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## OPTIMISATION OF BRAKING ROTORS BY NATURAL FREQUENCY ANALYSIS

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**Abstract:** Noise and vibration associated with the braking process in passenger automobiles has become an important economic and technological problem in the industry. The knowledge of natural frequencies of components is of great interest in the study of response of structures to various excitations. Hence a brake disc plate with central hole, fixed at inner edge and free at outer edge is chosen and its dynamic response is investigated. The objective of current work is to analyze the vibration characteristics as natural frequency, mode shapes of brake disc by shape optimization but with same ratios of inner to outer radius for inner edge clamped and outer edge free boundary condition. FEM software package is used for vibration analysis of brake discs with drilled holes with same boundary condition for determining different parameters like Natural frequency, Mode shapes. The disc brake is modeled using commercial computer aided design (CAD) software, Ansys.

**Keywords:** Vibration , disc brakes, mode shapes

### I. INTRODUCTION

Disc brake noise and vibration are known to involve structural coupling between such components as the rotor, pads, caliper, and knuckle. Depending on the frequency range of interest, the hydraulic system, body panels, steering column, and other vehicle components can also become active. In an aggregate sense, the disc brakes of only a few percent of new vehicles exhibit sufficient noise and vibration to generate significant customer complaints, but the volume and expense of remediation efforts, in addition to the perception of reduced product-line quality, place pressure on brake noise and vibration.

An acute problem is called as 'squeal' noise, which is typically defined as that occurring within the range 1.5 to 20 kHz at one or more of the rotor's natural frequencies and its harmonics. For ventilated and solid core designs, rotors have the distinction of being structural elements, members of the disc-pad friction pair, and efficient radiators of sound because of their large surface area. The study of the dynamic behavior of brake disc is important, as several machine components. It can be considered as annular plates with radial holes for the purpose of analysis. This study is fundamental for high-risk plants.

In each case, the rotor comprises the disc element which is in frictional contact with the pads during operation, and the hat element which provides the geometric offset necessary for mounting the rotor to the vehicle. The thickness, inner and outer diameter of the disc; and the numbers and spacing of the cooling vanes and mounting studs are some of the geometric parameters that set the rotor's natural frequency spectrum and vibration modes.

Singh & Saxena <sup>[1]</sup> have been investigated that transverse vibrations of skew plates of variable thickness with different combinations of boundary conditions at the four edges by using Rayleigh Ritz method. The two dimensional thickness variations are taken as the Cartesian product of linear variations along the two concurrent edges of the plate. The study of transverse vibration of plates of various shapes under different boundary conditions is important owing to a wide variety of applications in engineering design.

Ahmadian <sup>[2]</sup> et has been evaluated the experimental evaluation of the benefits of smart damping materials in reducing structural noise and vibration is presented. The construction of a special test rig for measuring both vibrations and structure-borne noise is used. Viability of smart damping materials for many industrial applications where reducing noise and vibrations is desired, with minimal amounts of added weight.

Ouyan & Mottershead <sup>[3]</sup> have been investigated that the velocity-dependent friction law with the Stribeck effect in a moving load model for the vibration and squeal of a car disc brake. Simulated numerical results produce a bounded region of instability for the rotating speed of the disc which is compatible with observed squeal phenomenon.

Tsuyoshi & Ishida <sup>[4]</sup> have been rotating machinery has effects of gyroscopic moments, but most of them are small. Then, many kinds of rotor systems satisfy the relation of 1 to (-1) type internal resonance approximately. The dynamic characteristics of nonlinear phenomena, especially chaotic vibration, due to the 1 to (-1) type internal resonance at the major critical speed and twice the major critical speed are investigated.

Albert [5] et al has been evaluated the response and natural frequencies for the linear and nonlinear vibrations of rotating disks are given analytically through the new plate theory. The results for the nonlinear vibration can reduce to the ones for the linear vibration when then on linear effects vanish and for the von Karman model when the nonlinear effects are modified. They are applicable to disks experiencing large-amplitude displacement or initial flatness and waviness. Bambill [6] et al has been evaluated the analytical and experimental investigation on transverse vibrations of solid circular and annular plates carrying a concentrated mass at an arbitrary position with marine applications.

Ambili [7] et al has been investigated the free vibrations of annular plates coupled with fluids. The natural frequencies of annular plates on an aperture of an infinite rigid wall and in contact with a fluid on one side are theoretically obtained by using added mass approach. Lee & chen [8] has been investigated that Annular disk idealization can be used to analyze many real-life mechanical components such as gears, brake rotors, clutches, flywheels, railway wheels, circular saws, and electric motor. In many cases, thickness is not negligible relative to other dimensions of the component, and thus one must consider the thickness effects in structural dynamic and acoustic radiation characteristics.

**II. OBJECTIVES:**

Analysis of disc is done for inner edge clamped and outer edge free boundary condition as fitted in motorcycles & conclude by comparing results .

- i) To find natural frequency by FEM (Ansys software)
- ii) To find mode shapes by FEM (Ansys software)
- iii) Compare & conclude natural frequency & mode shape after optimization.

Vibration analysis of brake disc is made by FEM software package using front brake disc.

**Methodology**

Research papers are discussed dealing with the vibration analysis of the disc brakes which includes the increasing application of vibration analysis concepts in design has prompted researchers to gain an understanding of the dynamic behavior of structures. Here dynamic properties of brake discs are investigated using the FEM analysis software (ANSYS) and discussion of mode shapes by meshing them. Discussions on FEM results will be done here to get the conclusions as per variables applied on brake discs.

**Table 1** Test specimen dimensions I.D. 130mm,O.D,260mm,Aspect ratio 0.5416 constant

SN	Disc thickness at friction area	Dia. of hole of holding wheel hub	Dia. of air cooling holes
1	4	10.5	8
2	3.20	10.5	8
3	3.20	13	8
4	3.20	13	9

**Table 2** Comparison of FEM Natural frequencies of disc brakes

SN.	4mm thickness (sample 1)	3.2 mm thickness (sample 2)	Disc Holder hole dia.13mm (sample 3)	Air ventilation hole dia.9mm (sample 4)
1	1741	1794	1741	1288
2	1752	1812	1752	1297
3	1752	1812	1753	1297
4	1770	1845	1761	1309
5	1771	1845	1771	1309
6	1778	1860	1778	1313
7	2772	2795	2771	2102
8	2929	2885	2929	2219
9	2930	2886	2930	2219
10	3394	3168	3394	2572

Different mode shape of annular disk brake for sample no.4

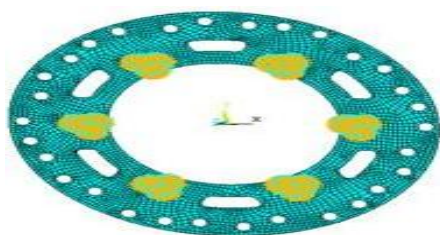


fig.1 meshed view with boundry conditions

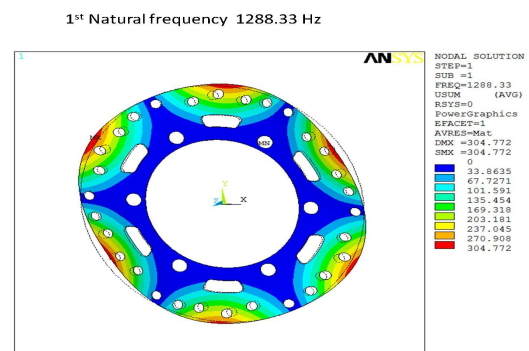
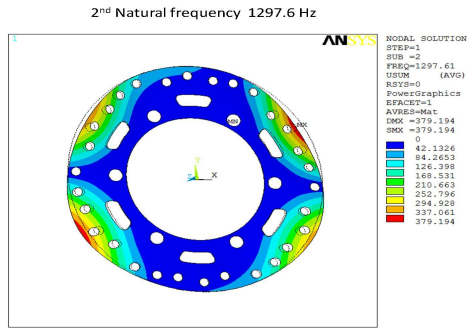
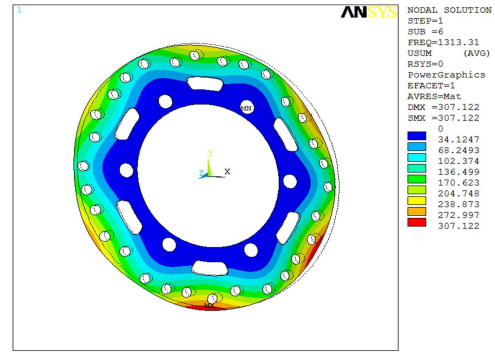


Fig. 4.9 FEM mode shape (0, 3)



6<sup>th</sup> Natural frequency 1313.31 Hz



4.10 FEM mode shape (0, 2)

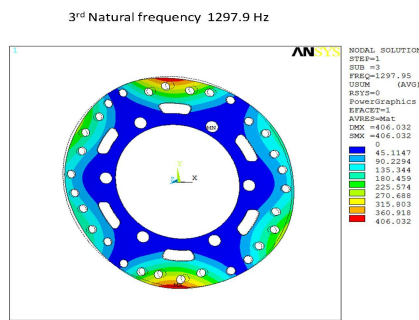


Fig. 4.14 FEM mode shape (1,0)

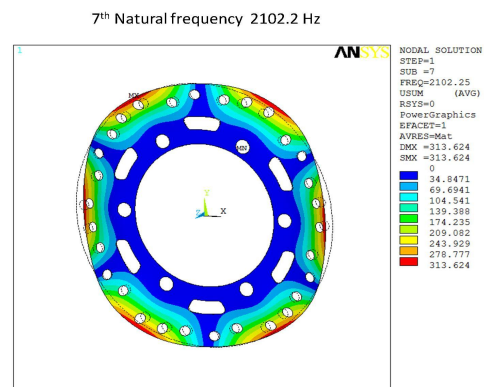


Fig. 4.11 FEM mode shape (0,2)

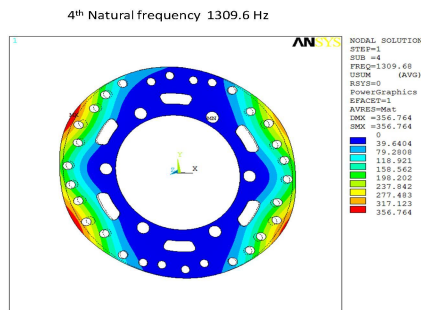


Fig. 4.15 FEM mode shape (0,3)

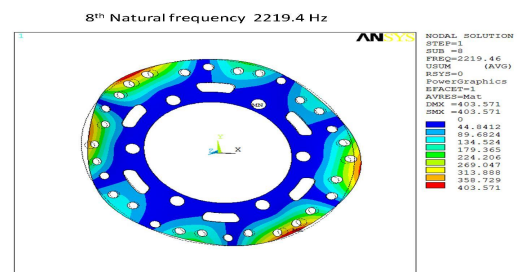


Fig. 4.12 FEM mode shape (0,1)

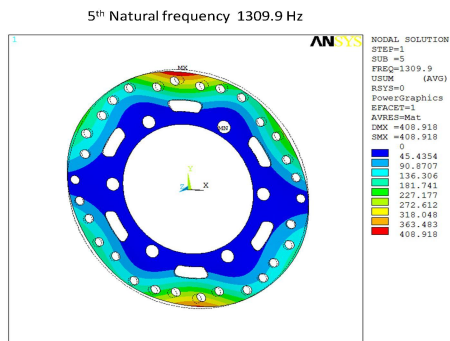
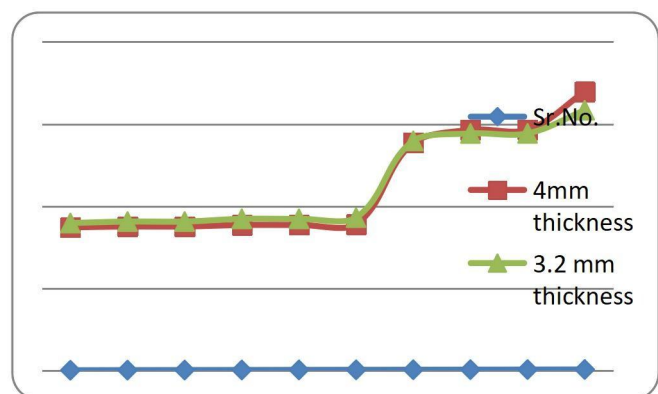
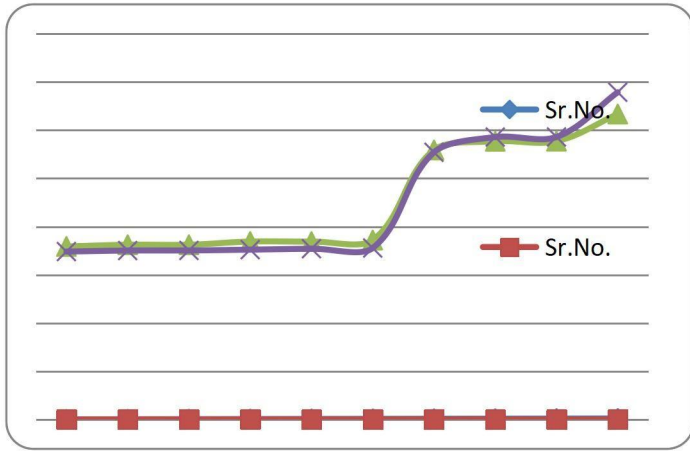


Fig. 4.16 FEM mode shape (0,4)



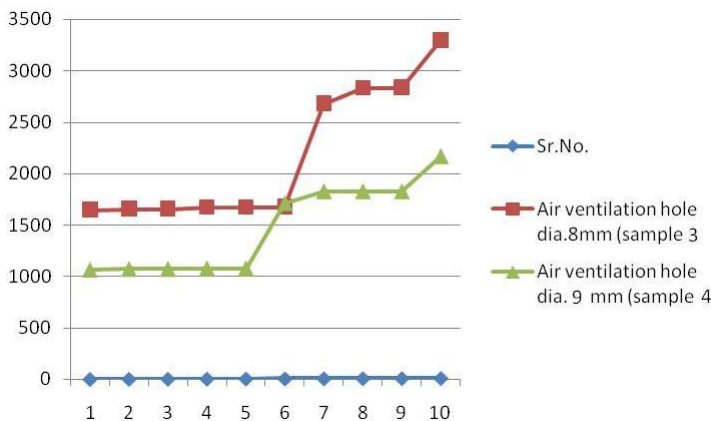
**Graph 1** Effect of wear of brake disc on FEM natural frequency.

**Remark:** Natural frequencies of disc brake of bike increases as the disc thickness decreases till first six natural frequencies but reverse effect after 7<sup>th</sup> natural frequency.



**Graph 2** Effect of increased diameter of brake disc holder hole.

**Remark:** Natural frequencies of disc brake of bike decreases as the brake disc holder hole diameter increases till first 7 natural frequencies but reverse effect after 7<sup>th</sup> natural frequency.



**Graph 3** Effect of increased air ventilation hole diameter on natural frequency of brake disc.

**Remark:** Natural frequencies of disc brake of bike decreases as the air ventilation hole diameter increases.

**III. CONCLUSION:**

Computed results have been obtained for the annular disc brake clamped at inner edge and free at the outer edge system. Natural frequencies of disc brake of bike increases as the disc thickness decreases till first six natural frequencies but reverse effect after 7<sup>th</sup> natural freq. but seventh frequency is changed very less. Natural frequencies of disc brake of bike decreases as the brake disc holder hole diameter increases till first 7 natural frequencies but reverse effect after 7<sup>th</sup> natural frequency. Natural frequencies of disc brake of bike decreases as the air ventilation hole diameter increases.

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