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Squeal Analysis of Disc Brake Rotor using Finite Element Approach

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Abstract— **Brakes are one of the important components in safety as well as performance of automobiles. From the time of emergence of automobiles, developers has been mainly focused on increasing braking power as well as reliability. As per the complaints from customers as well as high warranty costs, disc brake squeal noise is a complicated phenomenon in which automobile manufacturers have ever confronted. The finite element method (FEM) has become the preferred method in recent years, due to the high costs in performing experimental methods. In this study, the modeling of the disc brake rotor is been done on Solid works and later modal analysis is performed using ANSYS Workbench 15.0. The brake disc squeal is checked for materials like Aluminium, Grey Cast Iron and HSS M42 and material with least squeal is determined and is highly recommended.**

Keywords — Brake Squeal; Disc brake; Modal analysis; Natural frequency

I. INTRODUCTION

In today's automotive market, the competition is rising day by day for achieving better performance in vehicles. The disc brake is a device used for stopping or slowing the wheel rotation. Brake disc is generally made of Aluminum, Grey Cast Iron, and HSS M42 [1]. The brake pads produced are subjected to mechanic, hydraulic, pneumatic as well as electro-magnetic forces against two sides of the rotor disc. This friction enables the vehicle to stop or to slow with the help of disc and attached wheel arrangement. Kinetic energy of the moving member is been dissipated as heat energy by means of braking system. If the brake becomes too hot, its efficiency gets reduced gradually. This phenomenon is called as brake fade. These brakes fade later leads to brake squeal and produce high frequency noise above 1 kHz, also known as squeal.

Squeal sound is generally defined to be in the range between 1 kHz and 15 kHz. This range is divided into low frequency domain (1 ~ 3 kHz) and high frequency domain (5 kHz and over). By the introduction of modifications on caliper stiffness, mounting brackets and rotor geometry, brake squeal noise can be considerably reduced. Mostly, trial and error method was performed by brake pad manufacturing companies to find out the squeal problem. Suppliers had to depend on experimental testing methods in order to solve squeal and related problems. This method is costly as well as time consuming one. Thus this approach of addressing the issue is not good. For analyzing variety of structural as well as thermal problems of braking system, now a day's FEM has been widely used. Modal analysis is applied to the brake disc in order to analyze the squeal for different materials. This modal solution approach is based on non-linear contact analysis which helps in identifying design problems in development stages that leads to brake squeal.

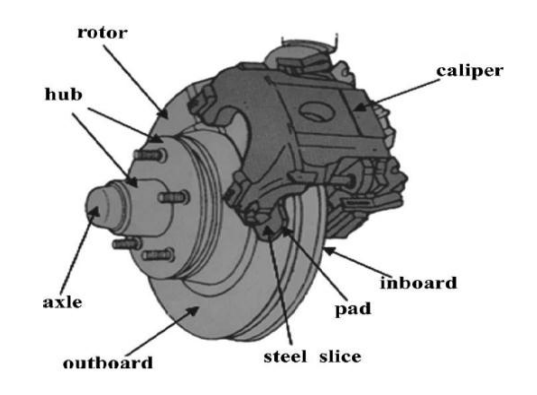

Fig 1: Disc Brake assembly [7]

II. ASSUMPTIONS FOR MODAL ANALYSIS

For performing modal analysis following assumptions are considered,

- Loads are not considered.
- Pressures are not considered.
- Damping effects are not considered.
- Considering pre-stress effects.

A. *MATERIAL PROPERTIES*

The materials properties and chemical compositions are discussed below.

1. *Grey Cast Iron:*
   Carbon – 3 to 3.5%
   Silicon – 1 to 2.75%
   Manganese – 0.4 to 1%
   Phosphorous – 0.15 to 1%
   Sulphur – 0.02 to 0.15%

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Remaining portion is Iron. The Grey color is due to the fact that the carbon has been present in the form of free Graphite. It has got low Tensile Strength, high compressive strength and no ductility. This can be easily machined. Grey Cast Iron castings are widely used in machine tool bodies, Automotive Cylinder blocks, heads, housings etc. Its melting point is 1300ºC.

2. *Aluminum:*

Copper – 3.5 to 4.5%
Manganese – 0.4 to 0.7%
Magnesium – 0.4 to 0.7%

The remaining content is Aluminium. It is a white metal produced from its oxide by means of electrical process, which has been prepared from Bauxite. It is a light metal having specific gravity of 2.3 and melting point 658ºC. The tensile strength of the metal varies from 90 MPa to 150 MPa. It has got good electrical conductivity and widely used in overhead cables.

3. *HSS M42:*

Carbon – 0 to 1.10%
Chromium – 0 to 3.75%
Molybdenum – 0 to 9.5%
Vanadium - 0 to 1.15%
Cobalt – 0 to 8%

It is widely used because of its higher red-hardness when compared to other conventional high speed steels and applicable in metal manufacturing process.

TABLE I PROPERTIES OF MATERIALS

PROPERTY	Grey Cast Iron	Aluminium	HSS M42
Density (kg/m^3)	7200	2690	7900
Young's Modulus (GPa)	110	68.9	210
Poisson's Ratio	0.28	0.36	0.29

III. MODELING OF DISC BRAKE

The figure shows the solid model of the disc brake by using SOLID EDGE by considering the BAJAJ Pulsar disc brake dimension.

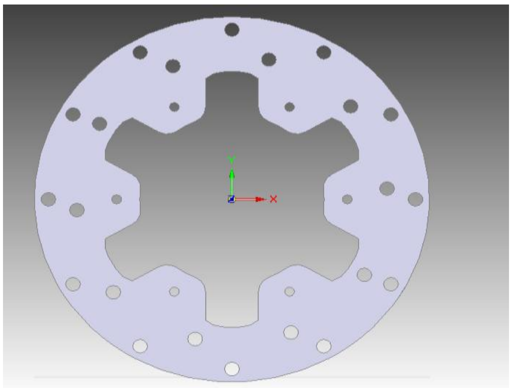


Fig 2: Model of Bajaj Pulsar Disc Brake

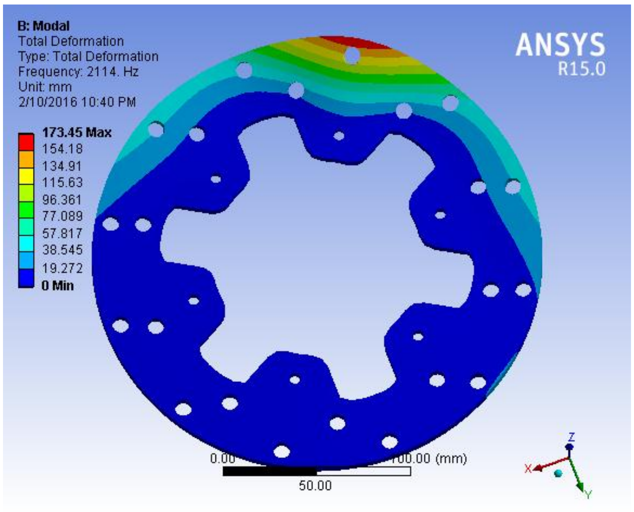
IV. ANALYSIS OF DISC BRAKE

A. *MODAL ANALYSIS*

The natural frequencies of disc rotor for grey cast iron, Aluminium and HSS M24 are analyzed at six different modes and a comparative study is made among these three materials. Material which generates least squeal is found out and recommended.

B. *RESULTS*

1. *GREY CAST IRON*



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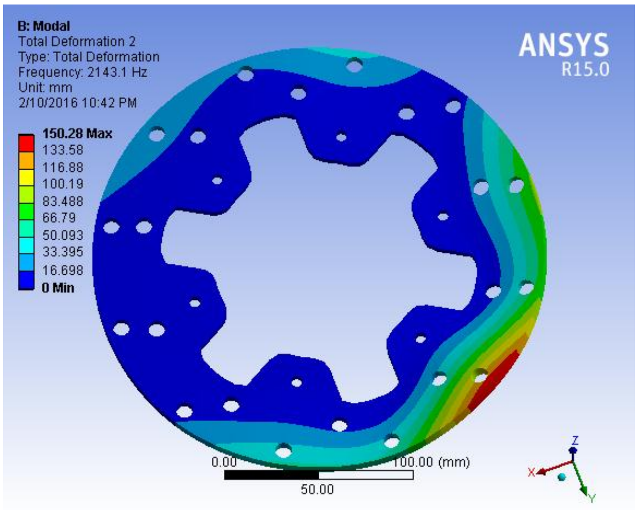

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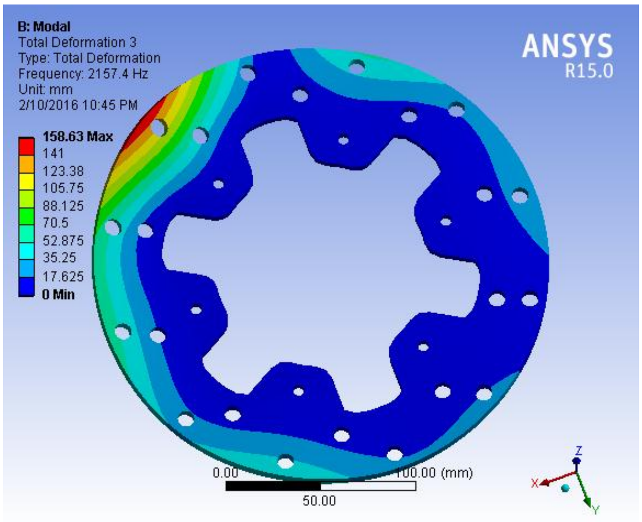

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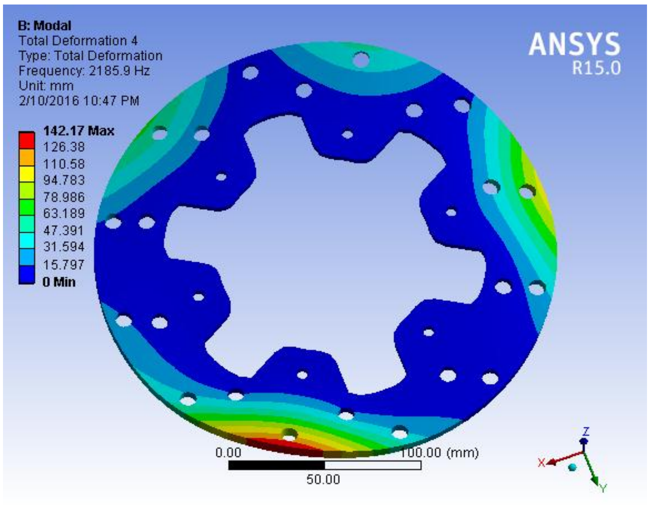

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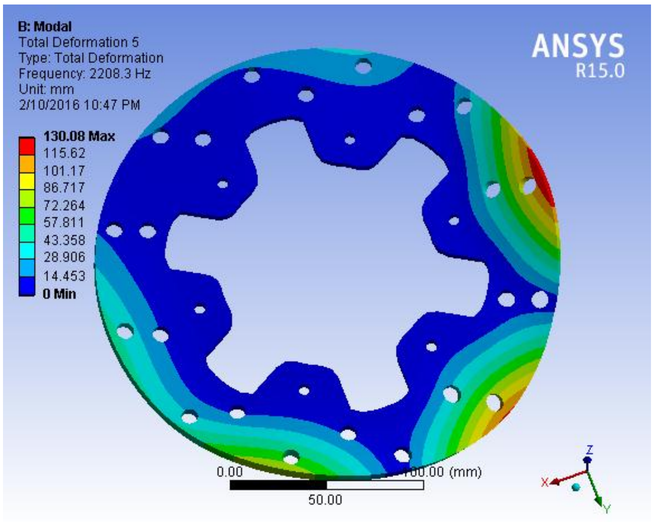

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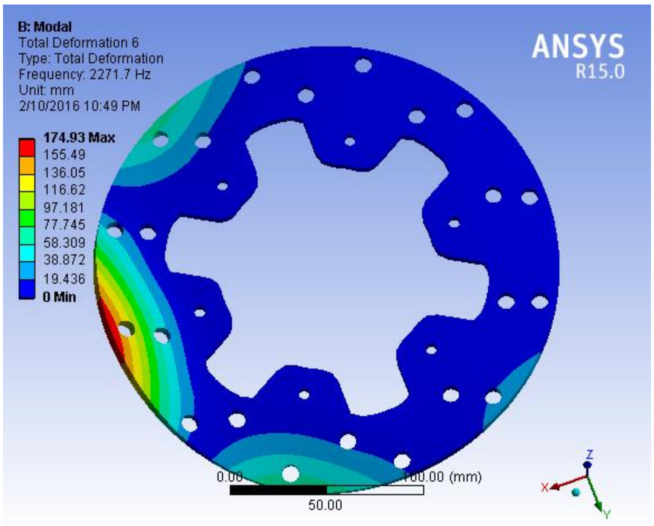

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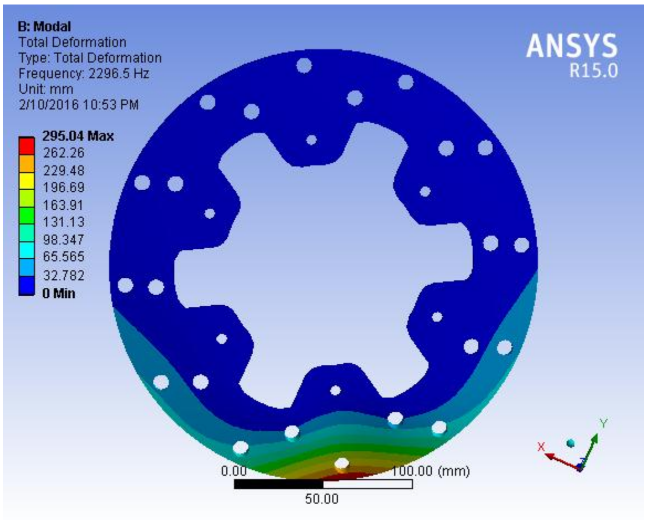
2. ALUMINIUM



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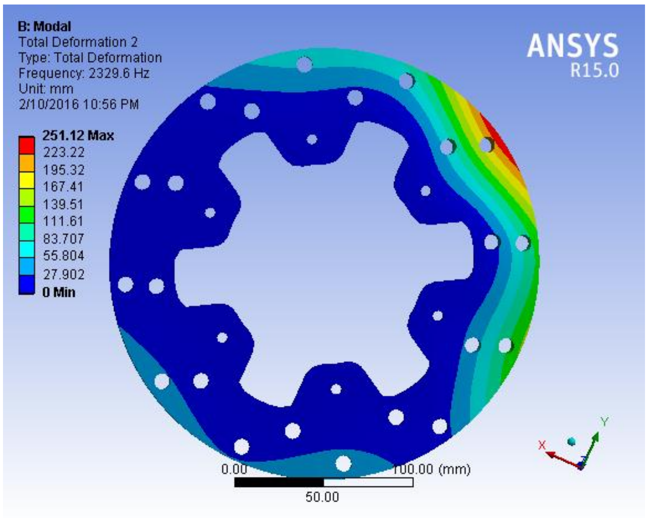

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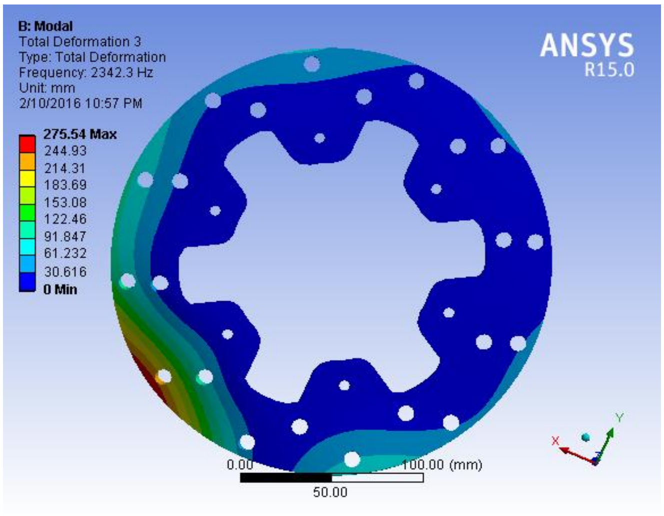

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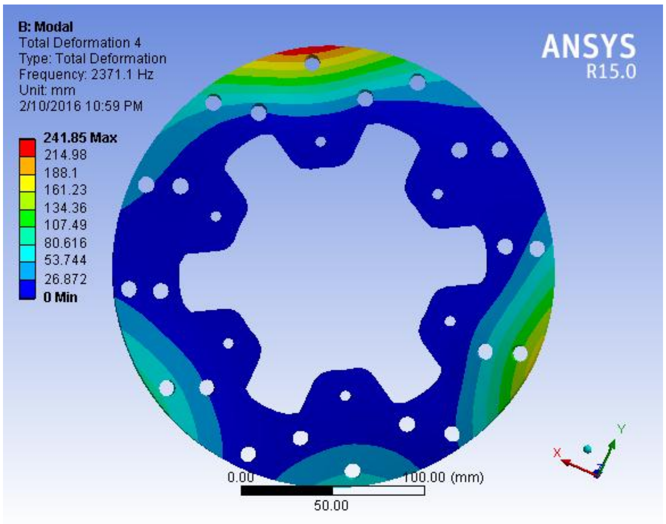

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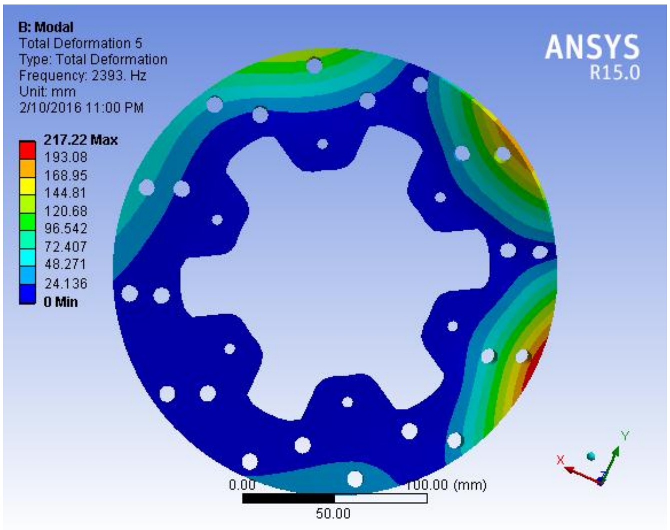

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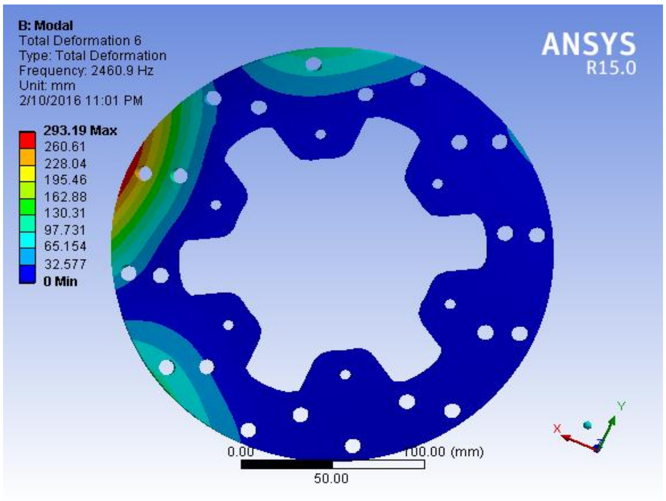

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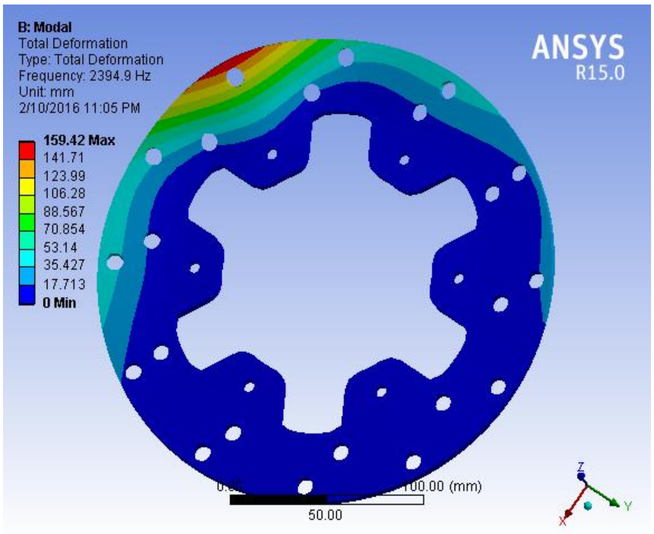
3. HSS M42



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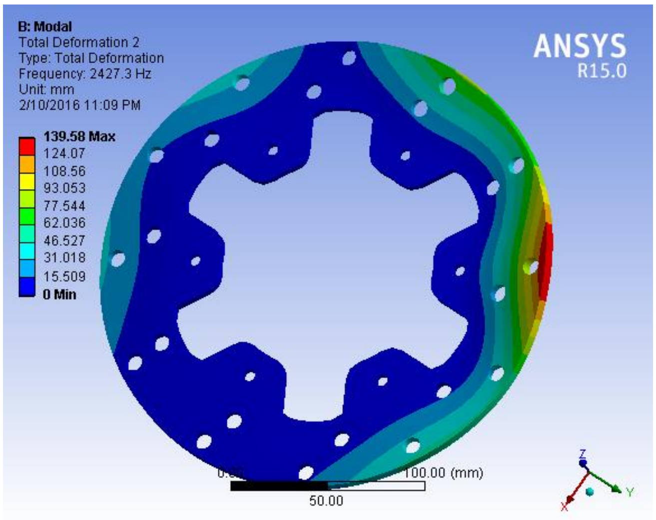

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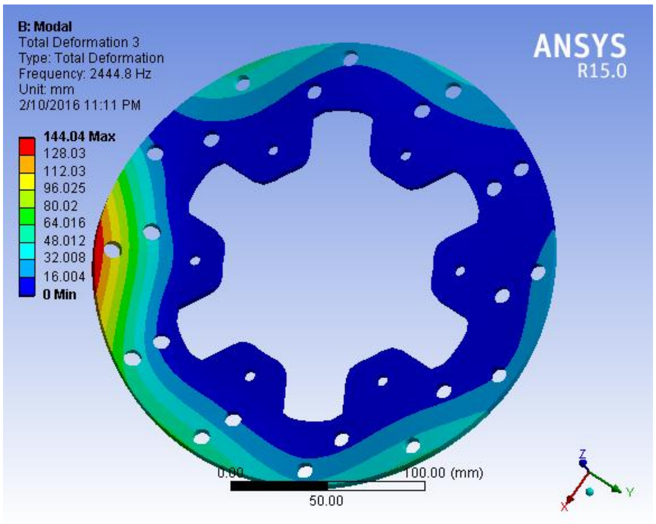

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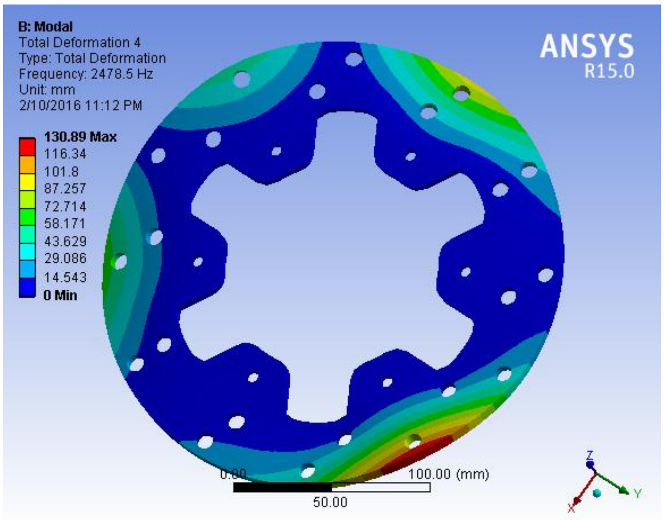

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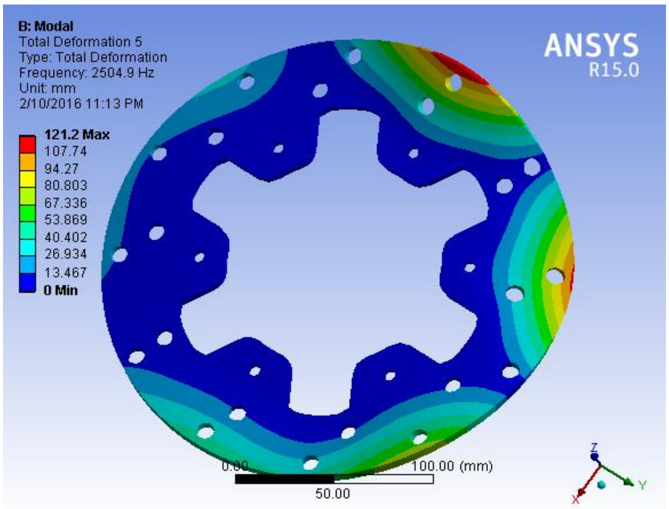

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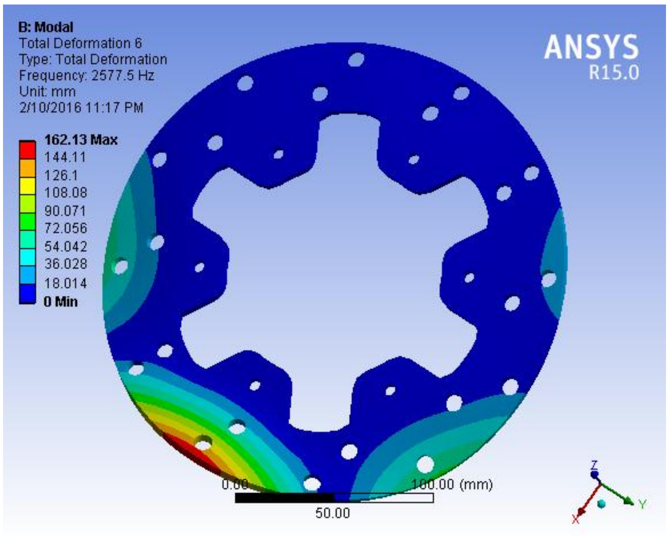

MODE 6

TABLE II COMPARISON OF RESULTS

MODES	MATERIALS AND MODAL FREQUENCIES		
	Grey Cast Iron (Hz)	Aluminium (Hz)	HSS M42 (Hz)
1	2114	2296.6	2394.9
2	2143.1	2329.6	2427.3
3	2157.4	2342.3	2444.8
4	2185.9	2371.1	2478.5
5	2208.3	2393	2504.9
6	2271.7	2460.9	2575.5

From the above table we can see that Grey Cast Iron has low squeal compared to Aluminium and HSS M24. Minimum squeal was obtained at mode 1, i.e. 2114 Hz for cast iron and 2296.6 Hz for Aluminium and 2394.9 Hz for HSS M24.and Maximum squeal was obtained at mode 6, i.e. 2271.7 Hz for Cast Iron and 2460.9 Hz for Aluminium and 2575.5 Hz for HSS M24.

V. CONCLUSION

In the present study we have conducted a modal analysis on disc brake of pulsar bike at 6 different modes and we analyses the natural frequency at each modes for the three materials. We understand that Grey Cast Iron has low squeal compared to other 2 materials. Minimum and maximum squeals were obtained at mode 1 and mode 6 respectively. The obtained squeals were with in the low squeal frequency range (1 KHz to 7 KHz). Since Aluminium has better stress withstanding ability than other two materials [1], Aluminum can be selected as the suitable material for disc brake.

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