MODAL ANALYSIS OF ANNULAR DISC

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Abstract

The study of the dynamic behavior of annular discs is important, as several machine components such as flywheels, clutch plates, circular saw plates etc. can be considered as annular discs for the purpose of analysis. The work presented in this paper is a modal analysis of annular disc structure by using finite element analysis software (ANSYS).Natural frequencies and maximum deformation of structure of three different materials are used for comparative study of the variation in characteristics of the structure for various ratios of inner to outer radius conditions. It is found that as aspect ratio approaches to unity (one) natural frequency approaches to its maximum value. Also the natural frequencies and deformation increases with increasing number of nodal diameters. Based on the results of finite element analysis of the three materials it is compared and concluded that the Nimonic 90 disc exhibits good behavior in case of natural frequencies and MP35N disc exhibits good behavior in case of deformation as the deformation is less in this compared to the other two materials.

Keywords: *Annular Disc, Aspect Ratio, Modal Analysis, Deformation, FEM etc…*

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1. INTRODUCTION

The knowledge of natural frequencies of components is of great interest in the study of response of structures to various excitations. As discs are often subjected to transverse vibrations and these vibrations decrease the mechanism's capabilities. Since the dynamic performance is always of interest, hence a circular plate with central hole, fixed at inner edge and free at outer edge is chosen and its dynamic response is investigated.

Discs are one of the most important safety and performance components as several machine components such as flywheels, clutch plates; circular saw plates etc. can be considered as annular discs for the purpose of analysis [1]. Development of discs has focused on increasing performance and readability. Material and aspect ratio selection of the disc is important as it affects the disc performance because it will affect the natural frequency and deformation of the disc. Proper selection is needed to avoid resonance conditions in the disc which can affect the disc life and performance. The disc will likely to fracture when experienced excessive vibration in a long term period [4].

Modal Analysis is the process of determining the inherent dynamic characteristics of a system in forms of natural frequencies, damping factors and mode shapes and formulates a mathematical model for its dynamic behavior. The goal of Modal Analysis in structural mechanics is to determine the natural frequency of an object or structure during free vibration [2]. Modal Analysis is based upon the fact that the vibration response of a linear time invariant dynamic system can be expressed as the linear combination of an asset of simple harmonic motions called the natural mode of vibration. The natural modes of vibration are inherent to a dynamic system and are determined completely by its physical properties such as mass, stiffness, damping and the spatial distributions [2]. Each mode is described in terms of its modal parameters such as natural frequency, modal damping factor and characteristic displacement pattern which are called mode shape [3]. It is important to test a physical object to determine its natural frequencies and mode shapes.

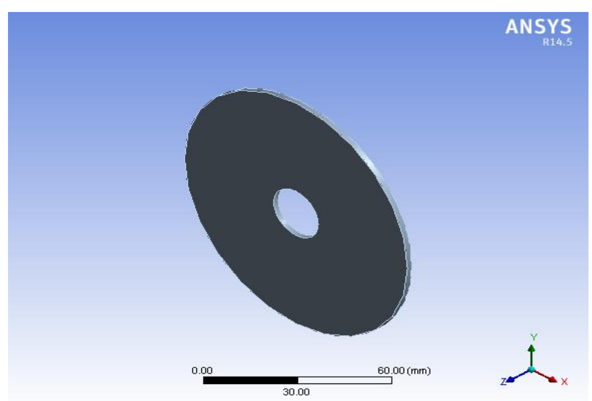

Fig-1: Annular Disc

2. MATERIAL PROPERTIES

Steel is an alloy of iron, with carbon being the primary alloying element, up to 2.1% by weight. Carbon, other elements, and inclusions within iron act as hardening agents that prevent the movement of dislocations that naturally exist in the iron atom crystal lattices. Varying the amount of alloying elements, their form in the steel either as solute elements, or precipitated phases, retards the movement of those dislocations that make iron so ductile and so weak, and so it controls qualities such as the hardness, ductility, and tensile strength of the resulting steel. Steel can be made stronger than pure iron, but only by trading away ductility, of which iron has an excess.

Nimonic 90 alloy is a wrought nickel-chromium-cobalt base alloy strengthened by additions of titanium and aluminum. It has been developed as an age-hardenable creep resisting alloy for service at temperatures up to 920°C (1688°F). The alloy is used for turbine blades, discs, forgings, ring sections and hot-working tools.

MP35N is a nickel cobalt based alloy of the multiphase alloy system has a unique combination of properties - ultra high strength, toughness, ductility and outstanding corrosion resistance. MP35N resists corrosion in hydrogen sulphide, salt water and other chloride solutions. It also has excellent resistance to crevice and stress corrosion cracking in sea water and other hostile environments.

Table-1: Materials and Their Properties

MATERIAL	STEEL	NIMONIC 90	MP35N
YOUNG'S MODULUS	$2.1X10^{11}$ N/M^2	$2.13X10^{11}$ N/M^2	$2.34X10^{11}$ N/M^2
POISSON'S RATIO	0.3	0.28	0.28
DENSITY	7850 KG/M^3	8280 KG/M^3	8570 KG/M^3

3. MODELLING AND ANALYSIS

ANSYS is general-purpose Finite Element Analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user designed size) called elements. The software implements equations that govern the behavior of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole.

The ANSYS Workbench environment is an intuitive up-front finite element analysis tool that is used in conjunction with CAD systems and Design Model. ANSYS Workbench is a software environment for performing structural, thermal, and electromagnetic analyses. The Workbench focuses on attaching existing geometry, setting up the finite element model, solving, and reviewing results.

Fig-1 Illustrate the disc structure model used for investigating the disc's bending modes. Three dimensional parameters b, a, and h represent the disk's inner radius, outer radius and half thickness respectively. For instance, over a representative sampling of four disks, typical b/a parameter values fall in the range of 0.1 to 0.4

Inner diameter of the disc is kept constant 20mm, while outer diameter is varied; thickness of the disc is kept 2 mm for all specimens. Boundary conditions for disc specimen are inner edge fixed and outer edge free [1,5].With these boundary conditions different ratios of inner to outer radius can be varied by changing the dimension of outer diameter of the specimens. Specimen dimensions tabulated in following table shows the range of ratios of inner to outer diameter that lies between 0.1 to 0.4

Table-2: Specimen Disc Dimensions

SPECIMEN	**RATIO (b/a)**	**INNER DIAMETER (MM)**	**OUTER DIAMETER (MM)**
DISC 1^{st}	0.1	20	200
DISC 2^{nd}	0.2	20	100
DISC 3^{rd}	0.3	20	66.66
DISC 4^{th}	0.4	20	50

4. RESULTS AND DISCUSSION

Modal analysis of annular disc is done by finite element method with ANSYS 14.5 software to calculate the natural frequencies and maximum deformation of annular disc with different aspect ratios. Results obtained from this analysis are shown in the following tables according to materials.

Table-3: Natural Frequencies (Hz) and Maximum Deformation (mm) of Disc of Steel for Different Aspect Ratios and Different Mode Nos.

Mode No	ASPECT RATIO							
	0.1		0.2		0.3		0.4	
	Freq.	Max. Def.	Freq.	Max. Def.	Freq.	Max. Def.	Freq.	Max. Def.
1	172.9	98.6	955.3	208.2	2912.3	332.6	7116	344.9
2	172.9	98.5	955.9	209.1	2912.3	332.4	7138.7	475.5
3	211.1	68.9	1032.4	146.8	2976.7	234.7	7139.4	481.2
4	279.3	105.2	1273.9	216.4	3503.7	338.8	8077	479

5	279.3	105.2	1274	216.6	3503.9	338.7	8078.3	479.4
6	618.5	114.5	2492.8	230.4	5841.8	352.4	11488	488.8

Table-4: Natural Frequencies (Hz) and Maximum Deformation (mm) of Disc of Nimonic 90 for Different Aspect Ratios and Different Mode Nos.

Mode No	ASPECT RATIO							
	0.1		0.2		0.3		0.4	
	Freq.	Max. Def.	Freq.	Max. Def.	Freq.	Max. Def.	Freq.	Max. Def.
1	168.4	96.0	930.2	202.8	2834.3	323.8	6905.9	330.9
2	168.4	95.9	930.4	203.5	2834.4	323.7	6945.7	462.6
3	204.9	67.2	1001.7	143.0	2888.3	228.6	6946.7	465.2
4	275.1	102.3	1252.9	210.4	3439.4	329.4	7913.1	466
5	275.2	102.3	1253	210.5	3439.6	329.4	7914.1	466.3
6	608.7	111.1	2453.9	223.7	5750	342.2	11301	474.8

Table-5: Natural Frequencies (Hz) and Maximum Deformation (mm) of Disc of MP35N for Different Aspect Ratios and Different Mode Nos.

Mode No	ASPECT RATIO							
	0.1		0.2		0.3		0.4	
	Freq.	Max. Def.	Freq.	Max. Def.	Freq.	Max. Def.	Freq.	Max. Def.
1	173.5	94.3	958.1	199.3	2920.1	318.3	7114.8	325.3
2	173.5	94.3	958.5	200.0	2920.1	318.2	7115.8	454.7
3	211.1	66.0	1032	140.6	2975.7	224.7	7156.4	457.3
4	283.5	100.5	1290.8	206.8	3543.5	323.8	8152.4	458.1
5	283.5	100.5	1290.9	206.9	3543.6	323.8	8153.5	458.3
6	627.2	109.2	2528.1	219.8	5924	336.4	11643	466.7

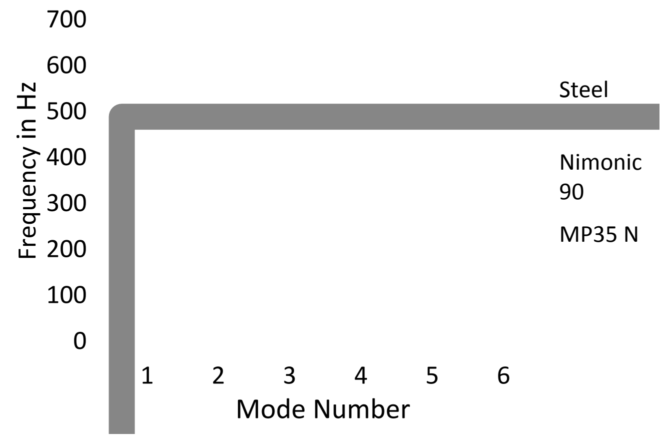

Fig-2: Natural frequency plot for aspect ratio 0.1

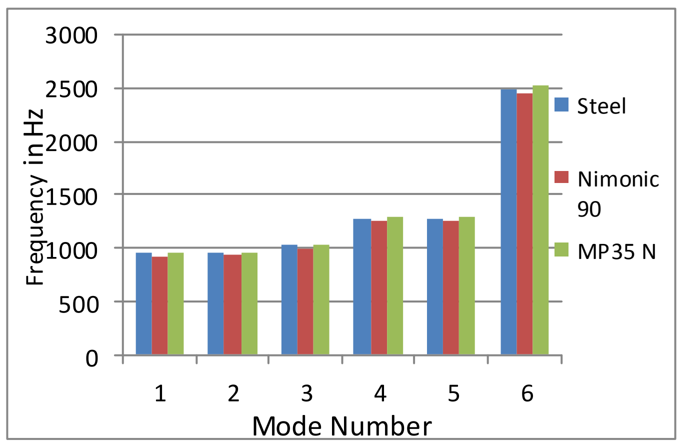

Fig-3: Natural frequency plot for aspect ratio 0.2

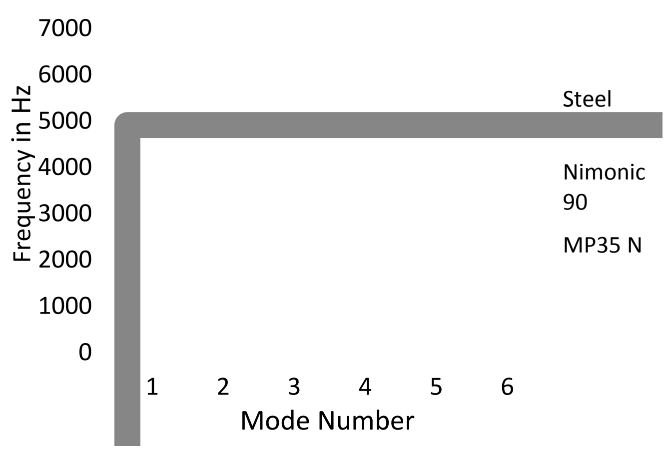

Fig-4: Natural frequency plot for aspect ratio 0.3

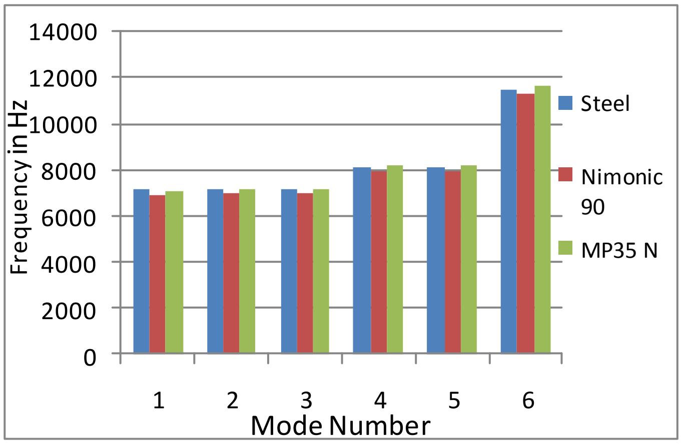

Fig-5: Natural frequency plot for aspect ratio 0.4

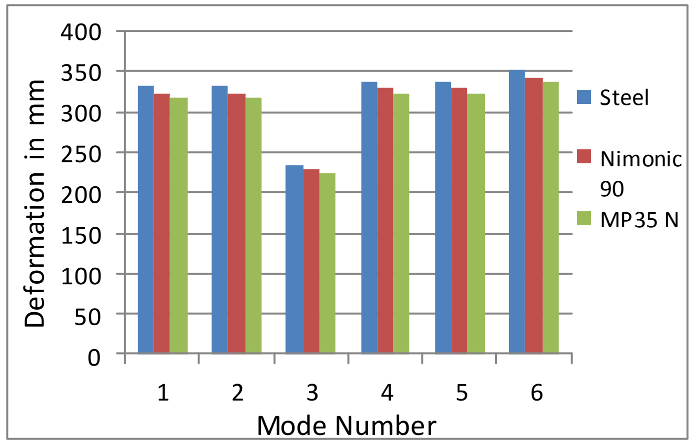

Fig-8: Deformation plot for aspect ratio 0.3

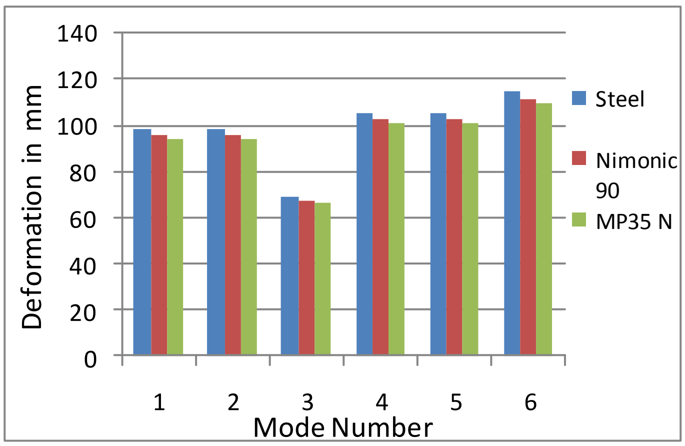

Fig-6: Deformation plot for aspect ratio 0.1

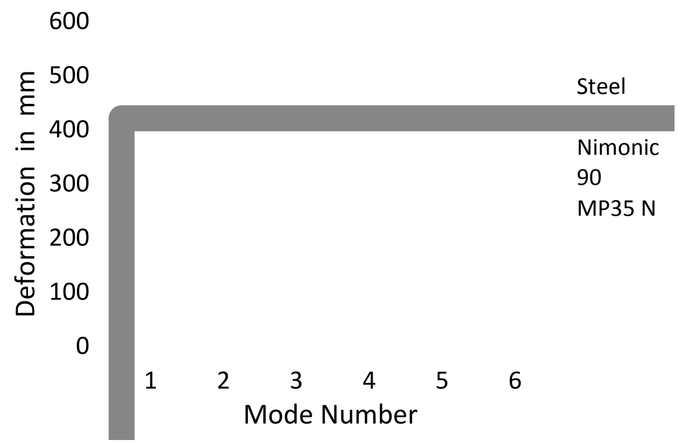

Fig-9: Deformation plot for aspect ratio 0.4

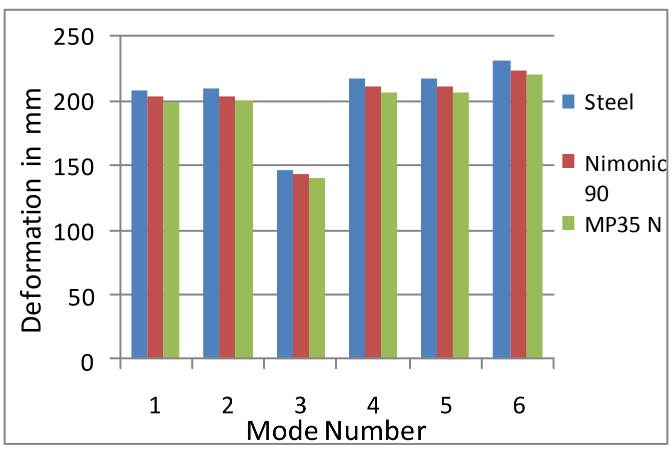

Fig-7: Deformation plot for aspect ratio 0.2

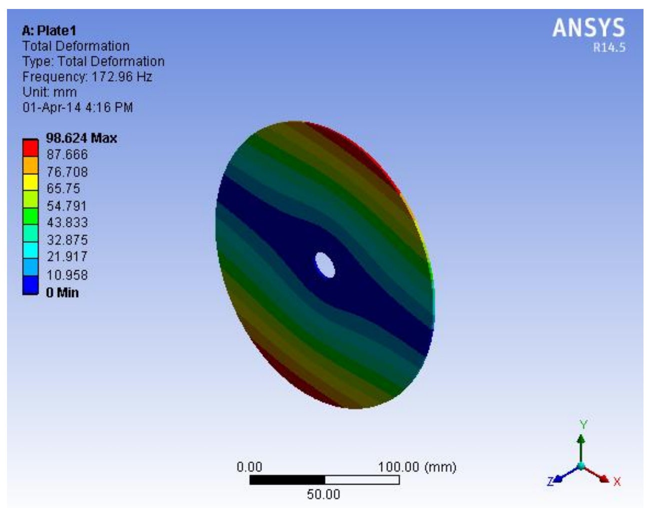

Fig-10: Deformation of steel for aspect ratio 0.1

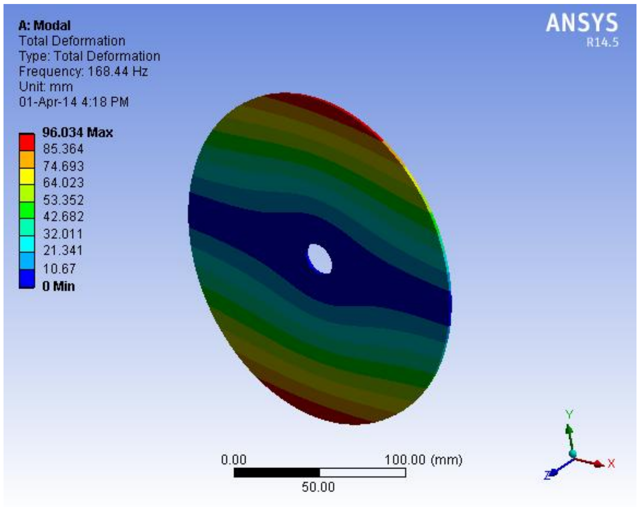

Fig-11: Deformation of Nimonic-90 for aspect ratio 0.1

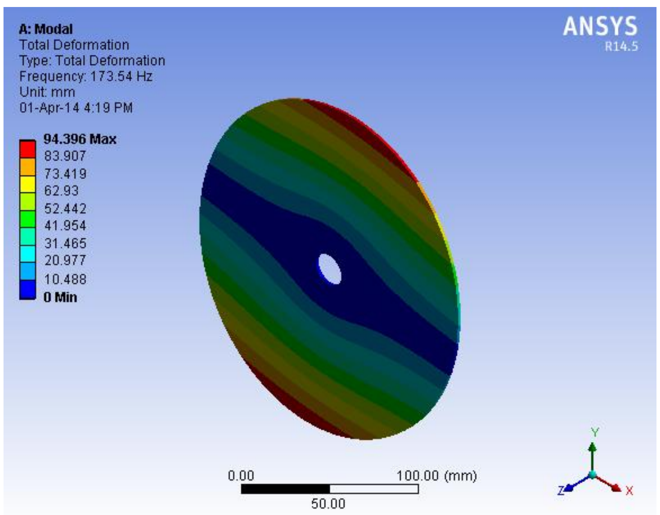

Fig-12: Deformation of MP35-N for aspect ratio 0.1

5. CONCLUSIONS

From the above results and discussions we can conclude that,

- The natural frequencies increase with increasing number of nodal diameters.
- The natural frequency of annular disc goes on increasing as the ratio of the inner to outer radius goes on increasing, as it approaches to 1 the annular disc to become a ring like structure.
- From the comparison of three different materials we can say that the that the Nimonic 90 material disc exhibit good behavior in case of natural frequencies compared to the steel & MP35N disc.
- In case of deformation is considered MP35N material exhibits good behavior as the deformation is less in this material compared to the other two materials.

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