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Optimized Thermo –Structural Analysis of Solid and Vented Disc Brake Using Finite Element Mathod (A Case Study)

Vivek Agnihotri[1] & Dr. M.K. Chopra[2]
[1]*(Department of Mechanical Engineering,, S.R.M.G.P.C College,Lucknow/U.P.Technical University, INDIA)*
[2]*(Department of Mechanical Engineering,, R.K.D.F College/R.G. Technical University, INDIA)*

Abstract : *The disc brake is a device for slowing or stopping the rotation of a wheel. Friction causes the disc and attached wheel to slow or stop. Brakes convert friction to heat, but if the brakes get too hot, they will cease to work because they cannot dissipate enough heat. Disc brakes are exposed to large thermal stresses during routine braking. The main cause of this paper is to minimize the thermal stresses with best suited material, best suited design & give optimized result.*

This paper studies about the model of a disc brake used in TATA SUMO N/M, 207 DI, 207EX – Wheeler; data has been given by R.M.ENGG, RAJKOT;GUJRAT.

Analysis is also done by changing the design of disc brake. Actual disc brake has no holes; design is changed by giving holes in the disc brake for more heat dissipation. In this paper, the author has investigated on ventilated and solid disc brake rotor of normal passenger vehicle. The work considers heat and temperature distribution on disc brake rotor. Modeling is done in Pro/E (3D-Modelling-software) and Analysis is done in ANSYS (finite element analysis-software). Thermal and Structural analysis is done on the disc brake. The materials used are Stainless Steel & Gray cast Iron. Both results have been compared for better justification. Thus, both results provide better understanding on the thermal characteristic of disc brake rotor and assist the automotive industry in developing optimum and effective disc brake rotor.

Keywords: *ANSYS, Disc Brake, Structural analysis, Thermal analysis, Thermal stresses.*

I. Introduction

1.1: Introduction

Normally, thermal stress analysis has been performed to any of material related to thermal process in order to oversee the behavior and character of material. Any abnormality regards to thermal input will give the high values on the stress magnitude of the studied materials.

A literature review was conducted to investigate the past research that has been done in many areas related to this work. In addition, description, histories, functions and theory of disc brake rotor will be discussed in this chapter. Furthermore, theory of finite element method related to thermal analysis will be presented as well in this paper.

A. Floquet et al [1] determined of temperature distribution and comparison of simulation results and experimental results in the disc by 2D thermal analysis using axisymmetric model.

R. A. Burton et al [2] showed the thermal deformation in frictionally heated contact wheel-mounted on disc brakes were exposed to severe non-symmetrical mechanical and thermal loads. The paper described the design process for two high-performance, hub mounted discs of different size and duty.

T. A. Dowat et al [3] proposed to contribute to dynamic and thermal analysis of the braking phenomenon. A dynamic model was established. Using this model the equation of motion of a car was derived for straight line braking.

K.Lee et al [4, 5] thermo elastic instability in an automotive disk brake system was investigated experimentally under drag braking conditions.

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J. R. Barber et al [10, 11] developed a procedure based on the Radon transform and elements of distribution theory, to obtain fundamental thermo elastic three-dimensional (3D) solutions for thermal and/or mechanical point sources moving steadily over the surface of a half space.

T. A. Dowat et al [12] proposed to contribute to dynamic and thermal analysis of the braking phenomenon. A dynamic model was established. Using this model the equation of motion of a car was derived for straight line braking.

K.Lee et al [13, 14] thermo elastic instability in an automotive disk brake system was investigated experimentally under drag braking conditions.

J. R. Barber et al [15] the frictional heat generated during braking causes thermo elastic distortion that modifies the contact pressure distribution.

S. Du et al [16] finite element method was used to reduce the problem of thermo elastic instability (TEI) for a brake disk to an Eigen value problem for the critical speed

1.2: Problem Formulation

Due to the application of brakes on the car disk brake rotor, heat generation takes place due to friction and this thermal flux has to be conducted and dispersed across the disk rotor cross section. The condition of braking is very much severe and thus the thermal analysis has to be carried out. The thermal loading as well as structure is axis-symmetric. Hence axis-symmetric analysis can be performed, but in this study we performed 3-D analysis, which is an exact representation for this thermal analysis. Thermal analysis is carried out and with the above load structural analysis is also performed for analyzing the stability of the structure.

1.3: Objective of Problem

The aim at the end of this project is to predict the temperature rise and the temperature behavior of solid & ventilated disc brake rotor with full passenger in the vehicle. In achieving this aim, project objectives are set as below:

- To understand the working principles, components, standards and theories through a literature study.
- To understand the working principle of FEA Software (ANSYS)
- To understand the fundamental of heat transfer through thermal & structural analysis of disc brake rotor.
- Best combination of parameters of disk brake rotor type like -solid, vented and Material there by a best combination is suggested.

1.4: Approach of Problem (Methodology)

The disc brake is a device for slowing or stopping the rotation of a wheel. Friction causes the disc and attached wheel to slow or stop. Brakes convert friction to heat, but if the brakes get too hot, they will cease to work because they cannot dissipate enough heat. This condition of failure is known as brake fade. Disc brakes are exposed to large thermal stresses during routine braking and extraordinary thermal stresses during hard braking. The main focus of this thesis is to minimize the thermal stresses with best suited material, best suited design & give optimized result.

The investigation has been carried out at R.M.ENGG, RAJKOT; GUJRAT. The products studied are TATA SUMO 207 DI, 207EX –brake disc.

After problem based study author suggested some change in design. Instead to use Plain solid Disc-rotor, suggested to use and produce some rectangular shaped vents on the periphery (thickness side) of rotor. Now, our next step is analyzing the result after modification in design with vents. With the help of Pro/E (modeling software), author undertook new design and with the help of Ansys- software, author undertook analysis and compared the result with Plain (solid) Disc-rotor.

1.4.1: Selection of Brake System

CASE (A):- TYPE: Solid Disc	CASE (B):- TYPE: Vented Disc
MATERIALS USED; (i) Gray Cast Iron	MATERIALS USED; (i) Gray Cast Iron
(ii) Stainless steel	(ii) Stainless steel

1.5: Modeling

1.5.1: Case (A): Solid Disc

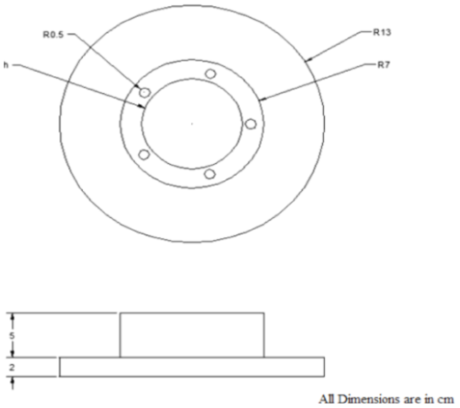


fig:1.1, 2D drawing of solid disc

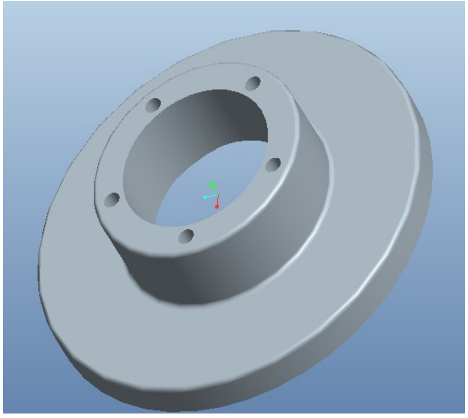


fig: 1.2, solid model of disc brake (isometric view)

1.5.2: Case (B): Modified Vented Disc

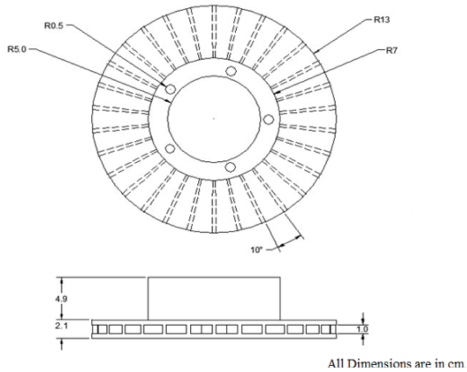


fig:1.3, 2D drawing of vented disc

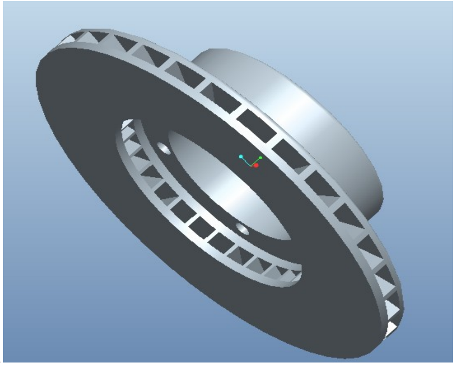
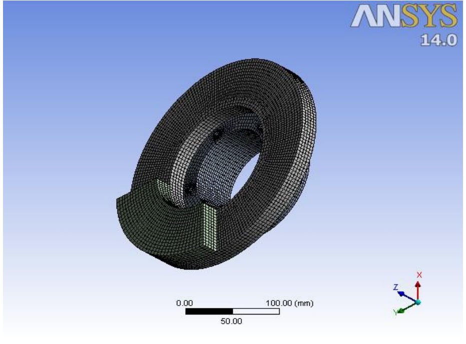


fig: 1.4, Ventilated Model of Disc Brake (Isometric view)

1.6: Finite Element Analysis

The inner radius, outer radius, and thickness of a disk are as 7, 13 and 5 cm, respectively. The thickness of pad is 2 cm. The convective boundary conditions are imposed on all boundaries to consider more realistic heat conditions. The ambient temperature is T_0 □ □ 22 □C in this study

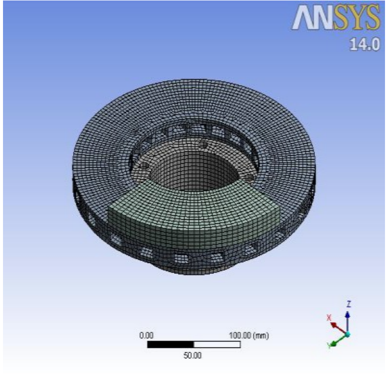
1.6.1(A): Mesh Generation: (Solid Disc)



Total Nodes: 156213 No. of Elements: 32599

Fig: 1.5, Mesh Generation: (Solid Disc)

1.6.2(B): Mesh Generation: (Vented Disc)



Total Nodes: 115872 No. of Elements 31057

Fig: 1.6, Mesh Generation: (Vented Disc)

II. Results/ Discussion

2.1: Case (A): Solid Type (I): Grey Cast Iron

2.1.1: Results:

(a): Temperature Distribution

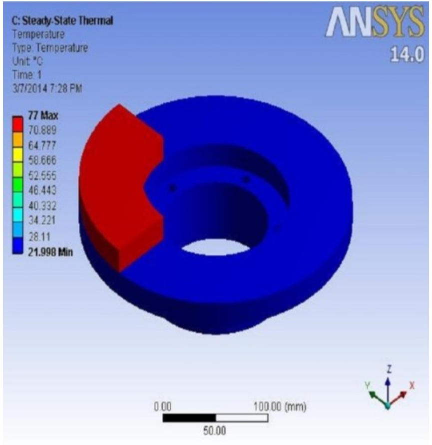


Fig 2.1, Temperature distribution on solid type-GREY CAST IRON Disk brake on the (front side)

(b): Total deflection on X, Y, Z Direction

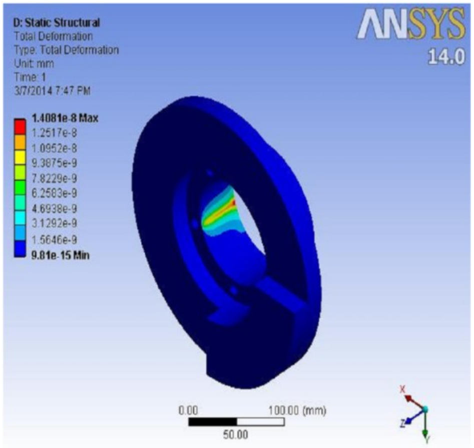


Fig 2.2, Total deflection of solid type Disk brake GREY CAST IRON

(c): Von-Mises Stress

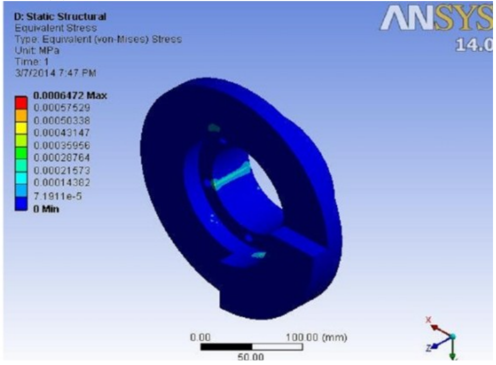


Fig.2.3, Von-Mises stress on solid type-Disk brake (CAST IRON)

(d): Stresses on X, Y, Z-Direction

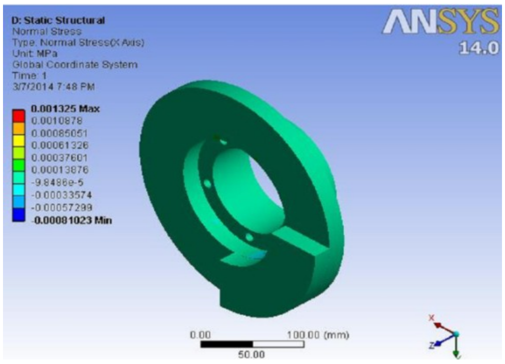


Fig 2.4, X-dir stress on Solid type-Disk brake (CAST IRON)

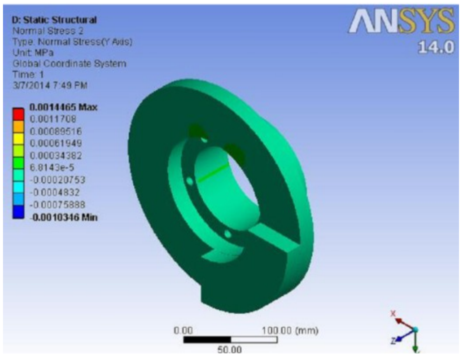


Fig.2.5, Y-directional stress Disk brake (Solid type) (CAST IRON)

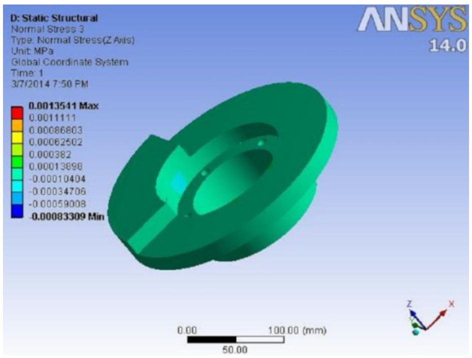


Fig.2.6, Z- directional stress Disk brake (Solid type) (CAST IRON)

2.2: Case (A): Solid Type (I): STAINLESS STEEL

2.2.1 RESULTS:

(a): Temperature Distribution

(b): Total Deflection on X,Y,Z Direction

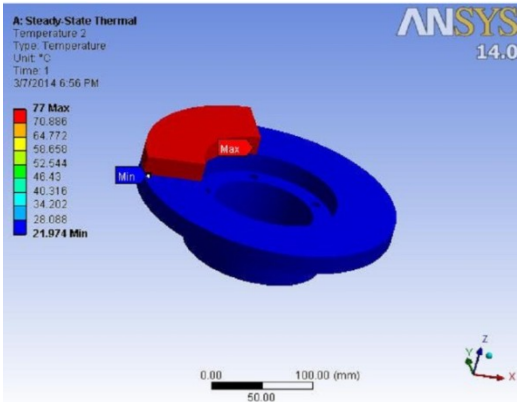


Fig.2.7, Temperature distribution on solid type-STAINLESS STEEL Disk brake on the (front side)

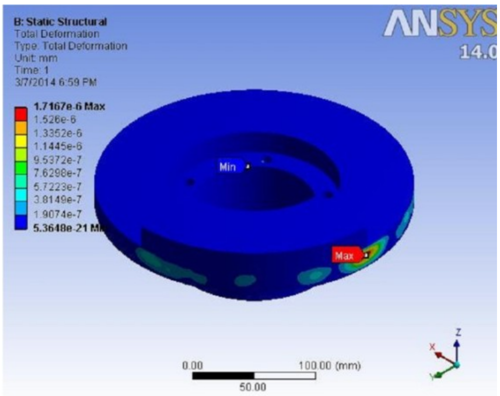
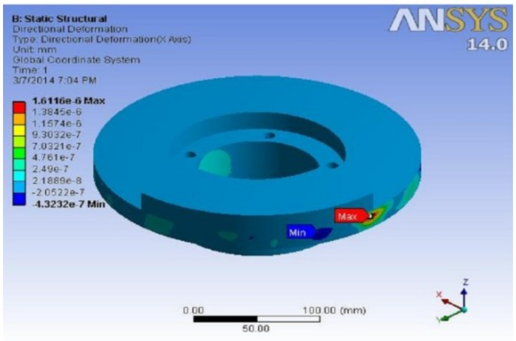


Fig.2.8, Total Deflection on Solid type Disk brake (STAINLESS STEEL)



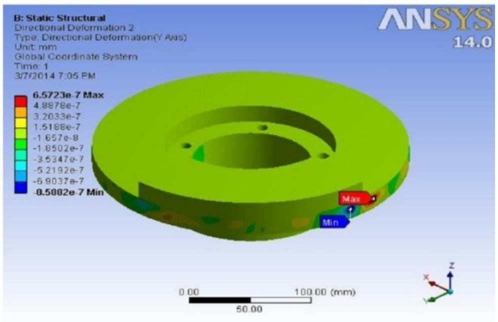
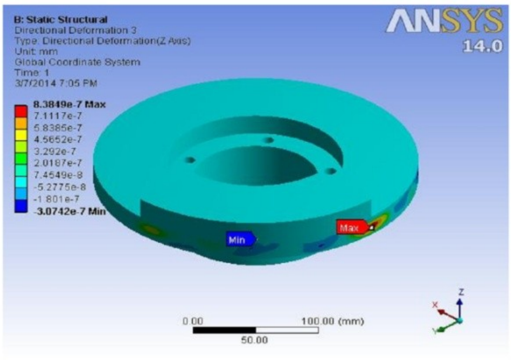


Fig.2.9, Deflection in X-direction Disk brake (Solid type) (STAINLESS STEEL)

Fig.2.10, Deflection in Y-direction Disk brake (Solid type) (STAINLESS STEEL)

(c): Von-Mises Stress



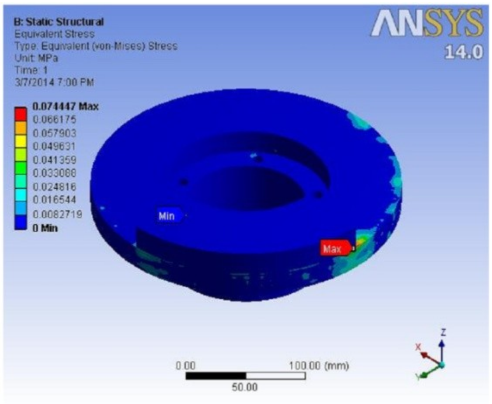


Fig.2.11, Deflection in Z-direction Disk brake (Solid type) (STAINLESS STEEL)

Fig.2.12, Von-Mises stress on solid type Disk brake (STAINLESS STEEL)

(d): Stresses on X, Y, Z-Direction

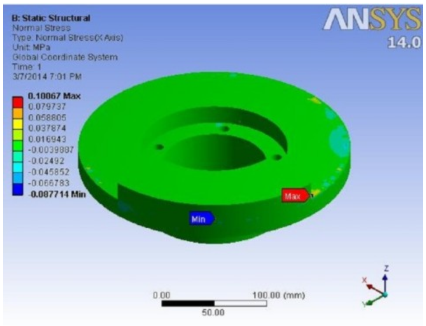


Fig.2.13, X-direction stress Disk brake
(Solid type) (STAINLESS STEEL)

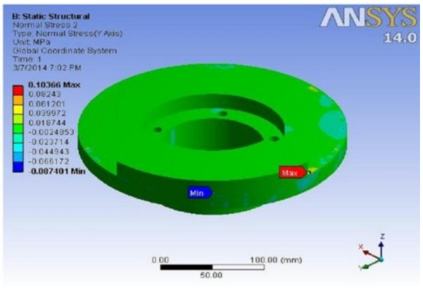


Fig.2.14, Y- direction stress Disk brake
(Solid type) (STAINLESS STEEL)

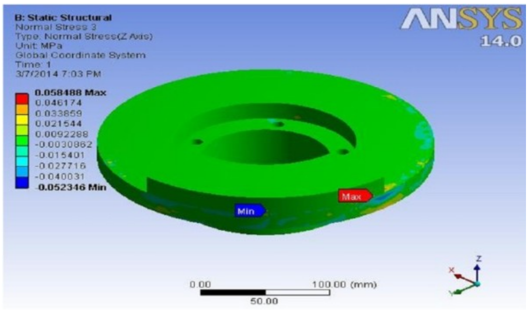


Fig.2.15, Z- direction stress Disk brake
(Solid type) (STAINLESS STEEL)

2.3: Case (B): VENTED TYPE (I): GREY CAST IRON

2.3.1: RESULTS:

(a): Temperature Distribution

(b): Deflection on X,Y,Z Direction

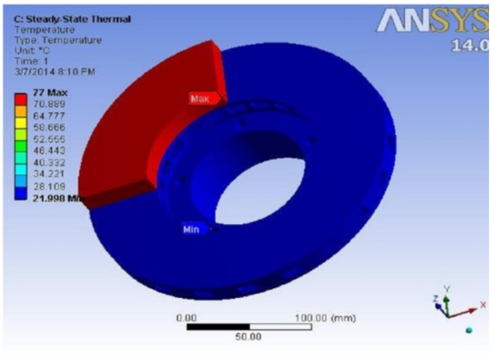


Fig 2.16, Temperature distributions on ventilated type-
CAST IRON Disk brake on the (front side)

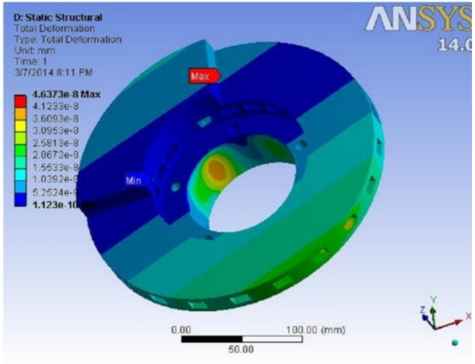


Fig.2.17, Total Deflection on Vent type
Disk brake (CAST IRON)

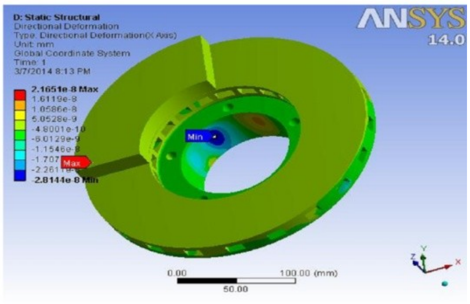


Fig 2.18, Deflection in X-dir of Vent type -
Disk brake (CAST IRON)

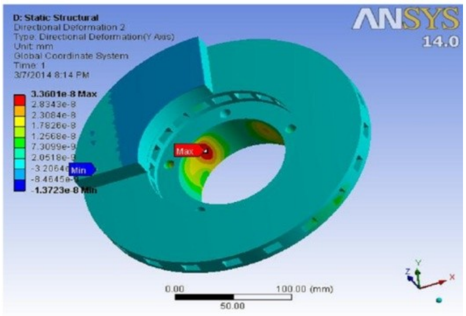


Fig. 2.19, Deflection in Y-dir of Vent type-
Disk brake (CAST IRON)

(c): Von-Mises Stress

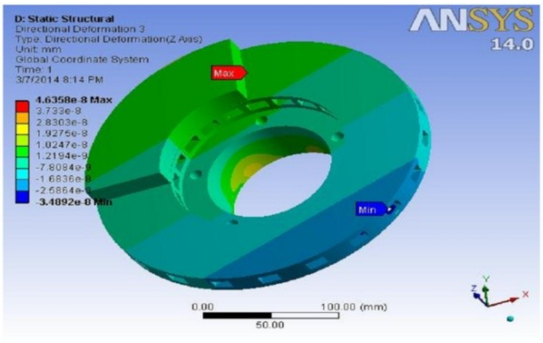


Fig.2.20, Deflection in Z-dir of Vent type Disk brake (CAST IRON)

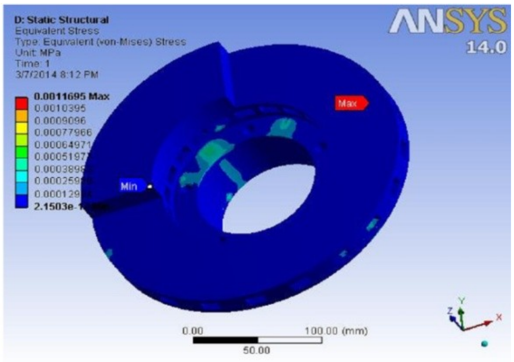


Fig.2.21, Von-Mises stress on Vent type Disk brake (CAST IRON)

(d): Stresses on X, Y, Z-Direction

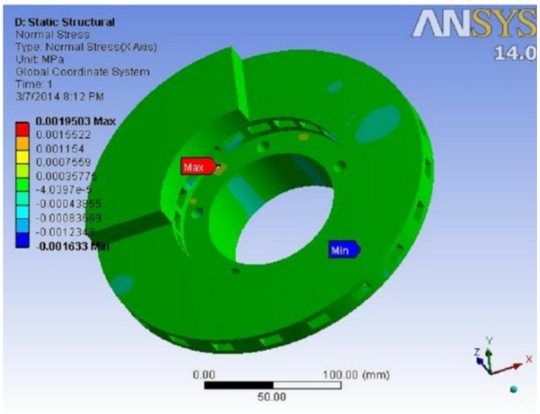


Fig.2.22, X-direction stress Disk brake (Vent type) (CAST IRON)

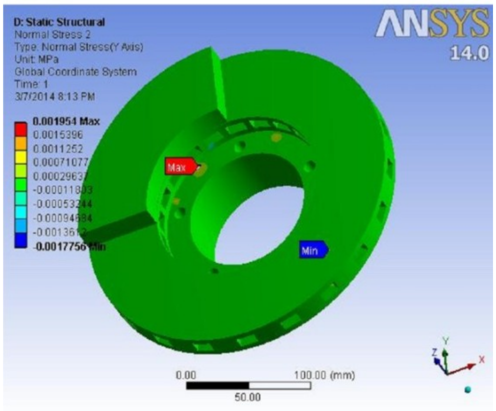


Fig.2.23, Y-direction stress Disk brake (Vent type) (CAST IRON)

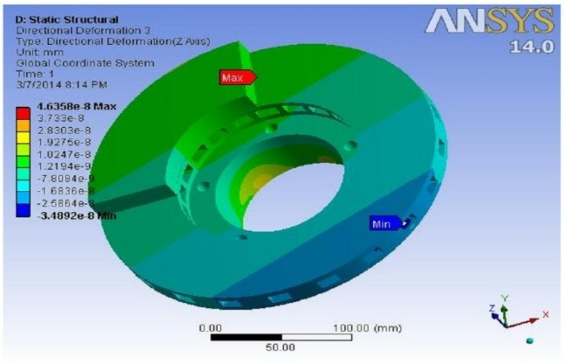


Fig. 2.24, Z-direction stress Disk brake (Vent type) (CAST IRON)

(II): <u>STAINLESS STEEL</u>

RESULTS:

(a): Temperature Distribution

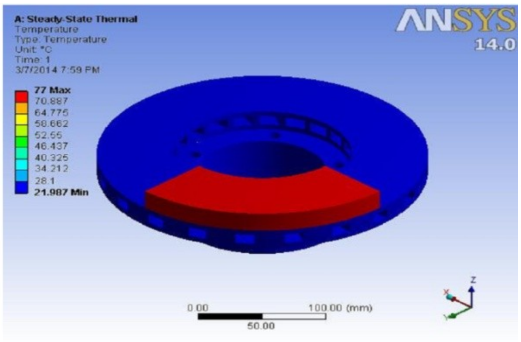


Fig.2.25, Temperature distribution on Disk brake (Vent type) on the front side (STAINLESS STEEL)

(b): Deflection on X,Y,Z Direction

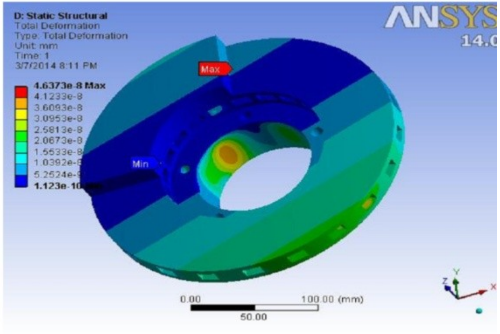


Fig.2.26, Total Deflection on Vent type Disk brake (STAINLESS STEEL)

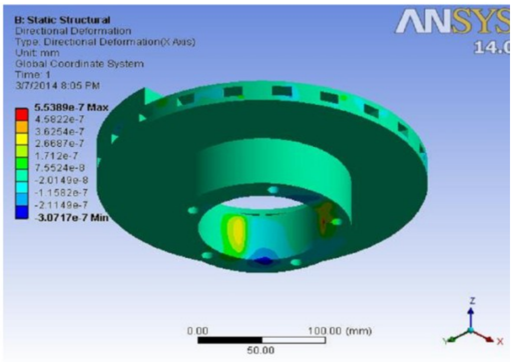


Fig.2.27, Deflection in X-direction, Vent type Disk brake (STAINLESS STEEL)

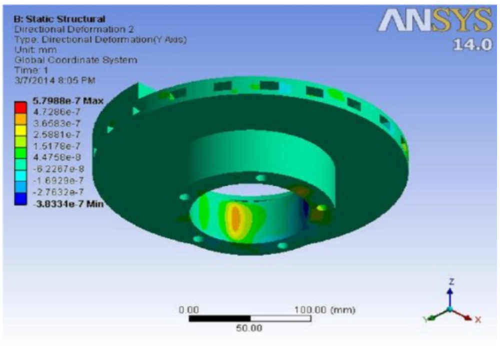


Fig.2.28, Deflection in Y-direction, Vent type Disk brake (STAINLESS STEEL)

(c): Von-Mises Stress

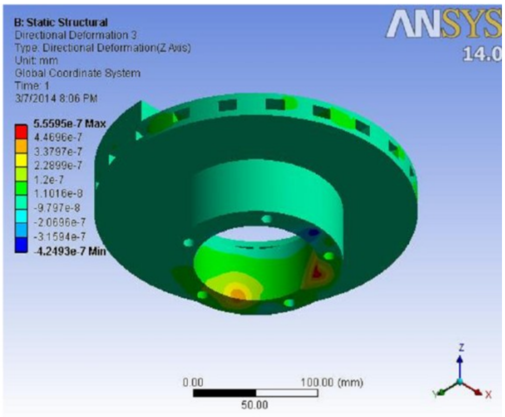


Fig.2.29, Deflection in Z-direction, Vent type Disk brake (STAINLESS STEEL)

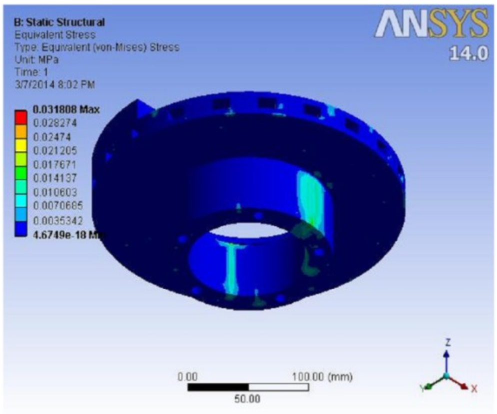


Fig.2.30, VonMises stress on Vent type Disk brake (STAINLESS STEEL)

(d): Stresses on X, Y, Z-Direction

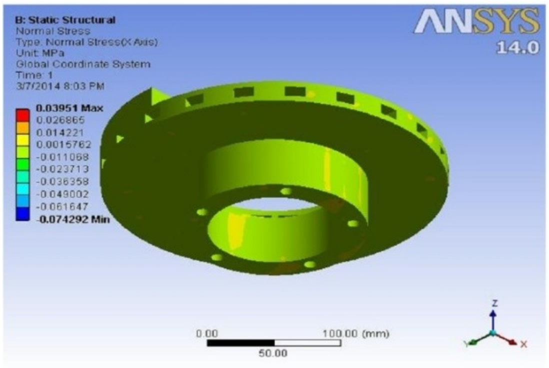


Fig2.31, X-direction stress, Disk brake-
(Vent type) (STAINLESS STEEL)

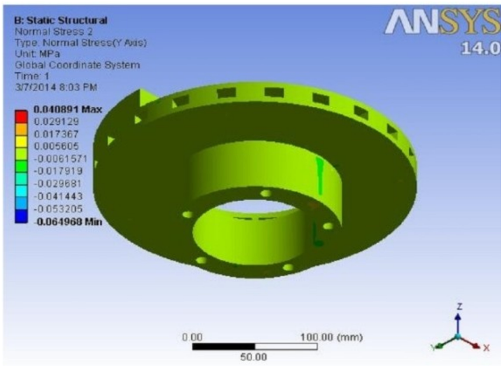


Fig.2.32, Y-direction stress, Disk brake
(Vent type) (STAINLESS STEEL)

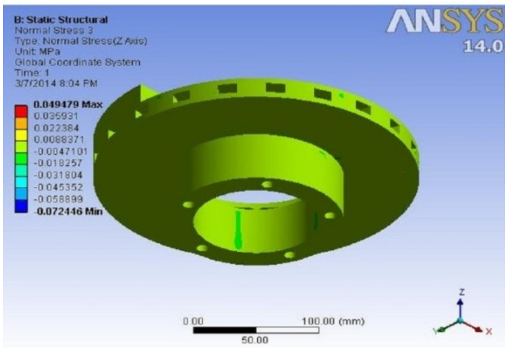


Fig.2.33, Z-direction stress, Disk brake (Vent type) (STAINLESS STEEL)

III. Conclusion

In this paper, the thermo elastic analysis of disk brakes (Solid and Vented) has performed. ANSYS software has been applied to the thermo-elastic contact problem with frictional heat generation.

The summary of result exhibited has been shown in the Table (5.1) & in the Table (5.2).

3.1: Table Of Result Analysis (Gray Cast Iron)

Table No. 3.1

Parameters	Gray Cast Iron	
	Solid Type	Vented Type
Total Deformation (mm)	1.4081 e -8	4.6373 e -9
Stress in x Dir.(M.pa.)	0.001325	0.0019503
Stress in Y Dir. (M.pa.)	0.0014465	0.001954
Stress in Z Dir. (M.pa.)	0.0013541	0.001593
Vonmises Stress (M.pa.)	0.0006472	0.0011695

3.2: Table Of Result Analysis (Stainless Steel)

Table No. 3.2

Parameters	Stainless Steel	
	Solid Type	Vented Type
Total Deformation (mm)	1.7167 e -6	6.07 e -7
Stress in x Dir.(M.pa.)	0.10067	0.03951
Stress in Y Dir.(M.pa.)	0.10366	0.040891
Stress in Z Dir. (M.pa.)	0.058488	0.049479
Vonmises Stress (M.pa.)	0.074447	0.031808

3.3: Interpretation of Table (3.1) and Table (3.2)

(a) Total Deflection (in mm.) is less in vented type disc brake and best suited material is Grey Cast Iron.
(b) Stresses (in MPa) in all direction (X,Y,Z) is less in Grey Cast Iron as compared to Stainless Steel, so best suited material is Grey Cast Iron.
(c) Von-mises stases (in MPa) is very less in Grey Cast Iron, so best suited material is Grey Cast Iron.

It is observed that the vented type disk brakes can provide better heat dissipation than the solid ones; present study can be provide a useful design tools and improvement of the brake performance in disk brake system. We can say that from all the values obtained from the analysis i.e. the Total Deformation, Stress in all direction, Von mises Stress exhibit that the vented disc is best suited design. Comparing the different results obtained from analysis, it is concluded that disk brake with vents and of material Grey Cast Iron is observed best possible combination for present application

Acknowledgement

Successful completion of any project involves interests and efforts of many people so it becomes obligatory on our part to record our thanks to them.

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