Optimized Design and Static, Dynamic Analysis of Disc Brake using Finite Element Analysis

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Abstract—**In this paper an effort is made on different materials and Analysis techniques of disc brake. The term itself indicates that slowing or stopping the disc which causes slowdown the vehicle. It is sandwich model with 2 pads and disc at centre. Disc is mounted to wheel & pads are mounted to the frame through calliper. When brake is applied, it generates heat between pads and disc due to friction. The aim of contribution was to study different structural & Thermal Analysis using Finite Element Methods (FEM), cooling performance increased by different Cut Patterns and study of analysis of different materials has been reported in literature.**

Keywords— Disc Brake,cut patterns, Static Analysis, thermal Analysis, Finite Element Method

1. INTRODUCTION

Brake is Device which uses to stop motion of machine by transferring the Kinetic Energy of the vehicle into Thermal Energy by Mutual Slipping of contacting components of brake system. Usually brakes made of Cast Iron or Ceramic Composites which include Aluminium, Kevlar and Silica. Brake pads also called as Friction Materials are made to engage both sides of disc to decelerate the system. When pad is pressed Normal to the Disc, the disc absorbs Kinetic Energy of vehicle and it will transfer into heat energy which is 90% heat energy absorbed by disc and remain absorb by pads and calliper. When temperature exceeds the critical value of material, it will cause to Brake Failure, Thermal Crack, Wear and Fade of Disc.

For effective decrease of frictional heat, several methods have to implement on disc. The list of following strategies can improve cooling system of disc and disc performance.

1. Ventilated Disc Brake.
2. Circulated Brake Fluid.
3. High Thermal Conductivity as well as High Strength Material.

2. OBJECTIVE

In today's growing automobile market competition for better performance of vehicle is growing drastically. Disc brakes are very important devices to decelerate the vehicle. The main Object of the literature work is to understand cooling system of brake, thermo-fluid mechanism, structural rigidity, low stress martials to design new model and optimize the design.

3. LITERATURE REVIEW

Praveena and et al.[1] designed Disc Brake Model which had low stress material and perform better. He analysed stress for different materials such as aluminium, Grey Cast Iron, HSS M42, and HSS M2. By comparing the structural and stress analysis for these four materials he concluded that Aluminium has suitable design and low stress material for better performance

T.V. Majunath and P.M. Suresh [2] studied Transient Thermal and structural analysis of Rotor Disc and had to perform better in several braking condition. He examined the von-mises stresses of disc brake for two different materials as well as for both ventilated and solid disc rotor. The Values from the results obtained that ventilated cast iron disc brake was best and suggested for strength and rigidity criteria under safety condition.

VirajParabet al. [3] did a Transient-Thermal analysis of Disc Brake with different materials such as Stainless Steel, Cast Iron and Carbon-Carbon Composites and compared deformation, stresses, and temperature. Finally concluded that stainless steel has better brake performance in deformation view and Cast Iron had best in stress point of view.

VirajVijaykumarShindeet et al. [4] did Thermal and Structural Analysis of Disc Brake for Different Cut Patterns using aerodynamics characteristics of flow through disc brake holes. Among circular and elliptical cut patterns he decided that elliptical cut patterns have better in heat transfer but weaker to withstand to brake force.

Rakesh Jaiswalet et al. [5] Performed stress concentration, structural design to choose low stress material. and explained that brakes must stop with in minimum distance in emergency, must not fade and wear. He used Finite element method to ind ut stress concentration, structural deformation, thermal gradient of disc brake.

Shahabah Bagwan et al. [6] studied a review on disc brake to reduce squeal noise. He investigated that brake squeal does not affect the performance of braking system even though it is not acceptable. He gave various parameters which influence brake squeal such as braking pressure, rotational velocity, coefficient of friction, damping and modification of disc & pads. He concluded that best way to reduce disc brake squeal was to improve structural modification of disc and pads.

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4.RESEARCH & METHODOLOGY

The process used to full fill the Objective of the study the following steps are involved.

- Preliminary study (Done Litreature review)
- CAD model by using CATIA
- Finite element analysis(Finite Element Software for Analysis)
- Selection of parameters (Cross-Section of Material and shape to constraint deformation and stresses)
- Design and development (Re-design of model)
- Modification, Results & Conclusion.

5.DESIGN ANALYSIS

As per actual dimensions the disc brake is designed in

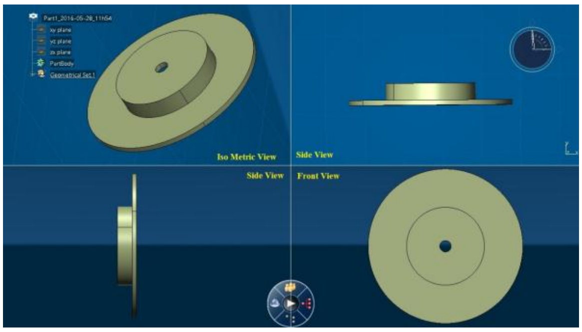

Figure 1. CAD Model Prepared in CATIA

CATIA. After importing CAD model into Hyper mesh. the model is prepared to do Finite Element Analysis Using Hyper Mesh Tool for Static analysis and Optimization.

From the several literature reviews we understand that Cast iron is best material suitable for strength wise and temperature distribution wise.

6. MESHING

In post processing we need Displacement and stresses produces in the model which indicate strength of disc brake. Optimization is technique used to decreases or removal of unwanted mass of the disc brake. Hyper mesh is best tool used for optimize technique using topology optimization module.

In this module we have to give specific variables like mass or volume which is to decrees and also impotent to mansion at what level of stress are permissible. From the optimization we got several curved strip and. From the optimization we removed unwanted mass and the resultant disc which is optimized shape of the disc brake again it has been re designed with **CAD** Tool. But where the disc pads hold the brake and where thermal energy created that disc surface, we are not yet designed for that we need thermal analysis at what thickness the temperature distribution is under permissible level

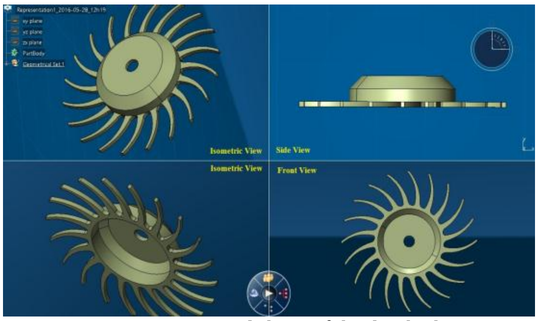

Figure 2. Optimized shape of the disc brake

Here thickness can be calculated by mesh thickness. Each mesh is equally discretised with define length so we can easily find out thickness of plate which has to place on curved tooth disc centre. meshing is equally discretised with thickness of 1 mm after distribution of temperature it is near about 6 mm is turn into less temperature. So from this analysis we are taking plate thickness which cover on the top and bottom of the disk is equal to 6 mm.

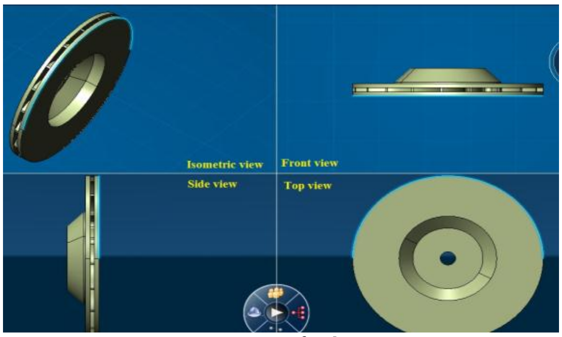

Figure 3. pre-final Disc

In this method fluid flow will be in straight path and mass flow will be high where as in drilled holes' air has to take turn and due to holes' disc may exhibit high stress concentration along circumferential or hoop stress when brake applied. Units.

7. OBSERVATIONS

Computational fluid dynamics (CFD) analysis has been performed to know temperature distribution throughout disc vent holes using air as fluid which passes through it. For CFD Analysis in HYPERWORKS providing a powerful tool known as ACUCONSOLE in this material property given to volume and boundary conditions given to surfaces such as Input, output and wall.

Here heat flux which has magnitude of 350K given to disc top and bottom surface of the disc. Air is the fluid which is passed through concave side to convex side with mass flow 2kg/s with 250k.

CFD Tetra mesh has been done with 3 mm and residual ratio of temperature, pressure, velocity of air and eddy-viscosity of fluid with respect to time has been generated using CFD tool.

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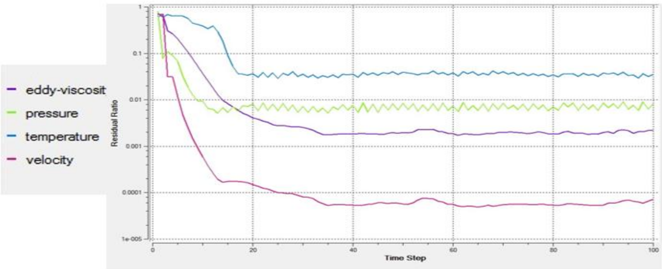

Figure 4.Residual ratio of temperature , pressure, velocity and eddy viscosity of fluid

After performing CFD analysis those results can also be viewed in the ACUCONSOLE Figure-5,6 and HYPERVIEW Figure-7,8 respectively.

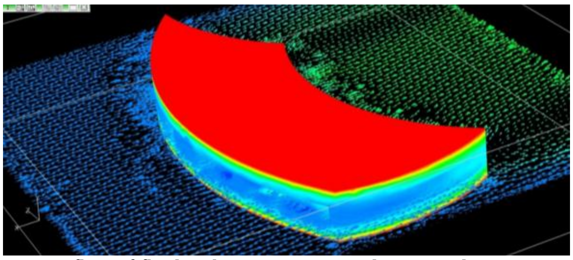

Figure-5.flow of fluid with temperature conduction and convection.

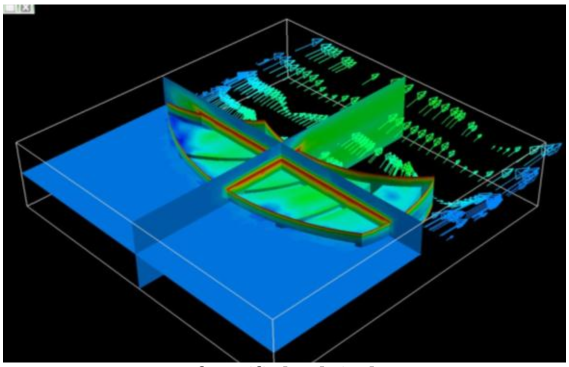

Figure **Error! No text of specified style in document.**. Temperature distribution in 3 mutually orthogonal planes

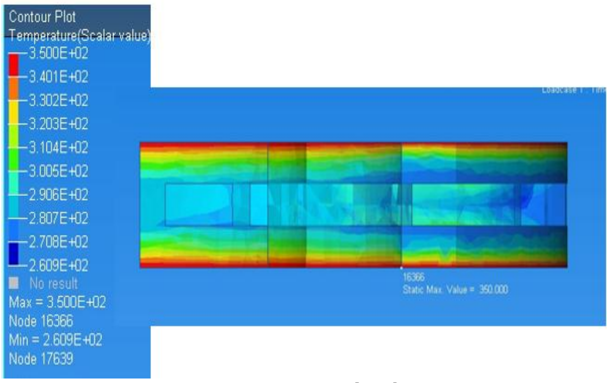

Figure 7.Temperature distribution

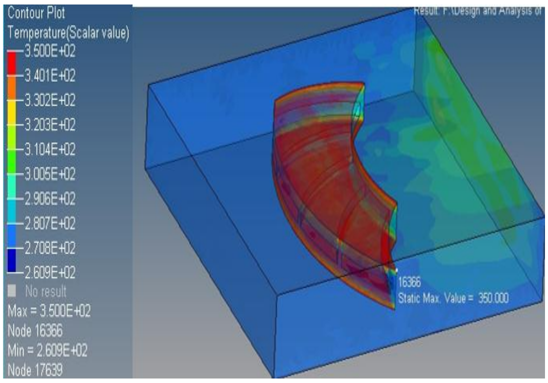

Figure 8 .volumetric temperature distribution

8. RESULTS AND DISCUSSION

From the results we got an idea about final disc design which has been shown in figure-9. which consists of free edge at edge of the disk brake to flow fluid free and allow to heat conduction in best way, at the same time it has to with stand static and dynamic loading conditions.

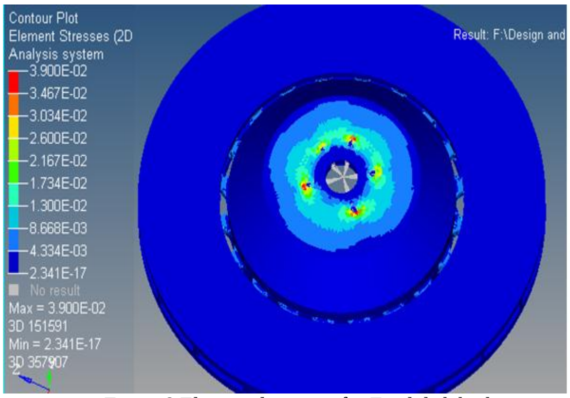

Figure 9.Elemental stresses for Final disk brake

	S.no	Displacement (mm)	Elmental Stresses (MPa)	Factor of Safety	Weight(kg)
	Disk without Optimization	4.3e-7	3.5e-3	81.3	4.2
	Disk with Optimization	2.21e-6	3.9e-3	73.5	3.8

Difference between Optimized and without optimized disk brake

CONCLUSION

It is clear that deformation value has been decreased 5.1%. Elemental stresses for optimized disk brake comes out to be 3.5e-3 where as with optimized disk brake elemental stresses comes out to be 3.9e-3. It is denoted that elemental stresses has been increased by 11.4%. In Safety without optimized disk has factor of safety calculated as 81.3% and the optimized disk has factor of safety calculated as 73.5%, which represent 9% decreased in factor of safety.

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