ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering [e-ISSN: 2067–3809]
TOME XIII [2020] | FASCICULE 4 [October – December]

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STUDY THE EFFECT OF VANES SHAPE ON THE CONVECTIVE COOLING OF THE VENTILATED BRAKE DISC

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Abstract: Today, the most brake systems used on vehicles are the disc brakes. During the braking process, the large amount of frictional heat is generated on the contact surfaces of disc brakes. In order to ensure the safety of the drivers and the traffic participants, the optimal performance of brake system of the vehicles under the different working conditions should be ensured. Therefore, it can be considered that the brake system an essential element in the vehicle. Practical experiences showed that the most important factor that affects performance of the brake system is the excessive heat that generated during the braking process. Therefore, it's necessary to pay high attention on the air cooling of the brake system. This is one of the reasons why the ventilated discs are used, besides that their usage provides the reduction of the inertial masses which meaning less cost. In order to provide a good cooling, it's necessary to find the optimal vanes shape to increase the degree of air cooling as much as possible. The aim of this research paper is to analyse the air flow through four different ventilated brake discs; each one has the shape of vane. Comparisons were made between the results of the selected models of the ventilated brake discs. The results presented the air flow currents through the disc, as well as the turbulences that occurred during the air flow around vanes.
Keywords: Ventilated disc brake, Convection problem, CFD, turbulences

INTRODUCTION

The first step in developing of a new product is the creation of the 3D model. Then, the same model is tested by numerical analysis, and if it meets the expectations, the part is fabricated and tested experimentally. If the experiment gives the positive results, more accurate the same results that are obtained by the numerical analysis, the part can be mass-produced. In this way, the costs are reduced, and the company that operates in this way becomes the market leader with its innovations.

When creating a new model of the ventilated brake disc, the experiment can be omitted, as the researchers have repeatedly confirmed many times, where the deviation between numerical analysis and the experiment is within the allowed limits [1, 2].

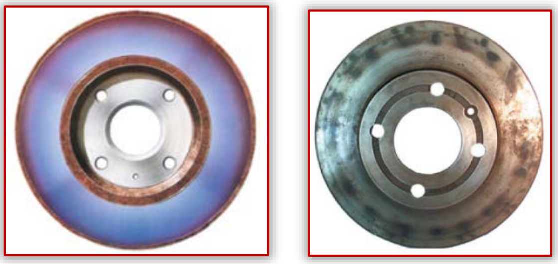
The shape of the vanes greatly influences the air flow speed through brake disc, as well as on the pressure that will occur due to air flow through it [3]. If a larger amount of the air passes through the brake disc, better cooling will be achieved. In order to achieve even better cooling, Galindo-Lopez and Tirovic [4] came to the conclusion that if one more vane is added between existing vanes, cooling would be better because there are a larger number of surfaces that cool down. In addition, the cooling rate would increase [5].

First of all, it is important to find such a shape and size of vanes in which the cooling will be more uniform and the mass flow value will be greater [1].

The air flow speed and turbulence are shown in this paper and the numerical analysis is performed in order to show which vanes are more suitable for use at the ventilated disc, more precisely, with which of them the higher velocity of the air flow will be achieved, with minimal turbulence. At the end, the values of the air mass flow are given, depending on the applied vanes on the brake disc.

MODEL AND BOUNDARY CONDITIONS OF VENTILATED BRAKE DISC

The basic role of the brake system is to slow down or stop the vehicle. However, during braking, a large amount of heat is generated on the brake disc, and this leads to the appearance of the thermal stresses, which further can lead to the occurrence of cracks and, at worse, to the fracture. Figure 1 shows typical damage patterns in brake discs.



(a) (b)

Figure 1. Disc damages because of thermal stress [6]: (a) Overheated brake disc; (b) Brake disc with hotspots

During braking process, the disc plays the role of a heat exchanger, but its capacity is limited. Therefore, this is one of the reasons why it is necessary to design discs with such vanes that will enable a good cooling. The second reason is to prevent the heat transfer to the brake pads. In this way, braking components will be protected and the safety of the driver, who operates such vehicle, as well as the other participants in the traffic, will not be disturbed.

In this paper, a disc whose dimensions are the same, but with different shape of the vanes, is observed, Figure 2. The model has been created in CATIA software package, while the analysis is performed in ANSYS software package (Fluid Flow module).

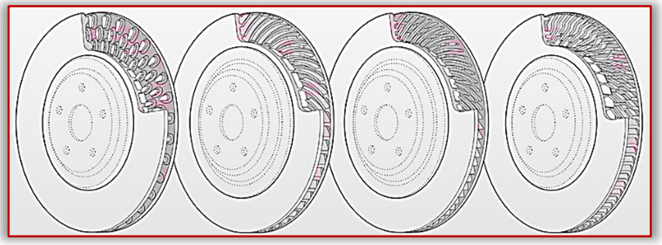
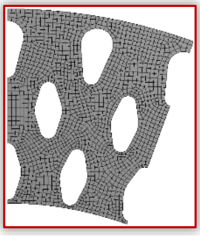
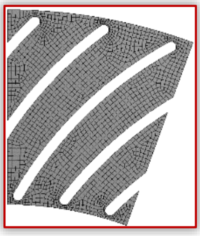
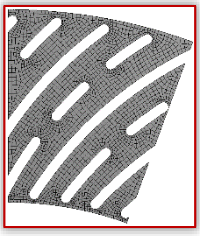
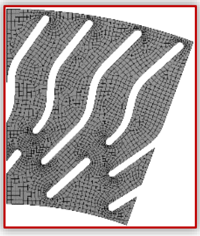


Figure 2. Four different ventilated brake discs [7]

In order to simplify the analysis, and reduce the time for calculation, only 1/18 of the disc will be observed, and considered for numerical analysis for all configurations due to the rotational symmetry [1, 2]. Table 1 shows the internal space of the disc, as well as vanes shape, and number of elements and nodes for each analysed model.

Table 1. Number of finite elements and nodes

		
Title	Pillar vane	48-vane
No. nodes	19052	30225
No. elements	15540	24556
		
Title	72-vane	72-vane flash
No. nodes	41378	48161
No. elements	33200	10128

The analysis was performed under the following boundary conditions:

≡ Vehicle speed is 120 km/h, more accurate the angular velocity of the disc is 107.26 rad/s,

≡ Air density is 1.225 kg/m^3,

≡ Environment temperature is 25 °C,

≡ Environment pressure is 101325 Pa.

The boundary conditions for each disc are the same. The applied model is k-ε. The reason for its application is widely used turbulence models as it provides robustness, economy and reasonable accuracy for a wide range of turbulent flows [8].

RESULTS AND DISCUSION

Airflow speed through the disc is shown in Figures 3 to 6, and the highest speeds occur in the disc with pillar vane. Furthermore, turbulence values for this disc are the lowest. The airflow is shown in the form of arrows so that the direction of movement of the air through the internal space of the disc can be seen. In addition, it can also be seen where the direction of air movement changes.

In addition, precisely because of those changes, the turbulence is appearing. Additionally, the occurrence of turbulence is also affected by the collision of air currents. The collision is happening after vanes trespassing. In addition, turbulences as well affected whether the vanes are made from one solid part or have discontinuities.

The disadvantage of higher turbulence values results in a lower air mass flow. As the air mass flow through the disc itself is smaller, a higher amount of heat remains on the disc. If there is a higher mass flow, more heat is dissipating to the environment.

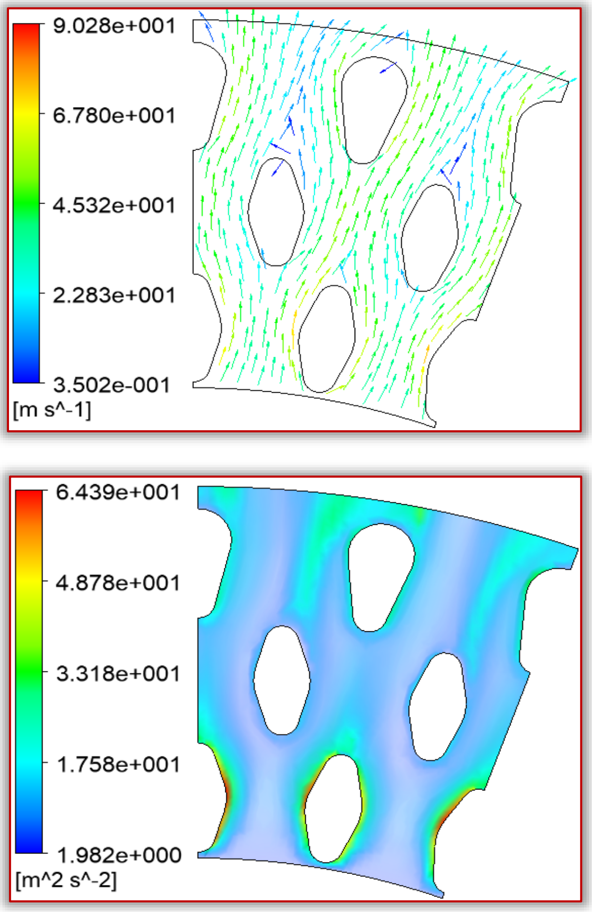


Figure 3. Air flow velocity and turbulences for disc with pillar vane

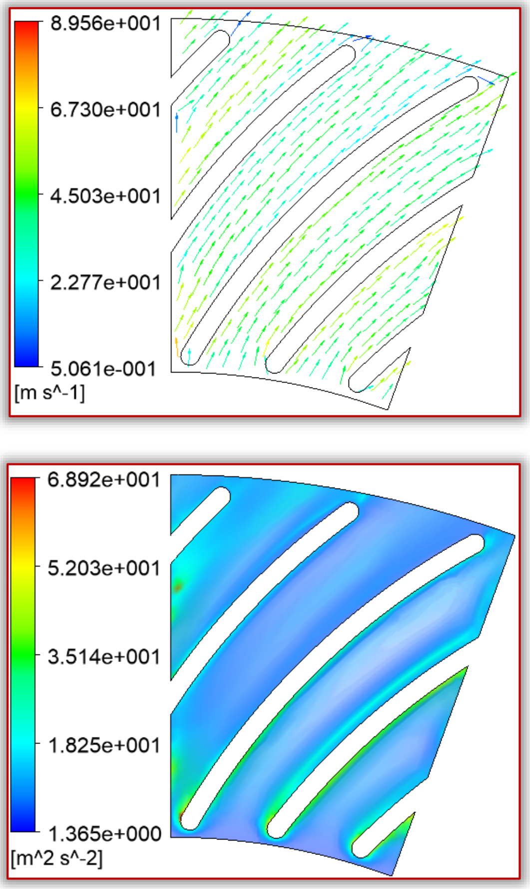


Figure 4. Air flow velocity and turbulences for disc with 48 vane

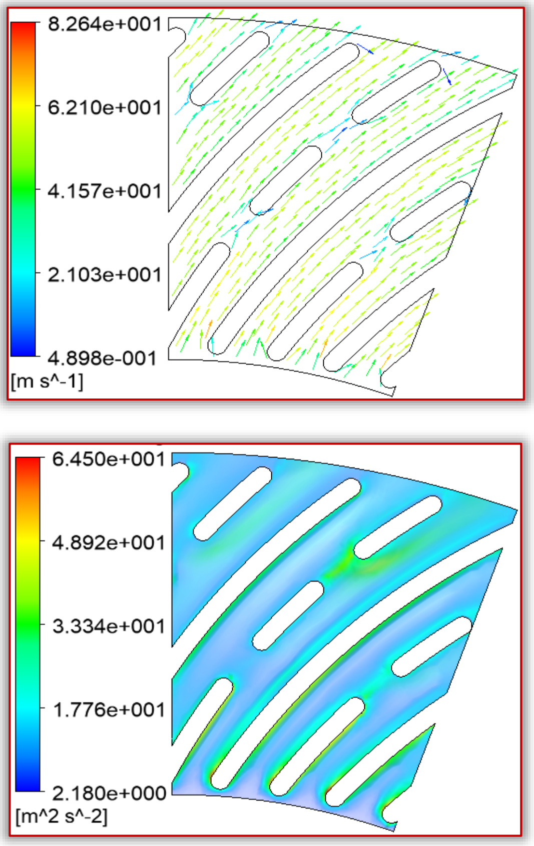


Figure 5. Air flow velocity and turbulences for disc with 72 vane

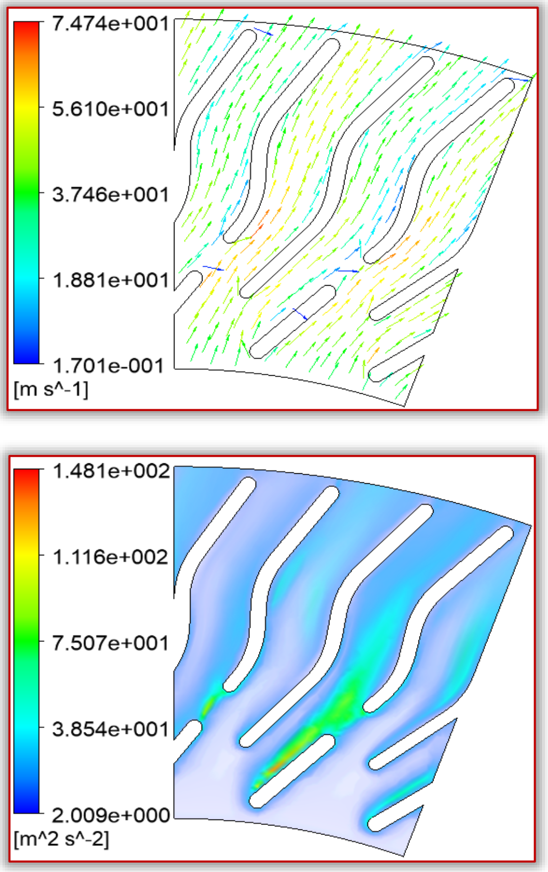


Figure 6. Air flow velocity and turbulences for disc with 72 vane flash

Regardless of the shape of vanes, turbulence occurs in each disc. The only difference is that they are the smallest in case of the disc with pillar vane, while for the disc with 72 vanes flash turbulence values are the highest. Table 2 shows the values of the air mass flow through the disc depending on the vanes shape.

Table 2. Mass flow rate for different ventilated brake discs

Title	Pillar vane	48-vane	72-vane	72-vane flash
Flow rate, gs^{-1}	0.977	0.971	0.971	0.973

CONCLUSION

The shape of the vanes has a great influence on the heat exchange with the environment i.e. the higher values of the air mass flow through the inner space of the disc, the greater the amount of heat will be dissipated into the environment. The air mass flow is the highest for disc with pillar vane, while the smallest is for the disc with 48-vane and 72-vane, which represents a difference of 0.61%.

The biggest changes in air flowing through the internal space of the disc occur with the disc with pillar vane, although due to the greater distance between vanes, it has the highest air flow. For future research, it is necessary to investigate how the distance between vanes for the remaining three cases affects the air mass flow, but it is important not to disturb mechanical properties of the part. In addition to the CFX analysis, the structural analysis in terms of exploitation conditions is also necessary to be performed.

Acknowledgement

This paper was realized within the framework of the project "The research of vehicle safety as part of a cybernetic system: Driver-Vehicle-Environment", ref. no. TR35041 funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

Note:

This paper is based on the paper presented at DEMI 2019 – The 14th International Conference on Accomplishments in Mechanical and Industrial Engineering, organized by Faculty of Mechanical Engineering, University of Banja Luka, BOSNIA & HERZEGOVINA, co–organized by Faculty of Mechanical Engineering, University of Niš, SERBIA, Faculty of Mechanical Engeneering Podgorica, University of Montenegro, MONTENEGRO and Faculty of Engineering Hunedoara, Unversity Politehnica Timisoara, ROMANIA, in Banja Luka, BOSNIA & HERZEGOVINA, 24–25 May 2019.

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ISSN: 2067-3809