

Thermal and Structural Analysis of Disc Brake for Different Cut Patterns

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Abstract— The thermal performance & heat dissipation of brake disc is based on aerodynamic characteristics of flow through brake disc holes. In this project, the cooling performance of two wheeler brake disc is analyzed by using two different disc designs. To analyze the effect of design on the cooling performance CFD software package, Fluent is used for simulation of air flow rate, velocity distributions, temperature contours. For these two designs, structural analysis is done in 'Ansys workbench- static structural analysis'. Modeling of discs was carried out in PRO-E.

Keywords- Von-Mises stress, Strain energy, Circular cut pattern, Elliptical cut pattern.

I. INTRODUCTION

Repetitive braking of a vehicle generates large amount of heat. This heat has to be dissipated for better performance of brake. Braking performance largely affected by the temperature rise in the brake components. High temperature may cause thermal cracks, brake fade, wear and reduction in coefficient of friction.

During braking, the kinetic and potential energies of a moving vehicle get converted into thermal energy through friction in the brakes. The heat generated between the brake pad & disc has to be dissipated by passing air over them. This heat transfer takes place by conduction, convection and somewhat by radiation. To achieve proper cooling of the disc and the pad by convection, study of the heat transport phenomenon between disc, pad and the air medium is necessary. Then it is important to analyze the thermal performance of the disc brake system to predict the increase in temperature during braking. Convective heat transfer model has been developed to analyze the cooling performance. Brake discs are provided with cuts to increase the area coming in contact with air and improve heat transfer from disc.

In this paper two different cut patterns of brake disc are studied for heat transfer rate. Heat transfer rate increases with number of cuts in the disc. This is because large area is exposed to air which makes more heat transfer through conduction and convection. But increase in number and size of cuts decreases the strength of disc.

So optimization between these two parameters is necessary.

II. LITERATURE SURVEY

J.Jancirani, S.Chandrasekaran and P. Tamilporai incorporated virtual heat transfer analysis of automotive disc brake. In this work they analyzed convective & radiative heat transfer from the disc brake components based on heat transfer mechanism. Mainly the results of convective heat transfer coefficient & radiative heat transfer coefficient are compared with practical values. This paper conclude that the material has large influence on convective & radiative heat transfer & to avoid thermal cracks temperature should be within optimum range.

Amol A. Apte and H. Ravi has analyzed finite element prediction on thermal performance of disc brake & stresses in a disc brake system. Validation of brake disc design is carried out through CAE/FEA. The procedure for prediction of thermal performance of disc is developed & it correlate with test data available for the recently available design & it applied to the new brake disc design.

M.Rama Narasimha Reddy, K.Harshavardhan Reddy, N.Balaji Ganesh has analyzed structural & thermal analysis of disc brake. In this work they compare the results for stainless steel & carbon steel & result obtained is that both the materials has stress value less than yield stress but thermal gradient of carbon steel is more than stainless steel so carbon steel is better than stainless steel.

III. METHODOLOGY

Mechanical modeling is done in PRO-E software. We took average dimensions of two wheeler brake disc. With these dimensions following two models were created with two different cut patterns as shown in following figure.

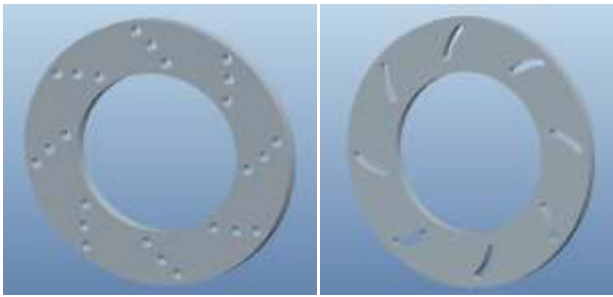


Fig 1. Two models with different cut patterns

Fig.(1) shows two models have same outer and inner diameters as 250mm and 150mm respectively. After geometry creation these models were imported in Ansys fluent for thermal analysis.

ANSYS–Fluent 14.0 Analysis:

To analyze flow domain problem Steps followed:

- 1) Geometry
- 2) Meshing
- 3) CFD Problem set up and solution

Geometry: The geometry modeled in PRO-E and then imported in DESIGN MODELER in ANSYS 14.0. Fluid enclosure is created around the disc with length is equals to two times from the rear edge of disc. Main purpose of enclosure is to simulate the flow around disc.

Meshing: Meshing is important to simulate the boundary technique of problem. Mesh quality has great influence on the results. Mesh size decides the numerical convergence of solution. If the mesh size is poor then it will not give proper results. Fine mesh give numerical convergence with accurate results. In this problem the fine mesh is generated around disc & coarse mesh at the enclosure because simulation is important at the disc as shown in following figures.

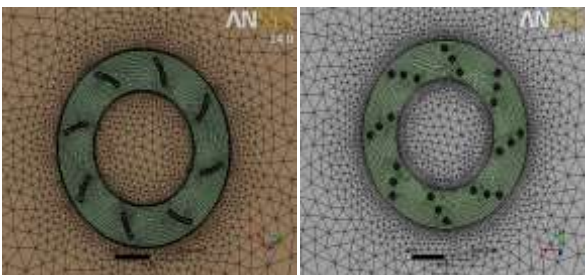


Fig 2. Meshing for two different cut pattern discs and air domain

Here we can see two different colored meshings for both the models, this is done intentionally as we wanted to see heat transfer from disc to air.

CFD Problem set up and solution: In this initial boundary conditions are set up in problem considering inlet velocity 30m/s & temperature at the disc is around 500K. Problem is solved taking 1000 iterations pressure based solution method is followed and K-Epsilon Model is followed for Turbulence flow. Disc has given rotational motion to simulate conditions as in actual.

IV. RESULTS & DISCUSSION

Static temperature contours:

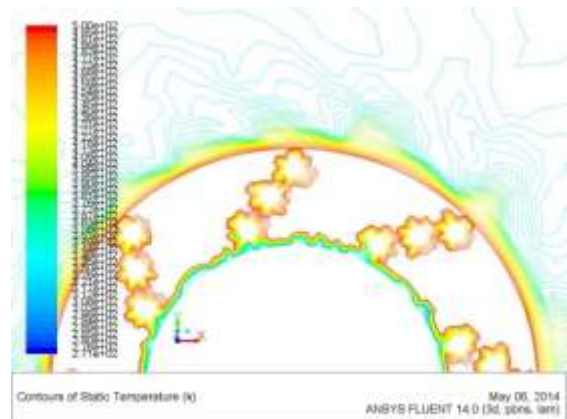


Fig 3. Temperature contours for circular cut pattern disc

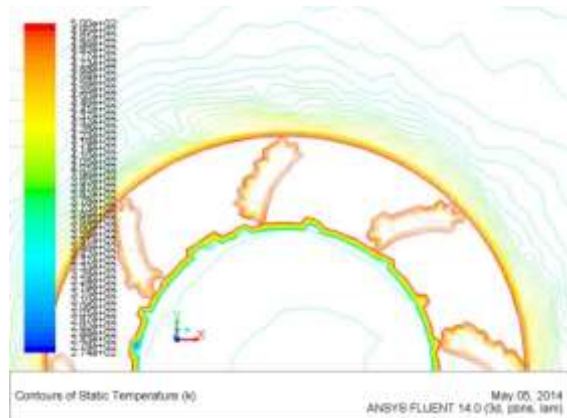


Fig 4. Temperature contours for elliptical cut pattern disc

From fig.(3) & fig.(4) we can see how temperature contours vary in color and the pattern. Circular type cut pattern disc shows dense red colored contours near cuts, air enters into the cuts but do not leave easily, so heated air remains there which should leave that place and allow new air to circulate through cuts. But in case of elliptical type of cuts we can see less dense red color region this is due to air circulation through cuts is better in this case.

Velocity vectors colored by temperature:

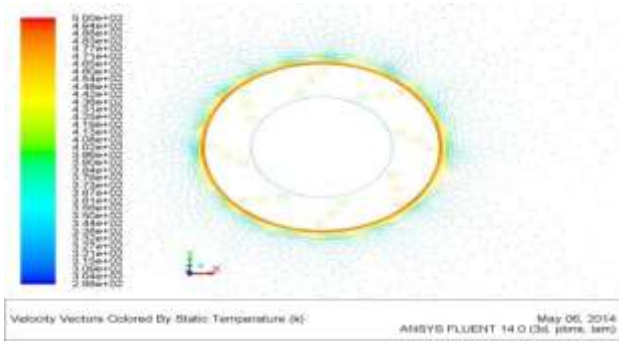


Fig 5. Velocity vectors for circular type cut pattern

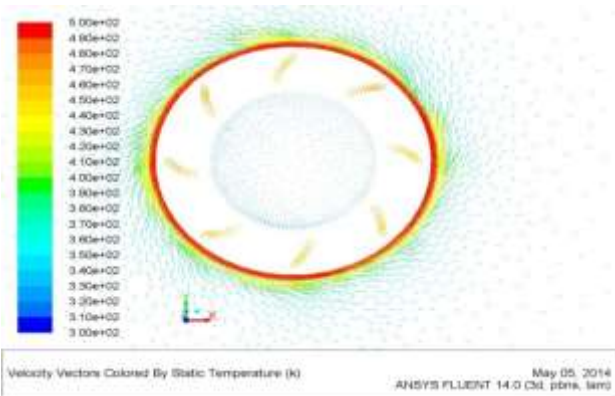


Fig 6. Velocity vectors for elliptical type of cut pattern

Above fig.(5) & fig(6) show that air movement around the disc and cuts. Layers close to disc are dark red colored which shows they are carrying more heat. From the values of scale for different colors shows that layers in circular type of cuts are more red than elliptical type of cuts. This means heated air in elliptical cuts leaves the space and allows fresh air to come contact with cut surfaces of disc and carry the heat from disc. This phenomenon for circular cuts take place on lower scale which shows there is better heat transfer for elliptical type of cuts than circular type of cuts. But we have to check the strength of this two type cut pattern made disc to withstand against braking force. For this structural analysis of these models is done in Ansys.

Ansys14.0 Static Structural:

For this analysis same disc models are used with material as Grey cast iron having following properties.

TABLE1. MATERIAL PROPERTIES FOR GREY CAST IRON

Material property	Value
Thermal conductivity	52Kg/m ² c
Density	7200 Kg/m ³
Elastic Modulus	110GPa
Poisson's ratio	0.28

With these material properties Geometry is imported into Ansys static structural. Fine grid generation is made for better results. Disc inner surface is fixed and it is given anticlockwise moment. Analysis is carried out for Total deformation, Equivalent Von mises stress, Directional deformation and Elastic strains. Following are the results of the analysis.

Total deformation:

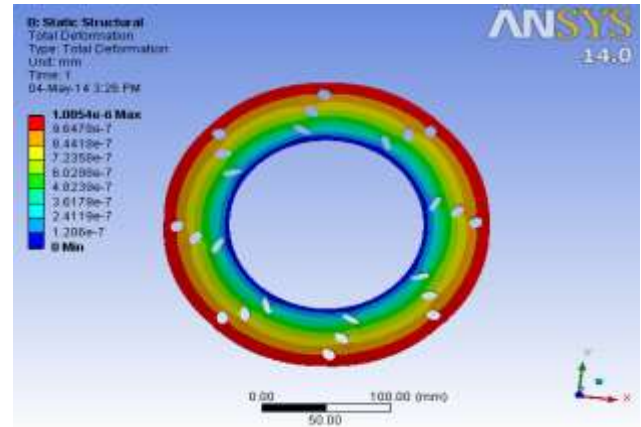


Fig 7. Total deformation for circular type cut pattern

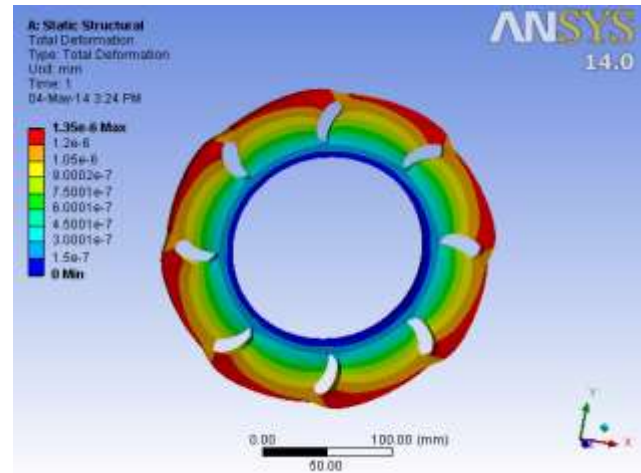


Fig 8. Total deformation for elliptical type cut pattern

Above fig.(7) & fig.(8) shows deformation is Highest at outer edge and lowest at inner edge. We can see maximum value of deformation for circular type cut is 1.005e-6mm whereas for elliptical type it is 1.35e-6mm. These values show that deformation for elliptical type is more than circular type cut disc for same load.

Equivalent Von-Mises stress:

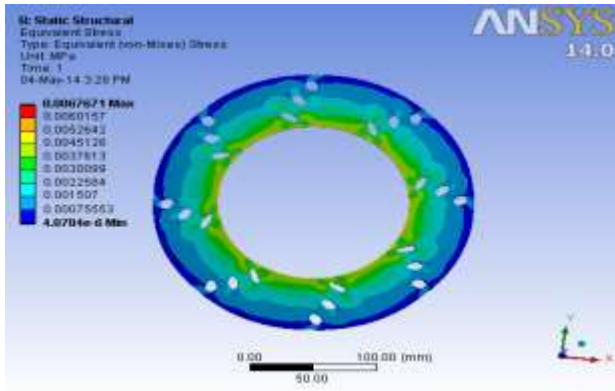


Fig 9. Von Mises stress for circular type cut pattern

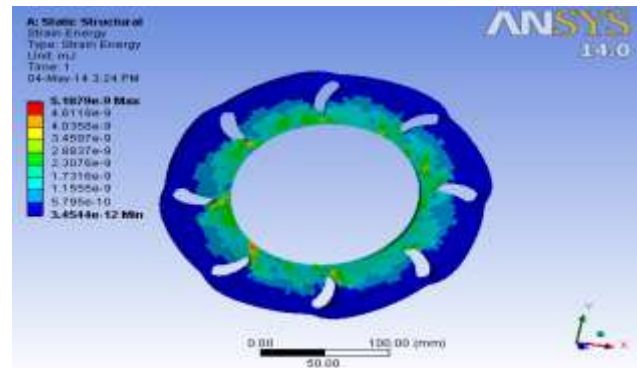


Fig 12. Equivalent strain energy for elliptical type of cut pattern

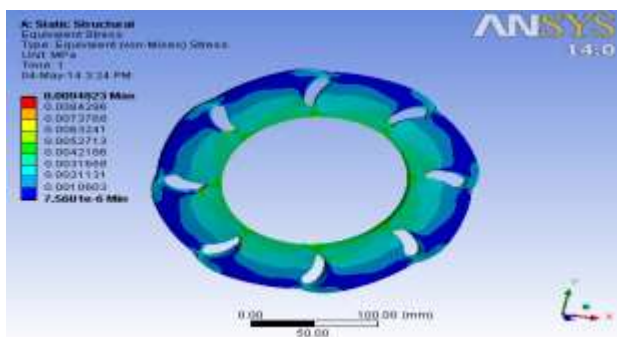


Fig 10. Von-Mises stress for elliptical type of cut pattern

Above fig.(9) & fig. (10) shows stress generated in disc for same loading. Here we can observe stress is opposite of deformation i.e. it is maximum at the inner surface and minimum at the outer surface. Maximum stress value for circular type cut pattern is 0.0067MPa where as for elliptical type of cut pattern it is 0.00948MPa. So here also maximum stress value for elliptical type cut pattern is more than circular type. It means elliptical type of cut pattern is weaker when compared with circular type of cut pattern.

Equivalent strain energy:

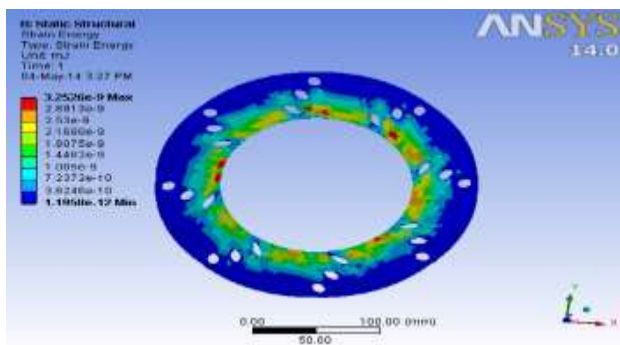


Fig 11. Equivalent strain energy for circular type of cut pattern

Above fig.(11) & fig.(12) shows the equivalent strain energy for these two type of cut patterns. From fig.(11) i.e. for circular type of cut pattern maximum strain energy is 3.25e-9MJ which is less than 5.18e-9MJ for elliptical type of cut pattern. These two values shows there more strain energy in elliptical type due to more deformation.

V. CONCLUSION

From thermal analysis we can conclude that elliptical type of cut pattern has better heat transfer than circular type of cut pattern. Structural analysis showed that elliptical type cut pattern is weaker to withstand braking forces when compared to circular type of cut pattern. So for having better heat transfer and structural strength optimization between these two profiles should be done.

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