Vibration Analysis of Circular Disc with Radial Cracks

Mr. Abhilesh Warade [1], Prof. Mr.V.V.Saidpatil[2]
[1,2] NBN Sinhgad School of Engineering , Pune 41India

ABSTRACT— *Disc are necessary structural parts in engineering application further as in daily life, like pressure vessel, missiles, liquid containers, and ship structures. The rotary engine, brake disc and diaphragm clutch spring are the well-known examples for the economic application of the annular plate with radial cracks. Circular plates area unit elementary structural parts in ocean engineering applications from offshore platforms to below water acoustic transducers.5 Circular doughnut-shaped plates with radial cracks area unit extensively employed in the development of craft, ships, cars and different vehicles. As disc area unit usually subjected to transversal vibrations and these vibrations decrease the mechanism's capabilities. Since the dynamic performance is usually of interest, therefore a circular shaped plate with radial cracks, fastened at inner edge and free at outer edges is chosen and its dynamic response is investigated during this thesis work as mentioned below. Firstly, exploitation FFT analyser, natural frequencies area unit detected by striking the plate with impact hammer; the response at a degree of a plate is measured by exploitation associate measuring device. FFT analyser analyzed the output of measuring device*

In the second methodology, the clamped disk was mounted on exciter and completely different mode shapes were detected by varied the exciting frequency. Mode shapes square measure snapped in photograph camera to match with FEM (HYPERMESH) mode shapes of it take a look at specimens. I.e. Modal analysis is performed on the structure to research and live the system's response to search out natural frequency of the annulated disc with radial cracks.

FEM and experimental results obtained area unit compared at the top and located similar results.
Keywords—***Disc,****FFT analyser, FEM, radial cracks*

I. INTRODUCTION

The study of the dynamic behaviour of annular plates with radial cracks is important, as several machine components, such as flywheels, clutch plates, circular saw plates etc. can be considered as annular plates with radial cracks for the purpose of analysis. This study is fundamental for high-risk plants. Unwanted noise and vibration associated with the braking system in passenger automobiles has become an important economic and technological problem in the industry. Disk 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 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 disk-pad friction pair, and efficient radiators sound because of their large surface area.

In each case, the rotor comprises the "disk" 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 disk; 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. Improved understanding of disk vibration offers one opportunity for targeted improvements in brake rotor design. There are two methods of vibration analysis used in this experimental work.

In First method, using FFT analyser, natural frequencies are detected by hitting the plate with impact hammer; the response at a point of a plate is measured by using an accelerometer. FFT analyser analysed the output of accelerometer.

In second method, the clamped disk was mounted on exciter and different resonance's was detected by varying the exciting frequency. Mode shapes are snapped in photo camera to compare with FEM mode shapes of same test specimens.

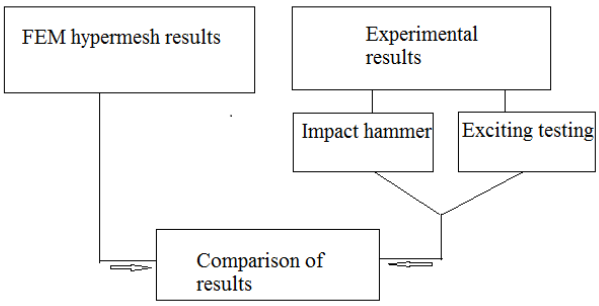

Fig. 1 Block Diagram

As shown in Fig. 1 the block diagram of system (FEM) finite element method is used for modelling and analysis of annular disk. The natural frequencies and mode shapes are determined for same ratio of inner to outer radius of the disk. Disc are having radial cracks but variable numbers and variable lengths of radial cracks for inner edge clamped and outer edge free boundary condition

The finite element method is a numerical method, which can be used for the accurate solution of complex mechanical and structural vibration problems. In this method, the actual structure is replaced by several pieces or elements, each of which is assumed to behave as a continuous structural member called a finite element.

The elements are assumed to be interconnected at certain point known as joints or nodes. Since it is very difficult to find the exact solution of the original structure under the specified loads, a convenient approximate solution is assumed in each finite element. During the solution process, the equilibrium of forces at the joints and the compatibility of displacement between the elements satisfied, so that the entire model is made to behave as a single entity. In next experimental method natural frequency and modes are find out with help of impact hammer test and exciting testing using whose results are tabulated through FFT analyser and different natural frequency are find out.

1. HYPERMESH software

The analysis capabilities of HYPERMESH as meshing software radioss as a solver and hyperview to view result. Include the ability to solve static and dynamic structural analysis, static or time varying magnetic analysis and various types of field and coupled field applications. This program contains many special features, which allow nonlinearities or secondary effect to be include in the solutions, such as plasticity, large strain, hyper elasticity, creep, swelling, large deflection, contact stress, stiffening, temperature dependency, material anisotropy and radiation.

2. Modal analysis:

Modal analysis determines the vibration characteristics (natural frequencies and mode shapes) of a structure or machine components. Same set of command is used for modal analysis that used in any other type of finite element analysis. Likewise, choose similar option from the graphical user interface (GUI) to build and solve models.

3. Modal analysis of annular plate

Analysis for annular disk with inner edge clamped and outer edge free is done here. For same aspect ratio of annular disc but variable numbers and variable lengths of radial cracks for inner edge clamped and outer edges free boundary condition. When the excitation frequency of any structure matches with one of the natural frequency of the plate then resonance occurs and a damage of plate takes place. So here objective is to determine the modal parameters and an effort can be made to avoid the resonance.

II. SIMULATION RESULT

Discussion on results obtained by FEM and experimental analysis is carried out here to reach the conclusion. Differences in results are compared for same ratio of the inner to outer diameters, but variable numbers and variable lengths of radial cracks for inner edge clamped and outer edge free boundary condition. Comparison of vibration results is done after experimentation and analysis by four methods as below:

a. To find natural frequency & modes by FEM (HyperMesh software)
b. To find natural frequency by FFT (Impact hammer test)
c. To find modes by exciter

Analysis and discussion is done for FEM and FFT analyzer result. To find natural frequency by FEM (HyperMesh software) Vibration analysis of annular plate is done by FEM (HYPERMESH) software to get natural frequencies and mode shapes of annular disk with same aspect ratio but variable (numbers and lengths) of radial cracks for inner edge clamped and outer edge free boundary condition. Results obtained from analysis are shown in Fig.2

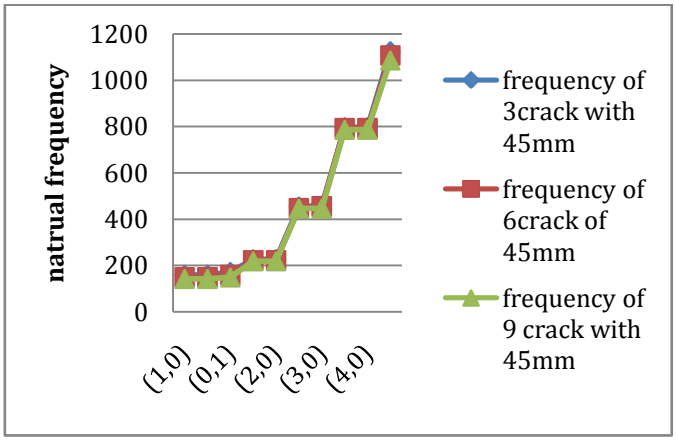

Fig. 2 Natural frequency plot for HYPERMESH results of 45mm crack length but different number of cracks

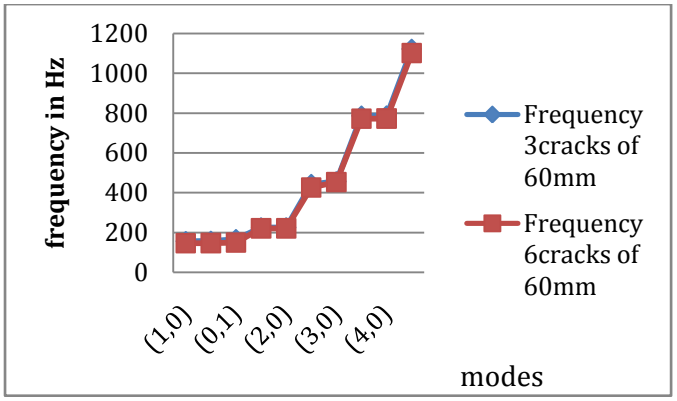

Fig. 3 Natural frequency plots for HYPERMESH results of 60 mm crack length but different number of cracks.

As we can see in Fig. 3 Natural frequency increases with increase in nodal diameter and it decreases with increase in number of cracks for same crack length 46 mm.

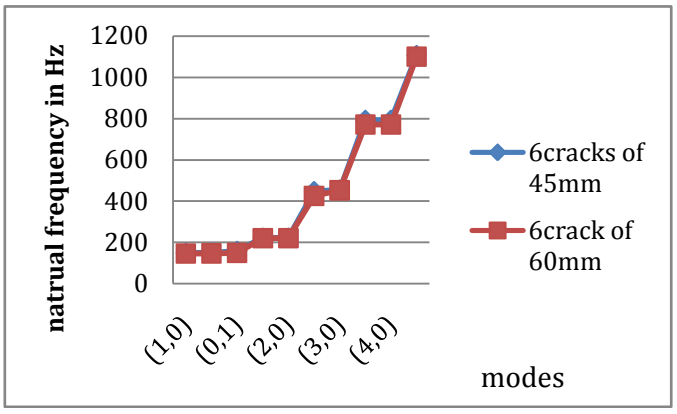

Fig. 4 Natural frequency plot for HYPERMESH results of 6 cracked disc but different crack lengths

As we can see in Fig.4 Natural frequency increases with increase in nodal diameter and it decreases with increase in length cracks for same number of cracks.

Now results obtained from hypermesh software and experimental results are compare to determine the natural frequency.

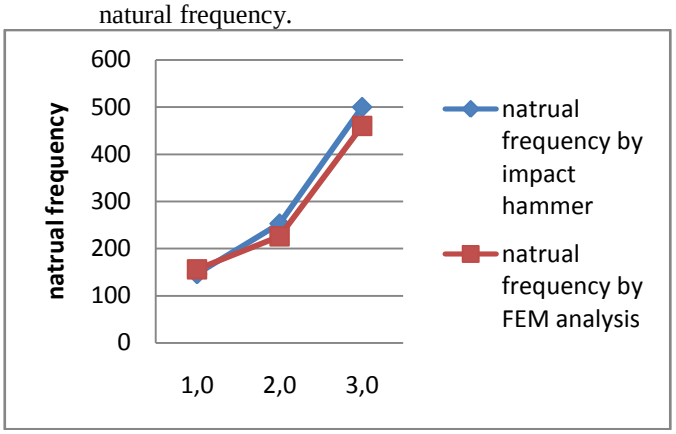

Fig 5. Modal diameter vs. Frequency (3 cracks of 45mm)

Concluding remark:-Natural Frequency Increases with increase in nodal diameter and impact hammer test results are matched with FEM results with negligible difference.

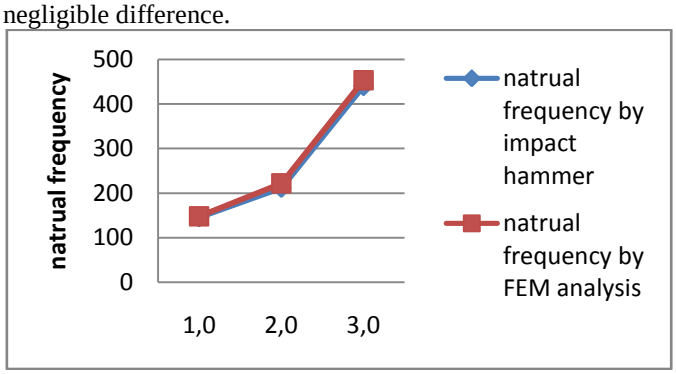

Fig No.6.Modal diameter vs. Frequency (6 cracks of 45mm)

Concluding Remark:-Natural Frequency Increases with increase in nodal diameter and impact hammer test results are matched with FEM results with negligible difference.

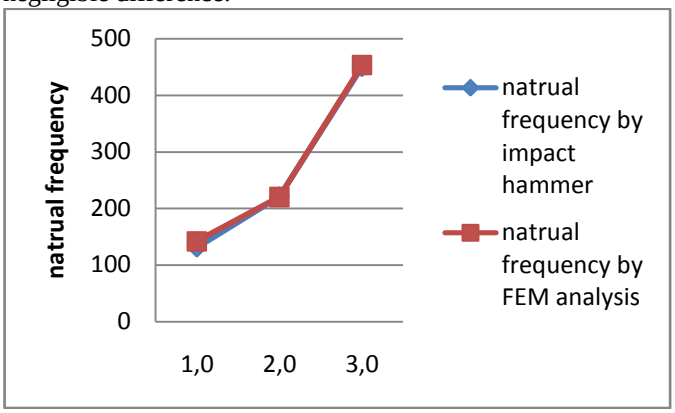

Fig 7. Modal diameter vs. Frequency (9cracks of 45mm)

Concluding Remark:-Natural Frequency Increases with increase in nodal diameter and impact hammer test results are matched with FEM results with negligible difference.

III. CONCLUSION

Variable number of cracks (3, 6, 9) and for variable crack length (45,60)mm with combinations are analysed by FFT-impact hammer test and FEM-HYPERMESH software analysis for getting vibration characteristics to get following conclusions.

1. Natural Frequency Increases with increase in nodal diameter and it decreases with increase in number of cracks for same crack length.
2. Natural Frequency Increases with increase in nodal diameter and it decreases with increase in length cracks for same no. of cracks.

Vibration analysis of annular disk with cracks and variable length for aspect ratio 0.1 is conducted by experimental and HYPERMESH method to reach the conclusion as:

- Natural frequency increases with increase in nodal diameter and both results are matched to average of 4% error which is acceptable.

References

[1] Vogel S. M. & Skinner D.W., "Natural Frequencies of Transversely Vibrating Annular Plates", Journal of Applied Mechanics, December, 1965, 926–931.

[2] Leissa Arthur W., 1969,"Vibration of Plates",NASA P160 Watson, GN, 1966.

[3] S. S. Rao and A. S. Prasad, "Vibrations of annular plates including the Effects of rotary inertia and transverse shear deformation", Journal of Sound and Vibration, 1975, vol 42, 305-324.

[4] Weisensel G. N. "Natural Frequency information for circular and annular Plates", Journal of sound and vibration, 1989, vol. 133, pp129-134.]

[5]D.V.Bambill, S.La.Malfa, C.A.Rossit, P.A.A.Laura, Analytical and "Experimental investigation on transverse vibration of solid, circular and Annular plates carrying a concentrated mass at an arbitrary position with Marine applications", Journal of ocean Engineering, vol31, pp127-138.

[6] M.Ambali, G.frosali, M.K.Kwak., "Free vibrations of annular plates coupled with fluids", Journal of sound and vibration, 1996 vol.191 (5),pp 825-846.

[7] K. Ramesh, D.P.S. Chauhan and A.K. Mallik,"Free vibration of annular plate with periodic radial cracks", Journal of sound and vibration, 1997, 206(2)266- 274