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# Research On Optimizing Brake Disc Shape To Improve Cooling Capacity Using Ansys Fluent Software

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***ABSTRACT:*** *Safety features of a new vehicle have always been a top priority throughout the development of the automobile industry. A moving vehicle needs a braking system to be able to control its speed and stop as required. During the braking process, the heat converted from the kinetic energy of the car's motion causes the temperature of the brake mechanism to increase, which results in overheating in brake components and then brake failure. This phenomenon is so dangerous for humans and goods on the vehicle. Therefore, in order to stabilize the temperature of the brake mechanism, ANSYS-FLUENT software is used to simulate, calculate and investigate the heat transfer of brake discs with different structures to the surrounding environment. After that, the most reasonable proposals for improving brake discs will be probably made.*

***KEYWORDS:*** *Disc brake, Static Analysis, Thermal analysis, temperature.*

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## I. INTRODUCTION

To slow down the vehicle or stop the vehicle at the driver's request, the car's brake system plays an important role. The braking system must be reliable enough to provide the driver with ability to control over speed. Frictional energy is the most common concept used in current brake systems when kinetic energy is converted into heat energy. The amount of heat generated is too large, leading to an increase in the temperature of brake components [1]. When the temperature of the components exceeds, and if you brake in a long period of time, the brake fluid might evaporate, causing brake failure. During braking, brake fluid pressure forces the brake pads to rub against both sides of the disc, so heat is generated. Most of this heat, approximately 90%, is absorbed by the disc through heat exchange by conduction [2, 3]. To achieve maximum braking performance, this heat has to be released to the surrounding environment as quickly as possible mainly by heat convection. The following features should be considered to keep the brake disc’s temperature stable while dissipating heat into the air.

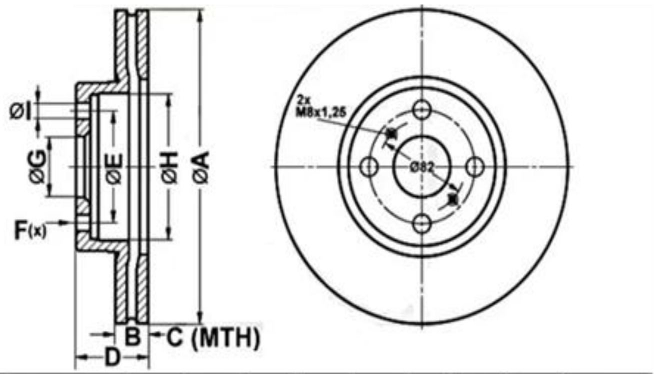
- Brake parts must have good wear resistance;
- In case of emergency braking with a certain distance, the vehicle must be able to stop completely and the driver must be able to control the vehicle so that it will not skid;
- No deterioration in braking performance can occur after a continuous and prolonged use.

To enhance the ability to release heat to the environment, two types of solid brake discs and brake discs with ventilation slots are often designed. Nowadays, modern high-speed vehicles are equipped with ventilated disc brakes. Ventilated brake discs have a larger surface area and lighter mass than solid brake discs, so they are recommended for use in passenger cars. The main purpose of this article is to simulate, calculate and examine the heat transfer of brake discs with different structures to the surrounding air environment by using ANSYS-FLUENT software in order to propose reasonable solutions for improvements in brake discs.

## II. MATERIALS AND METHODS

**Input parameters and some assumptions of the simulation problem**

Brake disc size parameters are taken from the Toyota Vios model being distributed in Vietnam, with the following sizes:

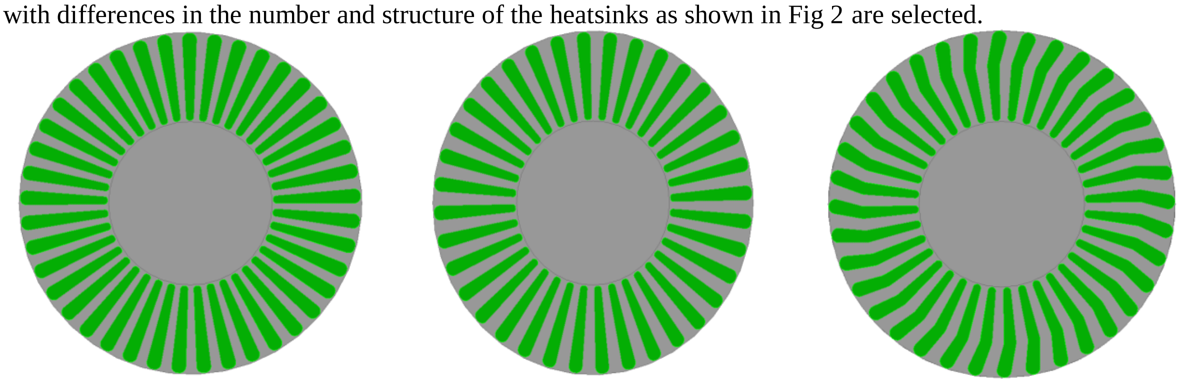



| | A | B | C | D | E | F(x) | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| | 275,0 | 22,0 | 19,0 | 46,5 | 100,0 | 4 | 55,0 | 131,0 | 14,5 |

**Fig 1.** Reference brake disc

**Geometrics models and simulation space**

With the view to improve cooling efficiency by optimizing the structure of the brake disc, 3 types of brake discs with differences in the number and structure of the heatsinks as shown in Fig 2 are selected.



(1) 41 radiator fins

(2) 36 radiator fins

(3) The heatsink has an exit angle

**Fig 2.** Cross-section of three types of brake discs

**Simulation space**

Brake discs participate in two types of motion: translational motion with the car and rotation due to the wheel's rotation, both of which have a significant effect on the flow around the brake disc and the heat transfer between the brake disc and the air flow surrounding it. These types of motion are modeled separately. The forward motion is not explicitly simulated, instead an air stream with the same velocity as the car but in the opposite direction is blown onto the brake disc.

**Model of the rotational motion of the brake disc**

The circular motion of the brake disc in the simulation domain space is simulated using the sliding mesh technique. The entire computational domain is divided into two spatial regions.

**Mesh division and the constraints of the simulation problem**

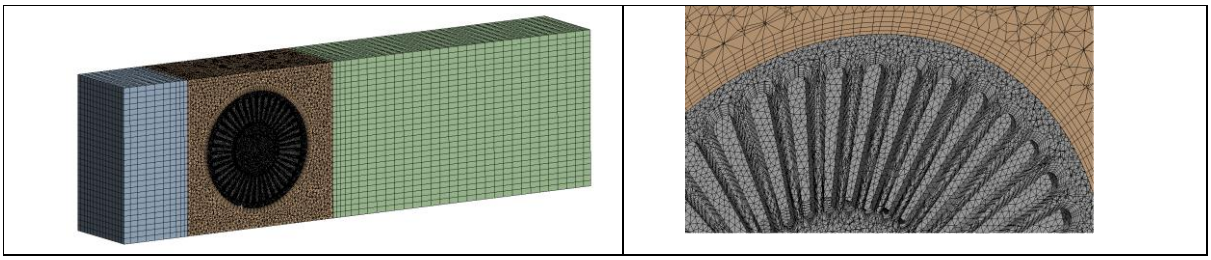


**Fig. 3.** Brake disc model after meshing

For elements located close to the brake disc surface, the mesh pitch is divided very small. The reason is that in this area the flow parameters change very quickly in the simulation room, so they need to be described in detail to ensure the accuracy of the results. After meshing the model properties are assigned as below.

**Table 1.** Gray cast iron brake disc properties (Gray cast iron)

| **Material Properties** | Value |
|---|---|
| Density, kg/m3 | 7850 |
| Thermal conductivity, W/m.K | 50 |
| Specific heat capacity, J/K.kg | 500 |

**Table 2.** Properties of air

| **Properties** | Giá trị |
|---|---|
| Density, kg/m3 | 1.225 |
| Thermal conductivity, W/m.K | 0.0242 |
| Specific heat capacity, J/K.kg | 1006.43 |
| Kinematic viscosity, $Kg.m/s^{-1}$ | $1.7894*10^{-5}$ |

- The input velocity of the air stream is 27.78 m/s (equivalent to 100km/h), and the inlet temperature of the air stream is 3000K;
- Output air pressure is equal to the atmospheric pressure;
- The convection heat transfer coefficient (h) between the brake disc and the surrounding air flow is 230 W/m2C;
- Properties of the brake disc surface model: disc shape is designed as "wall - no slip" or "non-slip wall", the temperature of the disc surface is selected to be 6730K and the disc rotates at the same time with the rotation area 87 rad/s.
- Properties of the walls that limit the simulation space: the "symmetry" property is chosen to eliminate the influence of the walls on the air flow interacting with the brake disc.

After meshing, assigning constraints and calculation conditions, simulation and advanced calculation of the cooling capacity of the brake disc are performed in the next section. However, grid independence must be evaluated at first. The results of checking the independence of the grid are given in Table 3.

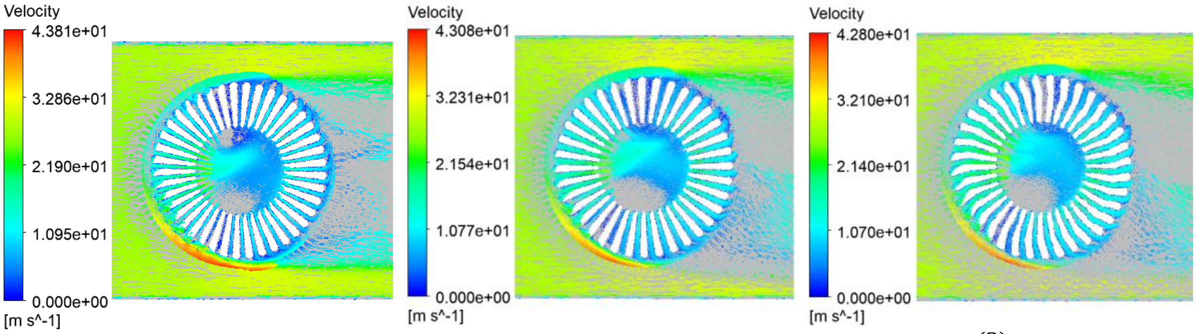
Table 3. Evaluation of grid independence

| Number of mesh elements | Maximum temperature at brake disc cross-section |
|---|---|
| 1235000 | $341.7^0$K |
| 1752691 | $332.6^0$K |
| 2677221 | $332.6^0$K |

In order to save calculation time, the number of second mesh elements as shown in Table 3 (1,752,691 elements) was selected for simulation.

## III. RESULTS AND DISCUSSION

Fig 4 shows the velocity distribution on the cross-sectional surface of the brake disc in three different structural types. Through these images, it is clear to see that the vortices are different in sizes with 3 types of brake discs mentioned above. While the vortex in brake disc 1 is the largest, it almost disappears in brake disc 3. The appearance of these vortices hinders the circulation of air flow through the brake disc, affecting the heat dissipation ability of the brake disc.




(1) (2) (3)

**Fig 4.** Velocity distribution in the symmetry plane of the brake disc

From the analysis of the velocity distribution, it can be seen that the volumetric flow of air flow passing through the type 3 brake disc is the largest. Therefore, the heat carried by the air flow through this type of brake disc is the highest, and the maximum temperature on the cross section is the lowest (fig 5).

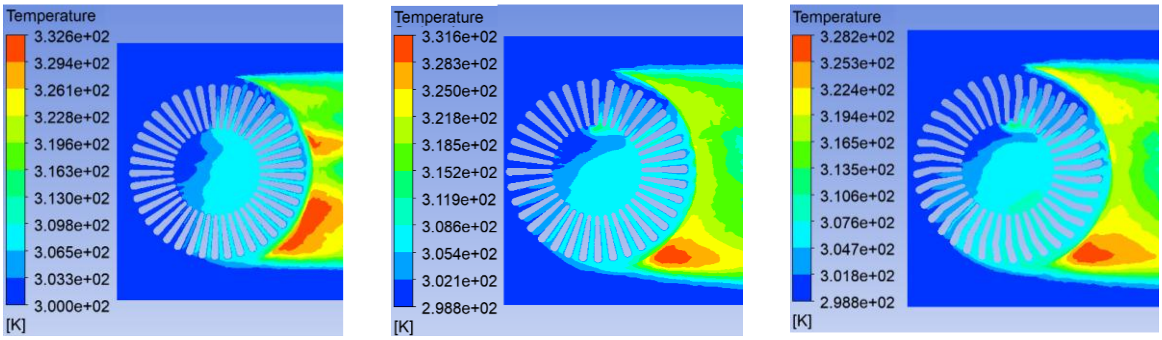



**Fig 5.** Temperature distribution on the cross-section plane of the brake disc

## IV. CONCLUSIONS

This study uses ANSYS – FLUENT software to perform simulations, calculations an examinations of brake disc models with different structures to evaluate heat dissipation ability and thereby provide the optimal structural optimization for the brake disc in order that the ability to cool the brake disc during braking can be improved.

Simulation results of the Toyota Vios base brake disc have shown that there are many possibilities to improve the heat dissipation ability of the brake disc, such as changing the number of fins and the airflow direction angle of the fins.

However, the simulation has not mentioned the durability of the brake disc. Besides, the simulation is only performed for the separate brake disc moving in the air flow, not for the brake disc mounted on the wheel and moving with the vehicle.

**Acknowledgment**

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