International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 3, No. 3, July 2014

Research Paper

MODELING AND SQUEAL ANALYSIS OF BRAKE DISC ROTOR USING ANSYS

Vignesh Shanbhag[1]*, Vikram Singh[1], Rathod Abhik[1] and Baskar P[1]

*Corresponding Author: Vignesh Shanbhag, ✉ vigneshsha@gmail.com

In automobile in order to stop the vehicle motion frictional resistance is applied by means of device called brake. In recent years Engineers have been able to eliminate most of the noise generated in the vehicle. However to eliminate friction induced squeal in vehicle brakes is challenging task for automotive engineers. In automobiles Disc brake and wheel are attached together. When brakes are applied to the disc it slows down or stops the rotation of wheel. This motion is caused due to friction between disc and the wheel. Due to this large heat is generated and brakes become too hot which leads to ceasing of work since no much of the heat is allowed to dissipate. This kind of failure is called as brake fade. In order to improve heat dissipation in our experiment ventilated disc rotor is used to determine Disc squeal. Modeling of the disc is been done on Solid works and Modal analysis is done on ANSYS 13.0. Ventilated brake disc squeal is determined for cast iron and Carbon-Carbon composites. Comparison is made among these three materials and material which generates least squeal is determined and recommended. Maximum squeal was obtained at mode 6 for both the materials and the frequency squeal obtained was less then High frequency squeal (8 KHz to 16 KHz) squeal.

Keywords: Brake disc, Squeal, Natural frequency, Modal analysis

INTRODUCTION

Disc brake slows down or stops the vehicle motion due to the occurrence of friction caused by pushing wheel brake pads against brake disc with set of calipers. Brake disc is made of cast iron, Aluminium alloys or carbon-carbon matrix composites. To stop or slow down the rotation of the brake wheel brake pads are mounted on brake calipers and is forced against both sides of the disc. Due to friction caused between wheel and attached disc wheel it makes the wheel to slow or stop. Here brake converts kinetic energy of the moving member to the heat and if the brake becomes too hot its efficiency gets reduced. This phenomenon is called as brake fade. These

[1] School of Mechanical and Building Sciences, VIT University, Vellore 632014, India.

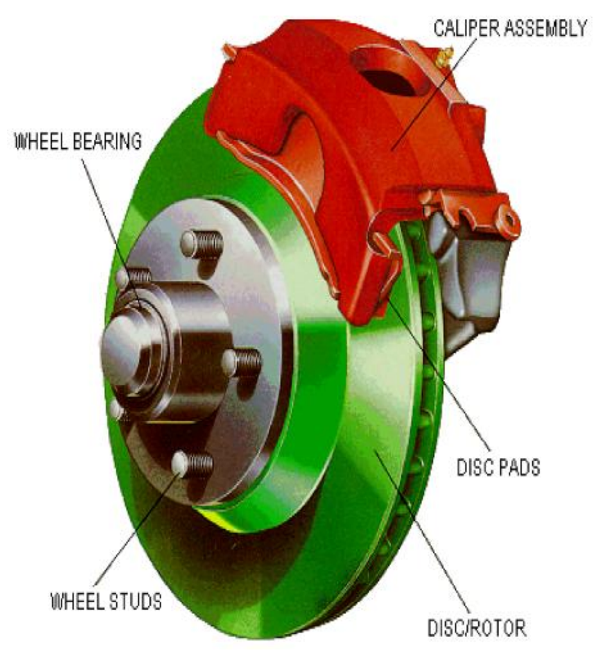
brakes fade leads to squeal. Brake squeal is friction inducing vibration (Ahmed Abdel-Naser *et al.*, 2012). A rotating brake disc causes instabilities within the brake assembly leading to vibration amplitudes causing brake squeal. This has become a serious problem in vehicles. Reducing disc brake squeal has become an important challenging task for researchers and engineers. They have been progress in reducing brake squeal in recent years. However brake squeal occurs too often, therefore its problem needs to be understood and solved. Noise induced by brakes and vibrations caused has become a serious issue for automotive industry due to inconvenience caused to the customer. This noise is referred as squeal. Squeal is noise whose frequency is 1000 Hz or higher that causes high and inconvenient sound pressure levels. Generally Noise are categorized into:

- Low-frequency noise whose range is 100 Hz to 1,000 Hz.
- Low-frequency squeals whose range is 1,000 Hz to 7,000 Hz.
- High-frequency squeals whose range is 8,000 Hz to 16,000 Hz (Mike Hebbe, 2012).

During high frequency squeal, friction induced oscillations are developed in brake disc which is known as brake squeal. This high frequency range affects sensitivity of human ear squeal mainly depends on pad, rotor, brake assembly material and geometry. Brake squeal also depends on the bulk properties of contact surface as well as surface properties.

Brake squeal noise caused during braking can be reduced by focusing on modifications such as caliper stiffness, mounting brackets and rotor geometry. Most of the brake pad manufacturing companies are currently doing trial and error method to address brake noise problem. Suppliers had to depend on experimental testing to determine squeal and solve problems. This method is not only costly but also time consuming method (Mike Hebbe, 2012). Therefore approach of addressing the issue is not good. Now a day's finite element method has been widely used for analyzing variety of problems in structural, thermal problems of brake system. In order to reduce squeal a pre stressed complex modal analysis is applied to the brake disc to look into importance of friction effects which causes instability. This modal solution approach is based on non-linear contact analysis. This way designs that causes irritating break squeal can be identified in early development stages. In our experiment we have preferred ventilated disc brake since it consists of set of vanes between the two discs which helps in artificial cooling by pumping air through the disc.

Figure 1: Disc Used in Automobile



PROBLEM DESCRIPTION

When vehicle is slowed down or stopped by using brake it generates various kinds of noises. One of them is squeal. This brake squeal is due to instability due to friction forces, leading to vibrations. To predict this instability we can perform modal analysis of prestressed structure (Ibrahim Ahmed *et al.*, 2012). While performing modal analysis following points are assumed:

1. Damping is ignored in a modal analysis.
2. Any applied loads are ignored.
3. Pre stressed modal analysis requires performing a static structural analysis first. In the modal analysis you can use the Initial Condition object to point to the Static Structural analysis to include pre stress effects.

OBJECTIVE

- To model ventilated disc brake in solid works.
- To carry out modal analysis of the ventilated disc with brake fads.
- To determine natural frequency caused due to sustained friction-induced oscillations.
- To compare results of cast iron, stainless steel, aluminium alloy and determine which material is superior to be used in brake disc.

MODELING AND MODAL ANALYSIS OF DISC BRAKE SYSTEM

Ventilated brake disc rotor was designed on solid works. Ventilated disc was preferred in our experiment for proper heat dissipation and reducing surface temperature (Chengal Reddy *et al.*, 2013). The saved drawing file from solid works was later imported to ANSYS 13 Workbench using Para solid extension. ANSYS software was preferred since it can handle any complex geometry shape for any material under different boundary conditions and loading conditions. In order to reduce squeal, best method of analyzing brake disc is by complex Eigen value analysis. This technique is available in ANSYS 13 and can be used to determine stability of brake disc. The real and imaginary part of complex Eigen values is responsible for level of instability of brake disc assembly. Once imported frictionless support was given to brake disc and fixed support was given to brake pad. Later meshing was performed and solution was obtained.

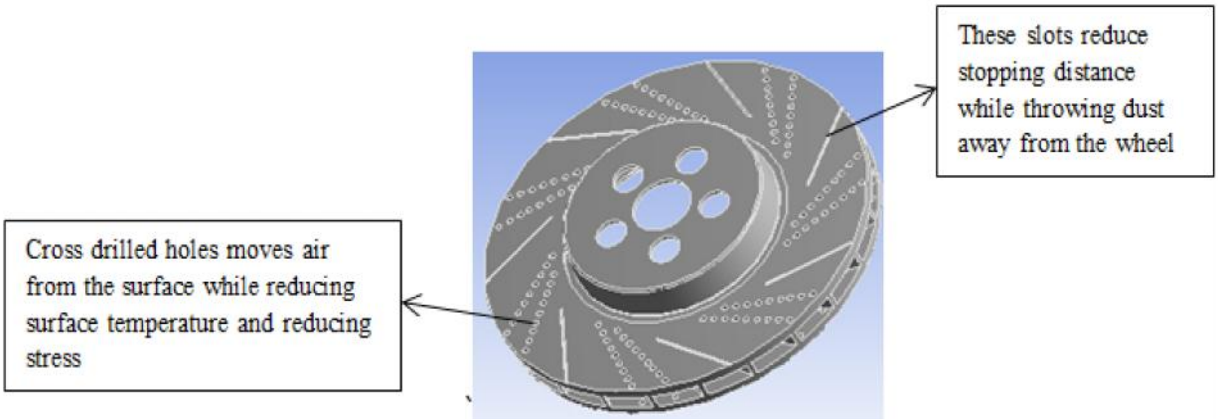
Table 1: Property Table

Properties	Cast Iron	C-C Composite
Density	7.2 g/cm^3	2.1 g/cm^3
Co-efficient of thermal expansion	1.1*10^{-5} C^{-1}	1.5*10^{-6} C^{-1}
Thermal conductivity	53.3 w/m-K	100-150 w/m-K
Specific heat	0.46 Kj/Kg K	1.42 Kj/Kg K
Tensile strength	152 to 430 Mpa	66 Mpa

RESULTS

From the above table we can see that Cast iron has low squeal compared to C-C Composite materials. Minimum squeal was obtained at mode 1, i.e., 1190.4 Hz for cast iron and 1479.8 Hz for C-C composite material and Maximum squeal was obtained at mode 6, i.e., 5426.3 Hz for cast iron and 6754.0 Hz for C-C composite material. Both Cast iron and C-C composite material squeal is within

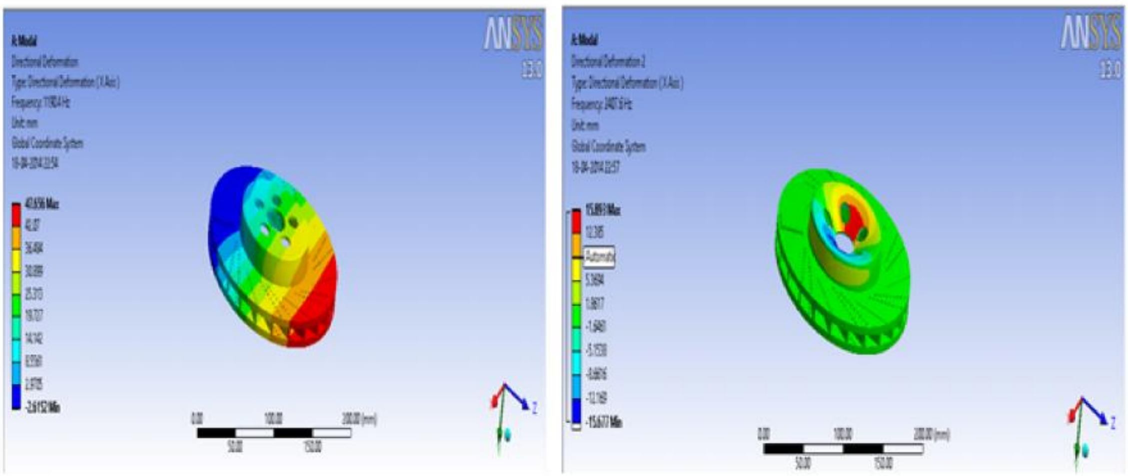
Figure 2: Ventilated Disc



Material / Mode	Frequency of Cast Iron Hz	Frequency of C-C Comp Hz
1	1190.4	1479.8
2	2407.6	3018.1
3	3077.	3827.1
4	4102.	5141.9
5	4116.9	5159.7
6	5426.3	6754.0

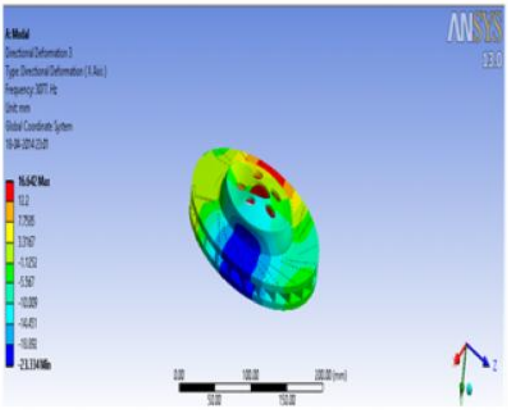
the low squeal frequency range. Better result of the squeal may be because of ventilated brake disc. From result we can see that as mechanical properties such as density decreases, squeal increases slightly. Though C-C composite material has more squeal then cast iron its squeal is within the low squeal frequency range. Considering better mechanical properties C-C Composite material compared to cast iron we can

Figure 3: Cost Iron

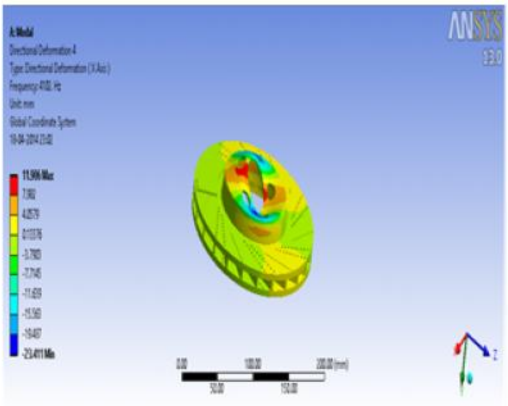


Mode 1 Mode 2

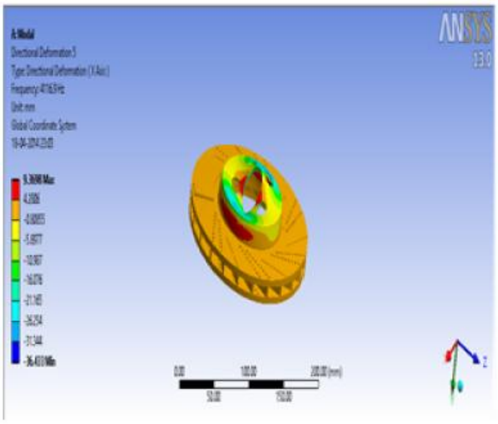
Figure 3 (Cont.)



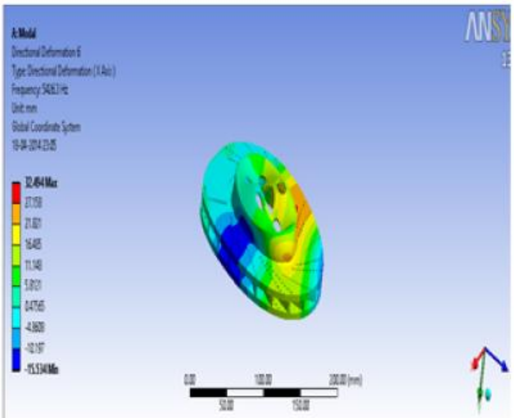
Mode 3



Mode 4

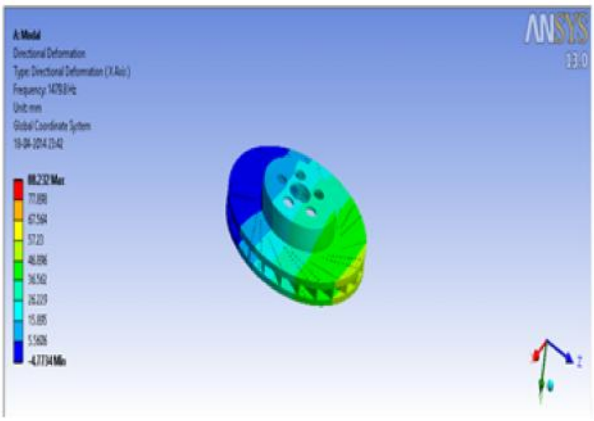


Mode 5

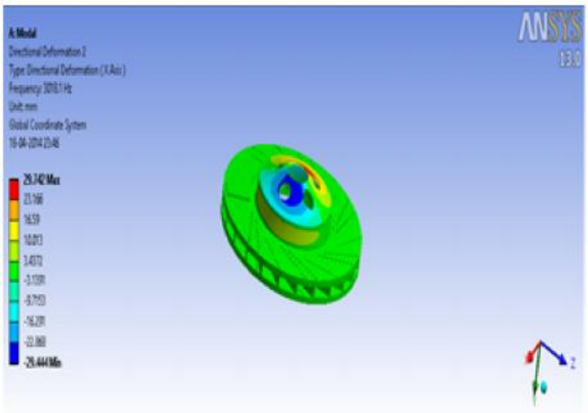


Mode 6

Figure 4: C-C Composite

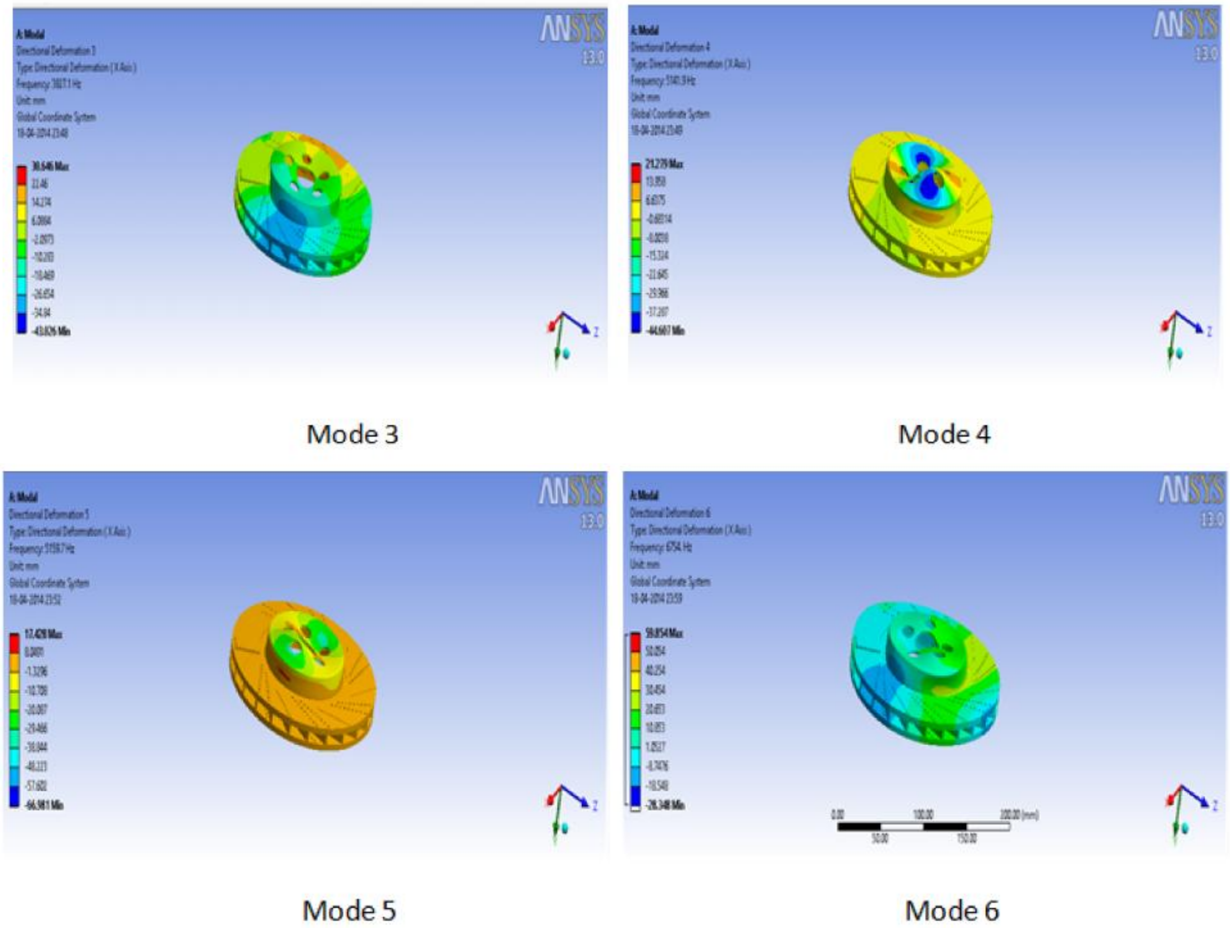


Mode 1



Mode 2

Figure 4 (Cont.)



conclude that C-C composite material is most suitable material for brake disc.

CONCLUSION

From Modal analysis of Ventilated brake disc performed on ANSYS 13.0 we can see:

1. Cast iron has low squeal compared to C-C Composite materials.
2. Minimum squeal was obtained at mode 1, i.e., 1190.4 Hz for cast iron and 1479.8 Hz for C-C composite material.
3. Maximum squeal was obtained at mode 6, i.e., 5426.3 Hz for cast iron and 6754.0 Hz for C-C composite material.
4. Both Cast iron and C-C composite material squeal is within the low squeal frequency range.
5. With reference to the above squeal results Ventilated type disc brake is best type of brake disc design.
6. Since squeal frequency for both materials is within low frequency range, considering the factor of mechanical properties such as density and co-efficient of thermal expansion we can conclude that C-C composite material is best material to be used in Brake disc.

REFERENCES

1. Ahmed Abdel-Naser, Ibrahim Ahmed, Essam Allam, Sabry Allam and Shawki Abouelseoud (2012), "Squeal Analysis of Ventilated Disc Brake Using Ansys", *International Journal of Energy and Environment*, Vol. 3, No. 5, pp. 809-832.

2. Chengal Reddy V, Gunasekhar Reddy M and Harinath Gowd G (2013), "Modeling and Analysis of FSAE Car Disc Brake Using FEM", *International Journal of Emerging Technology and Advanced Engineering*, Vol. 3, No. 9.

3. Ibrahim Ahmed, Essam Allam, Mohamed Khalil and Shawki Abouel-Seoud (2012), "Automotive Drum Brake Squeal Analysis Using Complex Eigenvalue Methods", *International Journal of Modern Engineering Research*, Vol. 2, No. 1, pp. 179-199.

4. Mike Hebbes (2012), "Breakthrough in Brake Squeal Prediction Helps to Eliminate Noise Problems Early in Design", ANSYS, Inc., USA.