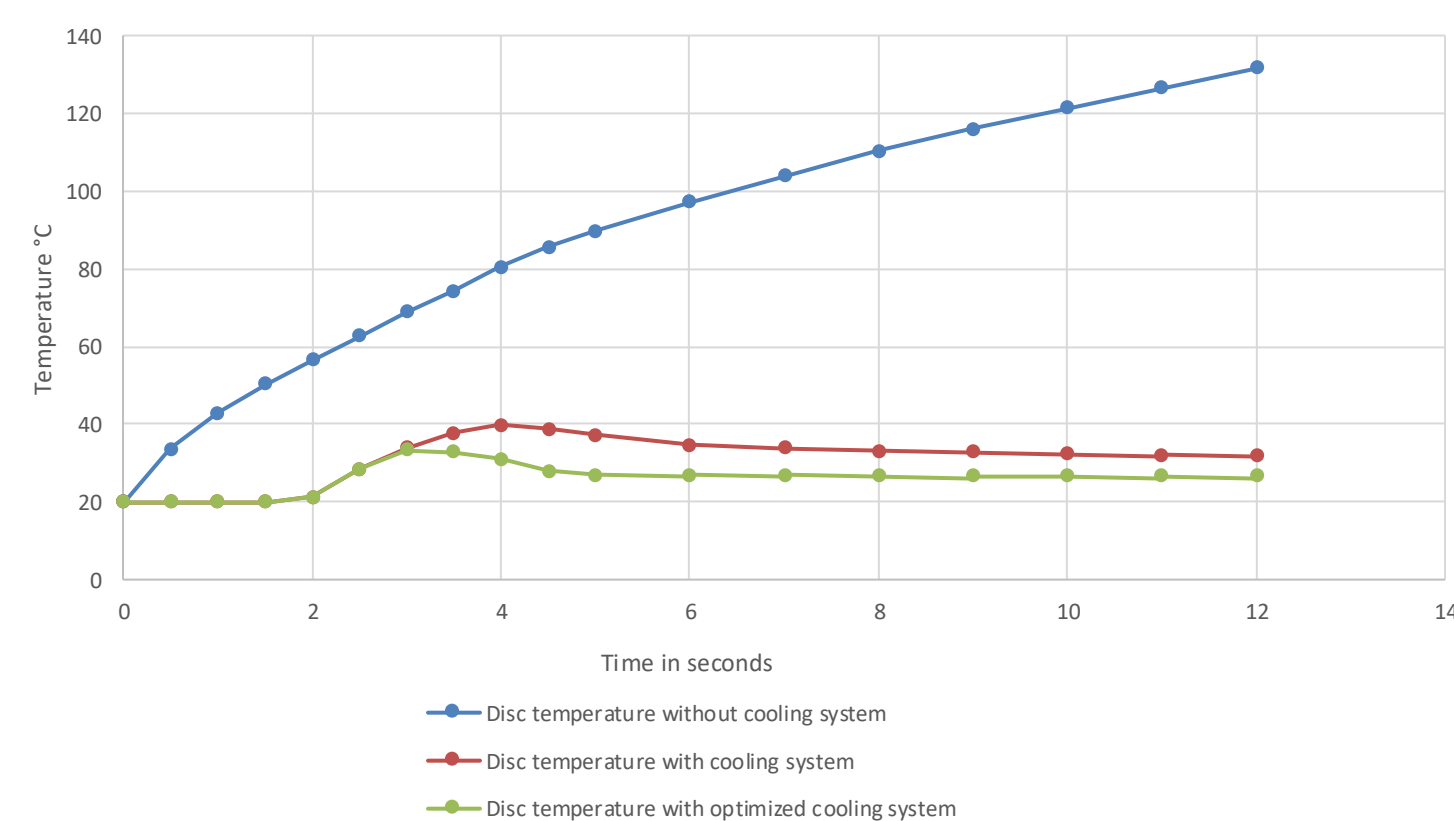


Figure 4. Disc and brake pad temperature analysis during real-life braking over time with the optimized cooling system

References

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