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Static and thermo-mechanical analysis of brake disc and pad using finite element analysis

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ABSTRACT

In the automobile, the braking system is a very important part. The brake pad plays important role in braking. Previously Asbestos is used as a brake pad, but asbestos is not good for the environment and human health. So, the use of Asbestos is prohibited. Currently, a lot of research is going on to find out a brake pad material that will replace Asbestos. Some materials selected for the brake pad are Carbon Fibre, Sic, ZrO_2, S_2 Glass fibre. Out of this material, Carbon Fibre is a material used for Brake pad. The static and thermomechanical analysis is performed in ANSYS Workbench. For this analysis, Carbon fibre is used for the brake pad and the Aluminium alloy is used brake disc. In static analysis, the deformation and stresses are found out and in thermomechanical analysis, Thermal effects are added to find out the deformation and stresses. It found that after the addition of thermal effects, the deformation and stresses are increased considerably. But both stresses and deformation values are within the failure limit.

Keywords- *Finite Element Analysis, Brake Disc, Brake Pad.*

1. INTRODUCTION

Automobiles braking system mainly consist of two main parts: brake disc and brake pad. The brake pad plays the main role in braking. After the application of pressure on the brake pad, it will in contact with the brake disc and trying to retard the motion of the vehicle. During this process lot of heat generated. This heat may cause serious problem to the braking system. So, the brake pad should have to withstand this condition. Previously Asbestos is used as brake pad material. But the use of Asbestos is prohibited due to its disadvantageous effect on environmental and human health. So, need to find out the material for the brake pad that will replace the Asbestos. Currently, a lot of research is going to find out brake pad material.

By referring to some standard research paper, we find out some materials for the brake pad. Carbon Fibre, Sic, ZrO_2, S_2 Glass fibre are some materials suggested for the brake pad. In this paper, Carbon fibre is selected for brake pad material.

To check the results of Carbon fibre, the finite element analysis method is an important tool. In the finite element method, the geometry of the part is divided into a finite number of elements. This process is called discretization. In this study, we used Ansys Workbench software. Static structural and Thermo-mechanical analysis is performed in Ansys Workbench. In this analysis, deformation and stresses are found out and compared with the expected limit.

Ali Bolhocine performed the contact analysis on 3- Dimensional brake disc model. In this analysis, he analyzed without considering thermal effects and with considering thermal analysis. he found that the deformation and contact stresses developed in the model with considering thermal effect are more as compared to without thermal effects [18]

S. R. Kakad gives mathematical modelling of the disc brake assembly. He developed a mathematical equation for the wear of brake-pad model. Uniform wear and uniform pressure theory used to develop this equation [11].

G. Ranjit Kumar performed steady-state thermal analysis on solid and ventilated disc. He found that by changing the straight grooves with curved grooves, the stresses and deformation is reduced [5].

K. Naresh Kumar performed the comparative thermomechanical analysis by considering Carbon fibre and Glass fibre material for the brake pad for the same input conditions. He found that Carbon fibre is the best material among the selected materials which will replace asbestos [1].

Dr R. Umamaheswara Rao in his review paper he studied various materials which will replace asbestos as a brake pad material. Out of these materials, most of the materials are from agricultural wastes or some of them are naturally occurring materials [20].

2. METHODOLOGY

The static structural analysis gives us information about the stresses, deformation etc. In this study we performed the analysis as follows:

1. Modelling of brake disc-pad assembly in CATIA V5 as per specified dimension.
2. Make the STEP file of that assembly and Export it.
3. Import this STEP file in Ansys Workbench.
4. Then apply the materials for parts and generate a mesh with a specified element size.
5. Application of boundary conditions for Static structural analysis.
6. Perform the Static analysis
7. Application of boundary condition for thermomechanical analysis.
8. Perform the thermo-mechanical analysis.
9. Results and Discussion
10. Conclusion.

3. FE MODELING AND SIMULATION

3.1 CAD Modeling

In this work, a 3D cad model of the Brake disc and pad is created in CATIA V5. The Cad model of the brake disc-pad is shown in fig-1. Brake disc and pad modelled separately and then combined in assembly. Ansys workbench is a simulation software used for structural and Thermal analysis

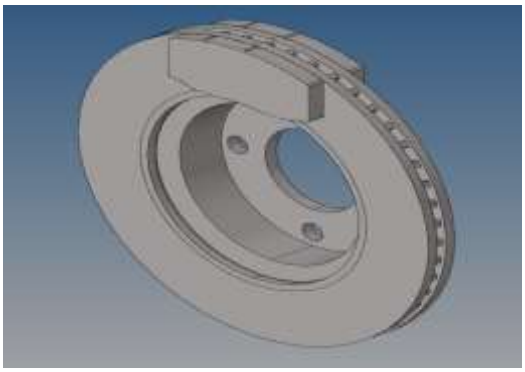

Fig -1 Cad model of Brake Disc-Pad

3.2 Material Selection

By referring to some standard research papers. Following are some of the materials which will replace Asbestos are Carbon Fibre, Sic, ZrO_2, S_2 Glass fibre. Out of them for Brake pad, Carbon fibre is selected and for brake disc, Aluminium is selected. Properties for both the materials are shown in Table 1.

Table- 1: Material Properties of Carbon Fibre and Aluminium alloy

Properties\ Materials	**Carbon Fibre**	**Aluminium alloy**
Density (kg/m^3)	900	2710
Elastic Modulus (Gpa)	226	68.3
Ultimate Strength (Mpa)	2550	
Poisson's ratio	0.27	0.33
Thermal conductivity (W/mk)	900	160
Specific Heat Capacity (J/kg.k)	710	896

3.3 Mesh Generation

For meshing. The average element size used is 2.5 mm. this size will capture every feature on cad. The total element count in brake disc is 247817, for brake pad 1 is 3376 and brake pad 2 is 3327 also this value shown in fig. total node count is 254520 and the total element count is 416452.

Statistics			
Nodes	403649	6440	6363
Elements	247817	3376	3327

Fig -2 Node and Element count

3.4 Contacts

In the simulation, contact between the two different parts is very important. Two contacts are created in this simulation. The first contact is created between the brake disc and brake pad 1. In contact, the target body is brake pad 1 and the contact body is the brake disc.

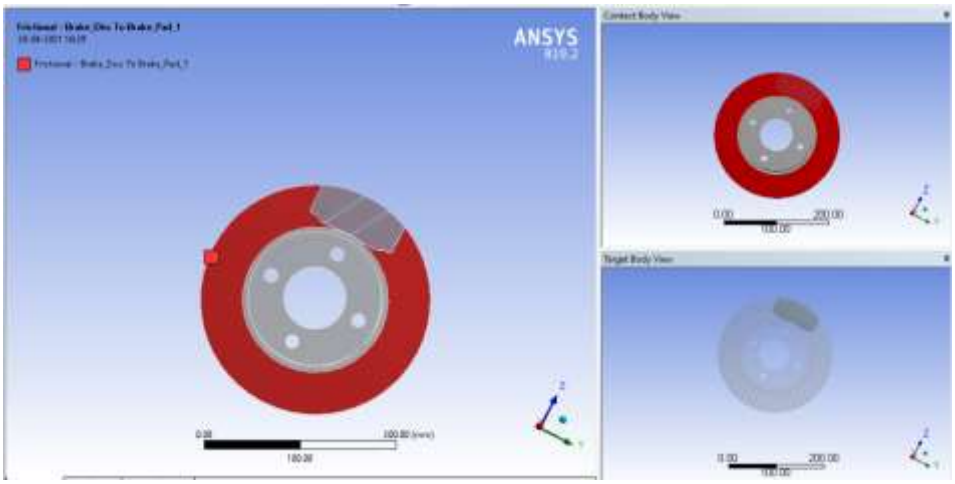

Fig -3 Contact between Disc and Pad 1

The second contact is created between the brake disc and brake pad 2. In this contact target body is the brake pad 2 and the contact body is the brake disc.

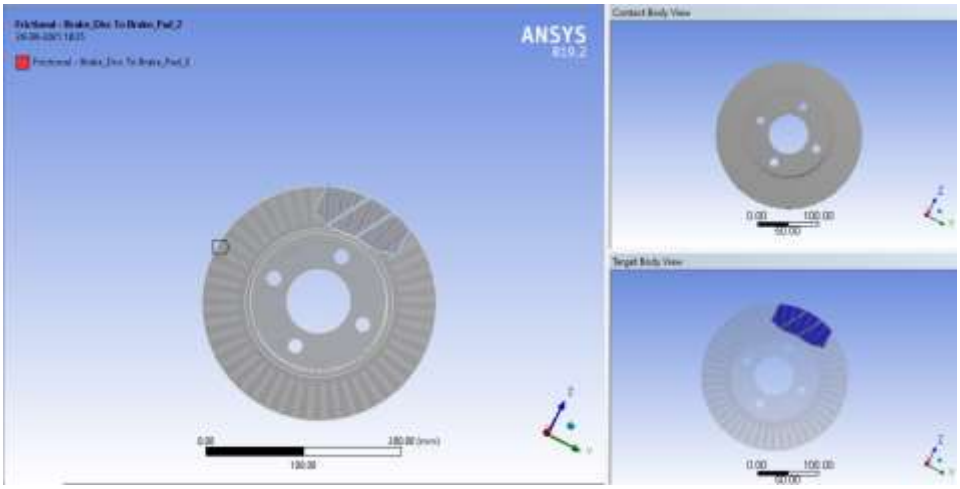

Fig -4 Contact between Disc and Pad 2

There are five types of contacts used in ANSYS. These contacts are bonded, frictional, frictionless, no separation and rough contact. In this contact frictional contact is used. The coefficient of friction of 0.28 is used for the brake disc and pad.

First, we performed static structural analysis without considering thermal effects. The boundary conditions used for static structural analysis are as follows:

3.5 Loading and Boundary Conditions

The loading and boundary conditions for static structural analysis are as follows:

1) The disc is rigidly constrained at bolt holes in all directions except in the normal direction.
2) The pad is fixed in all degree of freedom except in the normal direction.
3) A rotational velocity of 157.89 rad/s is assigned to the brake disc.
4) The pressure of value 1 MPa is applied at the faces of the brake pad. This pressure is applied on both the brake pad.

In thermo-mechanical analysis first, we performed the thermal analysis and the results of the thermal analysis are carry forwarded in thermomechanical analysis. the boundary conditions used are as follows:

1) The initial temperature considered is 28^0 C.
2) heat flux of value 1.32 W/mm^2 is applied at faces of disc and pad which are directly come in contact during braking.

3) The convective heat transfer coefficient of aluminium and air is 0.05 W/mm^2 ^{0}C and the convective heat transfer coefficient between Carbon Fibre and the air is 0.75 W/mm^2 ^{0}C.
4) Adiabatic heat condition is applied at brake pad faces and disc faces that are not in contact with the air.

4. RESULT AND DISCUSSION

4.1 Static Structural Analysis

The maximum deformation produced in the disc is 0.0024 mm shown in Fig-5. The maximum stress produced is 13.044 N/mm^2. The maximum value of deformation is found at the outer radius of the disc which is in contact with the pad. The maximum value of stress is found at the disc- pad interface. This maximum stress is in the brake disc at the pad location shown in Fig- 5.

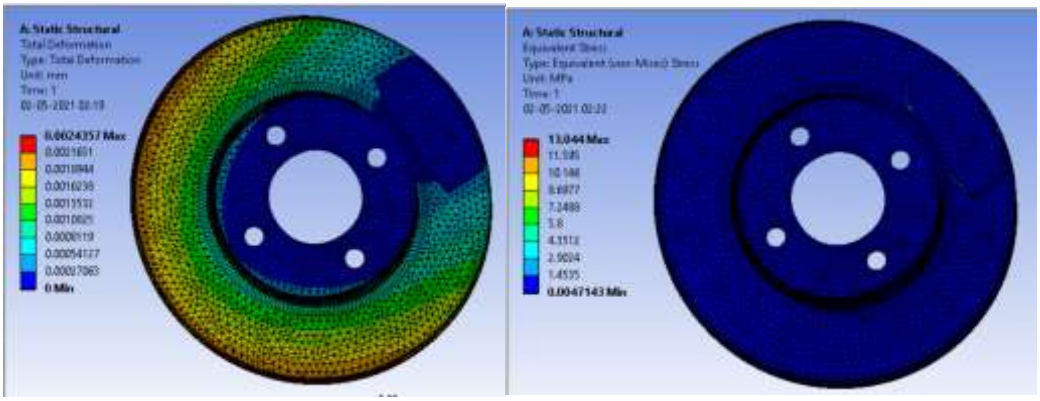

Fig -5 Deformation and Stress Plot

4.2 Thermal Analysis

In thermal analysis, the main input is heat flux which is generated during braking at the brake- pad interface. The maximum temperature developed in the disc area is 289.88 ^{0}C. The melting temperature of aluminium alloy is 650 ^{0}C. The temperature plot is shown in Fig-6.

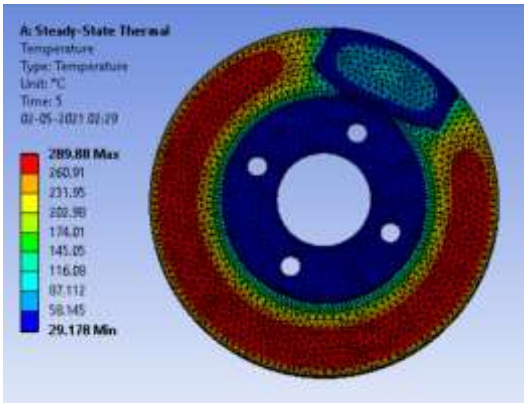

Fig -6 Temperature Plot

4.3 Thermo-mechanical Analysis

In thermomechanical analysis, the structural and thermal analysis is performed at the same time. It will add thermal effects with structural. Due to this the deformation and stresses developed are more. The maximum deformation is 0.84 mm. The maximum stresses developed are 327.34 N/mm^2. The maximum stresses occur on the brake disc. The deformation and temperature plot of thermo-mechanical analysis is shown in Fig-7.

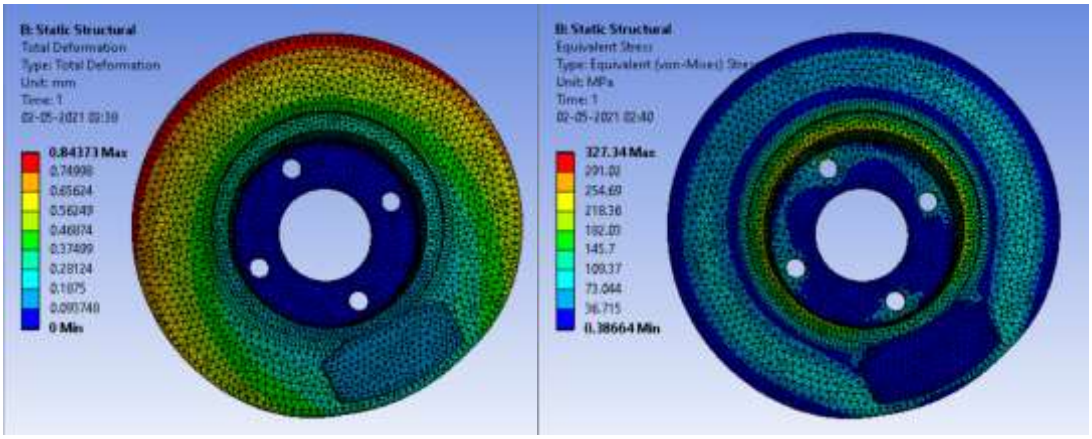

Fig -7 Deformation and Stress Plot in Thermo-mechanical Analysis

5. CONCLUSION

We performed static and thermomechanical analysis on the brake disc- pad assembly. For this Carbon fibre material is selected for the brake pad and the Aluminium alloy is used for the brake disc. The maximum stress developed in static structural analysis is 13.044 N/mm^2 which is very less than the yield stress of Aluminium. Then we performed thermal analysis. the maximum temperature developed is 289.88 ^{0}C which is also within the limit. These thermal effects are then combined with structural analysis. It is observed that the deformation and stresses developed in Disc- pad are increased but these values are within the failure limit. So, we can say that we can replace the Asbestos with Carbon fibre.

6. FUTURE SCOPE

This analysis is performed by considering Carbon fibre as a brake pad material. We also need to perform analysis by considering other material and need to do a comparative study. Also, these analysis results need to check with the experimental result. By comparing both results we need to draw some conclusion from this.

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