# DESIGN OPTIMIZATION OF DISK BRAKE ROTOR

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**Abstract-***The main function of brake system is to decelerate a vehicle including stopping. Brake are an energy absorbing mechanism that converts vehicle movement into heat while stopping the rotation of wheel. Driver exert a force on brake pedal which is amplified by power booster. The force on brake pedal pressurizes brake fluid in a master cylinder, brake fluid is designed for extreme conditions, the hydraulic force developed by brake fluid is transmitted to a wheel cylinder or caliper at each wheel which is used to force friction material against the drum. The friction between material and rotating drum causes the rotating part to slow down and eventually stop.*

*The Objective of this project to optimize and find out the effective design of disk with minimum weight by reducing raw material cost without affecting function and investigate effect of load on stress, displacement and model analysis through finite element analysis.*

*It was statically and modal analysis by using simulation software Altair Hypermesh and Ansys. Static analysis is to find out the total amount of stresses and displacement of disk. Modal analysis is to find out the Natural frequency of disk. Optimization is based on Linear static and modal analysis results, which can be used to enhance the efficiency of the design process. Considering the results obtained from optimization, geometric model was modified and iterated until satisfactory results were achieved. This process is repeated until all specified criteria are met.*

***Key Words***: **Expansion joints, thermal expansion, fatigue calculation, Modified design, Re-Analysis**

## 1.INTRODUCTION

In building plan we make the frameworks, structures, and strategy just to fulfill our essential prerequisites. These are a portion of the decisions to make forms, at which the essentials of designing and a portion of the customary law and determined basics can be utilized or connected to accomplish the required true objective. These building configuration devices comprises of breaking down the items, setting up the designing illustrations, figuring distinctive computations both hypothetically and scientifically and combination, testing and more to get fine parts.

In car brake outside imperviousness needed to apply the brakes utilizing reasonable brake cushions which makes the warmth and the era of warmth is because of the utilization of brake and resistance. The brake cushions does primary fundamental elements of making the resistance as rubbing and even the cushions ought to have the capacity to endure the heap which will shape by the plate brake rotor.

### 1.1 Finite Element Analysis :

While doing meshing the whole continuum will be divided into small elements and these elements are often called as the finite elements. Then at the analysis part the stiffness of the rotor will be formed and the amount of load acting (torsion and uniformly distributed) will be formulated. Here the displacement function of the finite element function may be formulated in the form of linear functions or may be in the form of higher order functional form.

### 1.2 Optimization :

The final optimization will be done based on the results which has been declared by the FE model which has been tested seriously under all suitable conditions and the most approximate form of the model will be selected for the further process.

## 2. OBJECTIVE AND SCOPE OF THE WORK

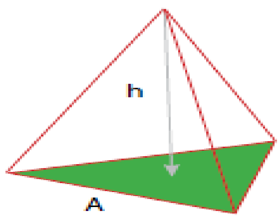
### 2.1 Objectives of project.

- The Objective of this task to upgrade and decide the compelling plan of Brake plate with minimum weight by reducing raw material price while not affecting function.
- To investigate result of load on stress, displacement and Vibration in Brake disc through finite element analysis.

### 2.2 Scope of Project:

- Brake disc design
- Finite element Meshing, loading, boundary conditions etc.
- Finite element Analysis
- Optimization

### 2.3 Quality check for Tetra elements-




**Tetra Collapse:**

Ideal Value = 1.0 (Acceptable > 0.1)
Tetra collapse = h * 1.24 / A
(Characterized as the separation of a hub from the inverse face isolated by the range of the face increased by 1.24)

**Quad face included angles:** 45°< θ < 135°

**Tri face included angles :** 20°< θ < 120°

### 2.4 Material Properties

A Stainless Steel SS420 material was used to describe the material behavior of disc in both Static and modal analysis.

Stainless Steel SS420

Young's modulus = E= 2.1×105 M-Pa,

Poisson ratio = μ =0.3,

Density of steel = ρ = 7.85×10-9 kg/mm3

## 3. RESULTS

### 3.1 Static Analysis Result

Linear Static analysis used to determine the displacements, stresses, strains and forces in structures or components cause by static loads. The material limits are determined by material properties and some known deformation theories. To check disc safety must know the material properties like max strength of disc, and the formulation of the deformation theory to be applied.

Type of analysis :-Static structural

Expected output :-Displacement & Stress

Software used :-Hyper mesh

### 3.1.a) Displacement Contour Plot

### 3.1.b) Contour Plot for Stress Analysis

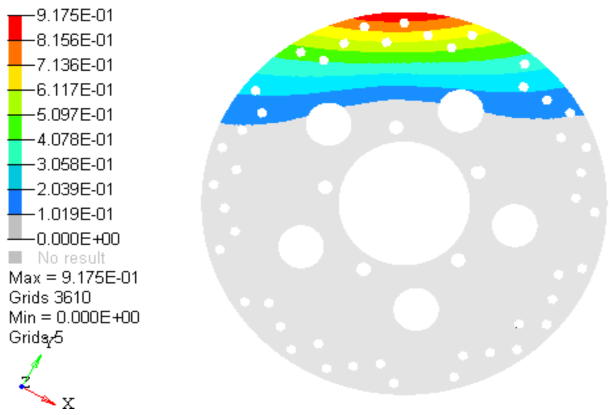



Figure 3.1.1 Displacement Contour plot– Disc

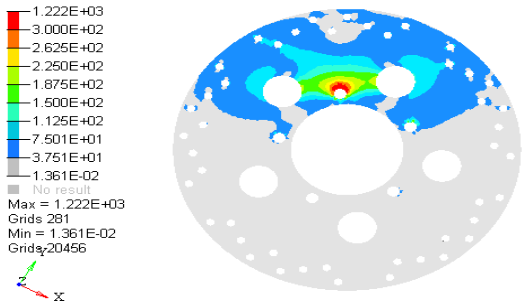



Figure 3.1.2 Contour Plot for Stress – Disc

**Results:-**

1. Disc Maximum Deflection = 0.9mm.
2. Von-mises Stress observed = 364.7MPa which is less than the yield strength of disc material so disc will be safe against load.

### 3.2 Modal Analysis Result

Natural frequency is frequency with which any protest will vibrate if aggravated or permitted to vibrate alone with no outer power. Natural frequency being inherent characteristics property of any component or assembly no external force applied during the analysis. Damping is neglected for natural frequency calculation.

The Dynamic analysis equation is given by:

$$m\ddot{x} + c\dot{x} + kx = F(t)$$

| Modes | Frequency |
|---|---|
| 1 | 534.7 |
| 2 | 537.8 |

| | |
|---|---|
| 3 | 613.8 |
| 4 | 947.6 |
| 5 | 1498.4 |
| 6 | 2251.5 |

Table 1: Natural frequency (Hz)

## 4. MODE SHAPE DISPLACEMENT CONTOUR PLOTS OF DISC

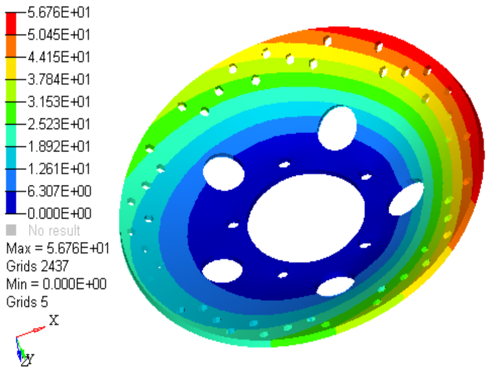



Figure 4.1 : 1st Mode shape

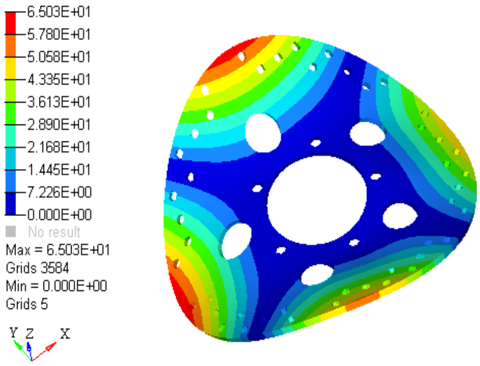



Figure 4.3 :2nd Mode shape

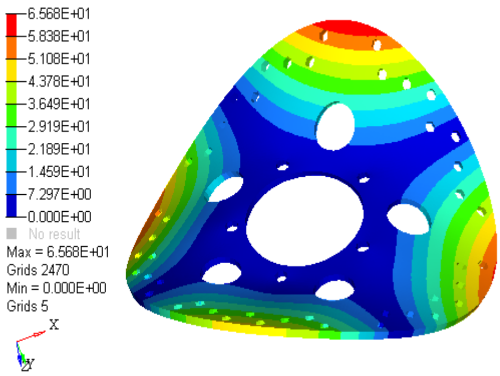



Figure 4.5 :3rd Mode shape

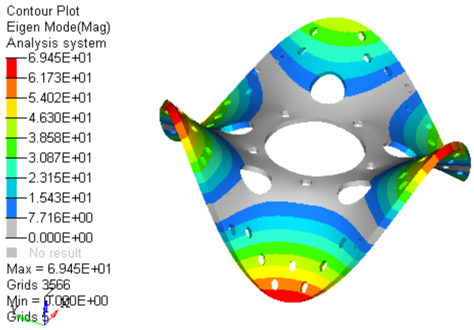



Figure 4.7 :4th Mode shape

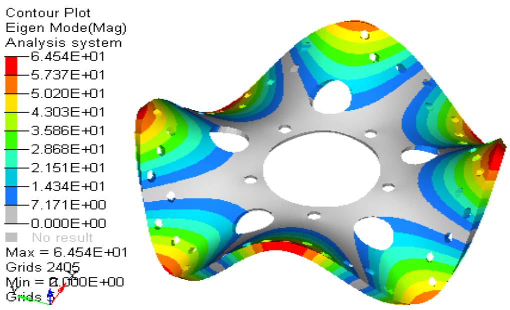



Figure 4.9 :5th Mode shape

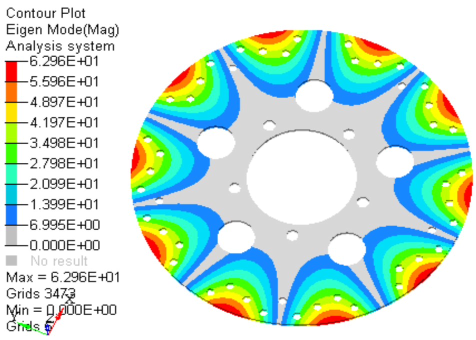



Figure 4.10:6th Mode shape

## 5. SCOPE OF OPTIMIZATION

To observe the maximum stresses, displacement and natural frequency of the model subjected to extreme condition and static structural and modal analysis was carried out by using Hypermesh.

Two load steps were used. One for linear static analysis, while other for Normal Mode analysis. The completed FEA model was solved using Optistruct Solver. Validation of data is crucial while performing analysis. Thus, the stress levels and deformation levels were checked for the worst case scenario.

| Sr. No. | Component | Material | Allowable stress (MPa) | Max. Displacement (mm) | Von mises stress (MPa) | Factor of safety |
|---|---|---|---|---|---|---|
| 1 | Disc | SS420 | 650 | 0.9 | 364.7 | 2.41 |

Table 2: Scope of Optimization

The factor of safety observed for given loading condition is more than 1.5 (specified limit for rotating components) thus the structure is safe and existing design of disc is possible to optimize.

## 5.1 Shape Optimization:-

The basic idea of shape optimization design is to put material in areas that actually want it and thin out un needed material from areas that aren't necessary for correct function so as to get the minimum shape that satisfies all the required functional necessities, like mechanical strength and rigidity. Spurred by the lightening desires mentioned on top of, recently the demand for the ability to see optimum shapes easily has been mounting.

### Finite Element Model

### 1) Meshing Model

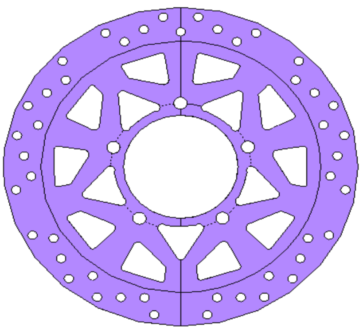


Figure 5.1.1 Schematic of a CAD model

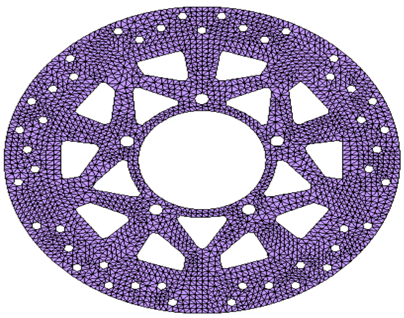


Figure 5.1.2Meshing model

Disc is meshed with about 27722 nodes 13926 elements. The modified CAD model was subjected to same loading condition, material properties, constraints and boundary conditions was taken into consideration.

## 5.2 Static Analysis Result

### 5.2.1 Displacement Contour Plot

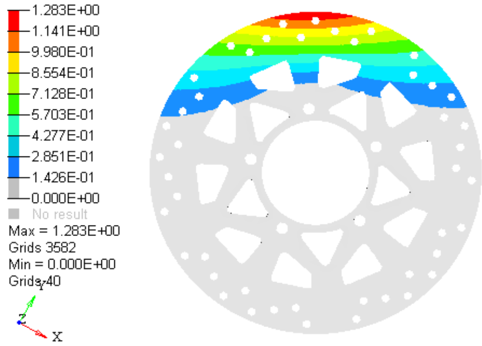



Figure 5.2.1 Displacement Contour Plot – Disc

### 5.2.2 Contour Plot for Stress Analysis

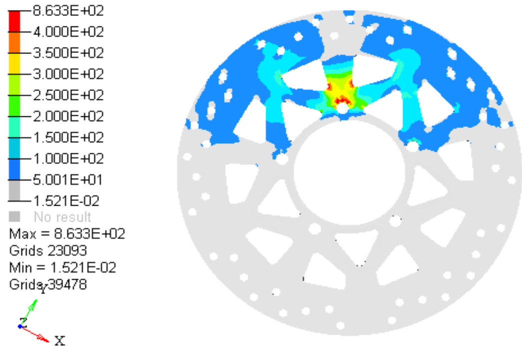



Figure5.2.2 Contour Plot for Stress Plot – Disc

### Results:-

1. Disc Maximum Deflection = 1.28mm.
2. Von mises Stress observed = 421MPa which is lower than the yield strength of disc material so disc will be safe against load.

## 5.3. Modal Analysis Result

An investigation was carried out to study the effect of natural frequency and weight due to modification of disc wall thickness, addition of rib and modification of design stage of the disc. The ribs are the important element in the design of disc it helps to sustain the maximum load also helps in optimization. From the result which has been found from the above analysis we can observe that for different sets we have different values for Natural frequency and the value of frequency(Hz) goes on increasing.

| Set | Frequency |
|---|---|
| 1 | 796.3 |
| 2 | 811.6 |
| 3 | 991 |
| 4 | 1600 |
| 5 | 2558.9 |
| 6 | 3698.8 |

Table 3: Natural Frequencies (Hz)

Modular investigation had performed in sans free condition, to discover initial 10 common frequencies of the model. Square L.anczos . technique is utilized to fathom the essential condition.

### 5.3.1. Mode shape Displacement Contour Plots of disc

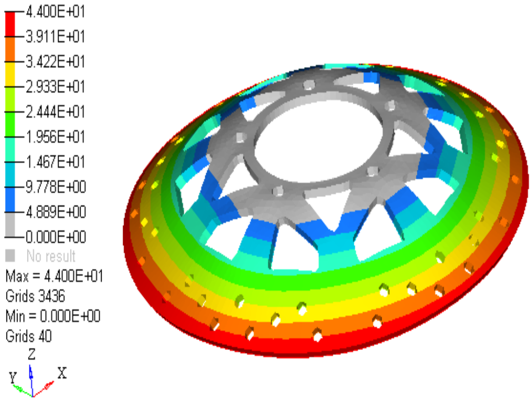



Fig No 5.3.1 : First mode shape.

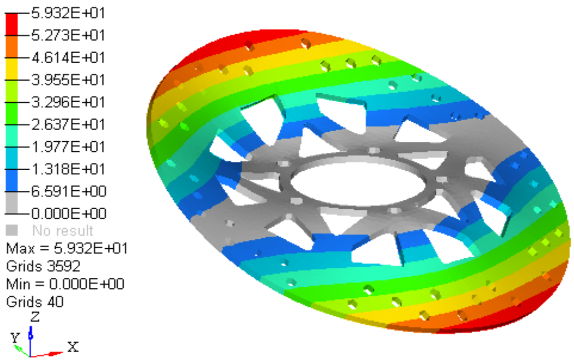



Fig No 5.3.3: 2nd mode shape.

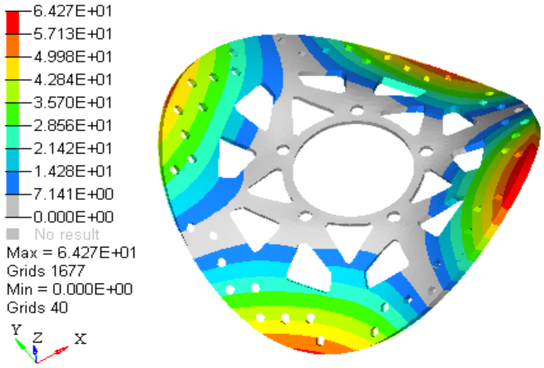



Fig No 5.3.5: 3rd mode shape

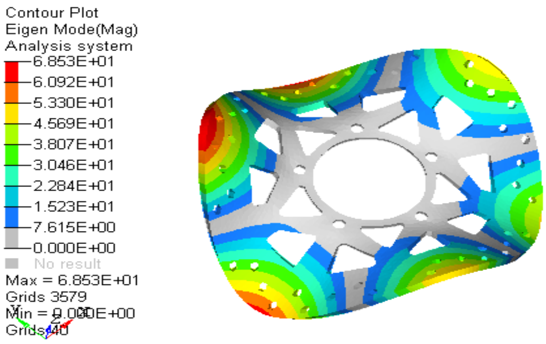



Fig No 5.3.7: 4th mode shape.

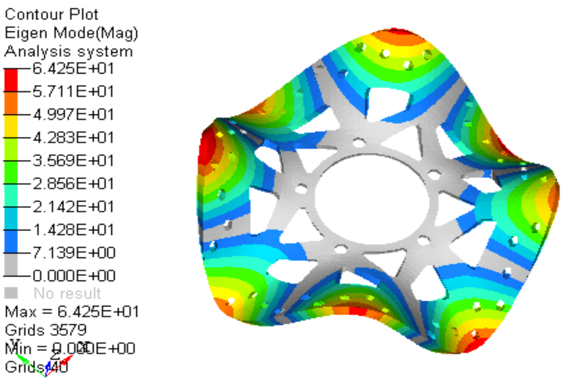



Fig No 5.3.9: 5th mode shape

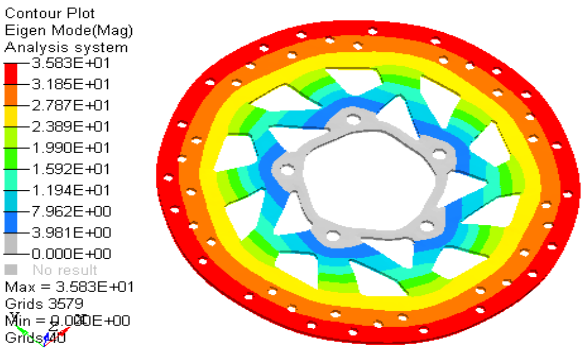



Fig No 5.3.10: 6th mode shape

## CONCLUSION

- Maximum stress and displacement is within control and yielding a factor of safety around 1.5 necessary for Disc brake.
- Existing brake disc weight 1.746kg. The Von mises stress and the maximum displacement are found 364.7MPa and 0.9mm. which is less than the yield strength of disc material so disc will be safe against load.
- Shape optimization brake disc weight 1.528kg hence up to 14% optimization possible than brake disc. The Max. Von mises stress and the maximum displacement is found 421MPa .and.1.28mm. which is less than the yield strength of disc material so disc will be safe against load.
- The ribs are the important element in the design of disc it helps to sustain the maximum load also helps in optimization.
- The Shape optimization has been successfully optimized which gives high quality brake disc at a lower cost.

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## BIOGRAPHIES

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