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Harmonic Analysis & Weight Optimization of Centrifugal Blower by FEA

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A B S T R A C T

Centrifugal blower are used extensively for on-board naval application have high noise and vibration levels. This noise produced by rotating component is mainly due to random loading force on blades and periodic iteration of incoming are with the blades of the rotor. The contemporary blades in naval application are made up of aluminium or steel and generated noise that causes disturbance to the people working near the blower. This research paper aims at examining the choice an alternative metal for better vibration control and weight optimization. For the FEA analysis purpose we used modelling software CATAI V5R20, and for analysis purpose we used ANSYS V16.0. We considered three different materials viz. Mild Steel, Aluminium 1060, SS316L with respect to different industrial application. Modal analysis is performed on all the three materials to find out first six natural frequencies.Harmonic analysis is done to reduce noise level due to unbalance mass in impeller. The present work aims at examining the choice of material according to their industrial application for better vibration control and also optimizing the geometry for better results.

Keywords: Centrifugal blower, Modal Analysis, ANSYS V16.0, FEA, Harmonic Analysis

1. Introduction

Centrifugal blowers are widely used in various industrial applications. Centrifugal blowers are mainly composed of two main parts, the casing and the impeller. The impeller is often considered an integral part of a vacuum motor because its housing and motor are assembled as one unit. The principles involved in the design of fans are almost similar in all respects important to centrifugal pumps, except that the term "centrifugal pump" is often associated with the fluid as the operating fluid.While the fan is said to run on air [1]. The effect of centrifugal force on the rotating air inside the impeller creates suction centre, creating a partial vacuum that helps circulate more air through the wheel, as shown in the figure below.

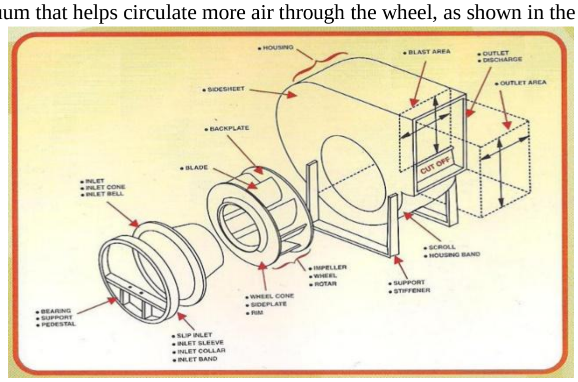

Fig. 1 - Centrifugal Blower

Centrifugal blowers are more like centrifugal pumps than fans. The impeller usually gear-driven and rotates at 15,000 rpm. In multi-stage blowers, air is accelerated as it passes through each blade. In single stage blower, there is very less rotation for air and hence it is more efficient. Centrifugal blowers typically operate at a pressures of 0.35 to 0.70 kg/cm2, but higher pressurescan be achieved.

2. Literature Survey

[1] Weight Optimization & Vibration Analysis of Centrifugal Blower by FEA, International Journal of Research Publication and Reviews,International Journal of Research Publication and Reviews, Vol 3, no 4, pp 1319-1324, April 2022

[2] Effect of Impeller Parameters on the Flow inside the Centrifugal Blower using CFD, International Journal of Recent Technology and Engineering (IJRTE)ISSN: 2277-3878, Volume-8 Issue-6, March 2020. In this paper work a numerical analysis is carried out to understand the different impeller configurations of centrifugal blower with the help of GAMBIT 2.4.6 and FLUENT 6.3.26 software.

[3] Optimization of critical parts of centrifugal blower by Modal &CFD Analysis, International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163Volume 1 Issue 12 December 2014. In this research work the optimization of small but critical parts of centrifugal blower is done with the help of ANSYS CFD software. Here food grade metals are used for the analysis purpose.

[4] Static and Dynamic Analysis of a Centrifugal Blower Using FEA, International Journal of Engineering Research & Technology (IJERT) Vol.1 Issue 8, October-2012 ISSN: 2278-0181, in this research work static and dynamic analysis is done to reduce the vibration and impact. The current research work aims to examining the choice of composites as an alternative material for better vibrational control. This research work was done with the help of Hypermesh 10.0 and ANSYS software to perform Modal analysis on Aluminium and composite blower.

[5] Numerical Analysis of Internal Flow Field of Multi-Blade Centrifugal Fan for Floor Standing Air- Conditioner, Jia Bing Wang Huazhong University of Science and Technology, here numerical analysis of internal flow field of multi-blade centrifugal fan for floor standing Air- Conditioning system is done to optimize blower discharge. This research examines the effect of splitter vanes corresponding to various geometrical locations on the impeller and diffuser.

[6] A Numerical Study the Acoustic Characteristics of a Centrifugal Impeller with a Splitter, Technical Research Lab, CEDIC Ltd., #1013, Byuksan Digital Valley, Kasan-dong. In this research work, numerical study was done on acoustic characteristics of centrifugal impeller with splitter. These are mainly used in gas turbine engines due to their ability to create high pressure ratio in relatively smaller working area. But this also causes the major problem of high noise and frequency. In the present research work we are going to study on this problem.

[7] Evolution of Static & Dynamic Analysis of a Centrifugal Blower Using FEA, International Journal of Advanced Trends in Computer Science and Engineering (IJATCE), Vol.2, Issue 7, January – 2013. Here static and dynamic analysis of blower is done to reduce its vibration and impact. Centrifugal blowers are used widely in naval applications. The noise level of such blowers increases due to random loading force and periodic iterations. It happens because of conventional material used for fan blades. This research work deals with study of different materials used as blower and to analyse their effect on vibrations and noise. Modeling and analysis work is done in CATIA V5 R19 software and ANSYS software respectively.

3. Scope and Objective

The Contemporary blades in Centrifugal Blower used in naval applications are made up of Steel. The objective of present work is to design an Impeller of a Centrifugal blower with three materials, which are:

a. Mild Steel
b. Aluminium 1060
c. SS316L (Food Grade Steel).

To analyse which material made impeller gives better results in terms weight, Output pressure, Out-put velocity, Breaking point, efficiency and cost-friendly. These results can be obtained by performing the following analysis on each material type.

a. Harmonic analysis
b. Optimizing Impeller for noise reduction
c. Weight optimization

4. Problem Definition

After study of previous research work presented, we come to notice that the numerical work as well as analytical work is done on the centrifugal blower from the point of view of vibration with mechanical industrial grade materials and very less work was carried out on harmonic behavior of the materials on consideration of other industries like food industry, Naval applications etc. To overcome this problem, we are going to study for those areas and their respective materials for the work application.

5. Methodology

To achieve our objective of research work, we are going to follow below mentioned methodology of work

- Study of Materials and parameters of present blowers.

- Modeling
- Harmonic Analysis work
- Result and discussion
- Conclusion

5.1 Study of material and parameters

Industrial use of blowers according to selected materials are given as follows:

- **Mild Steel Blower** – These are widely used blowers in exhaust systems of furnace, boilers, oven etc.
- **Aluminium 1060** – This material gives high stability with good corrosion resistance. It widely used in automobile sector as cooling fan and ventilation purpose where weight is criteria.
- **SS316L** – This material is extensively used in food industry to avoid corrosion level.
  Following are the parameters for the present Centrifugal blower:
- Type –Flanged mounted type centrifugal blower
- Flow rate – 12000 cfm (cubic feet meter)
- Operating temperature - 16℃
- Fan RPM – 1440
- Power output – 13.91 HP
- Efficiency – 85%
- Motor Power – 12 HP
- Torque – 6.91 Kg-m
- Noise Level – 88db

Following table gives us brief idea about the materials mechanical properties which we are going to analyse

Table 1 –Material Properties

Properties	Mild Steel	Aluminium 1060	SS316L
Density (Kg/m^3)	7880	2700	8000
Poisson's ratio	0.28	0.33	0.25
Young's Modulus (GPa)	205	71	193
Yield Strength (MPa)	270	117	205

5.2Modeling and Analysis Work

Modeling of the research work is done with the help of Creo 5.0 software as it have wide range of tools and many other software formats are supported to this software so we can get more transferability of the model into different applications as per the requirement. After completion of the model in the design software, we later transfer this file to the analysis software. Here we are using ANSYS 16.0 as our analysis software because it gives more accurate results for the problems of natural frequencies. To use the model in the ANSYS software we need to convert the existing model file into STEP or IGS format so that it can be viewed in the analysis software. Following figures shows the modeling and analysis software's user interface.

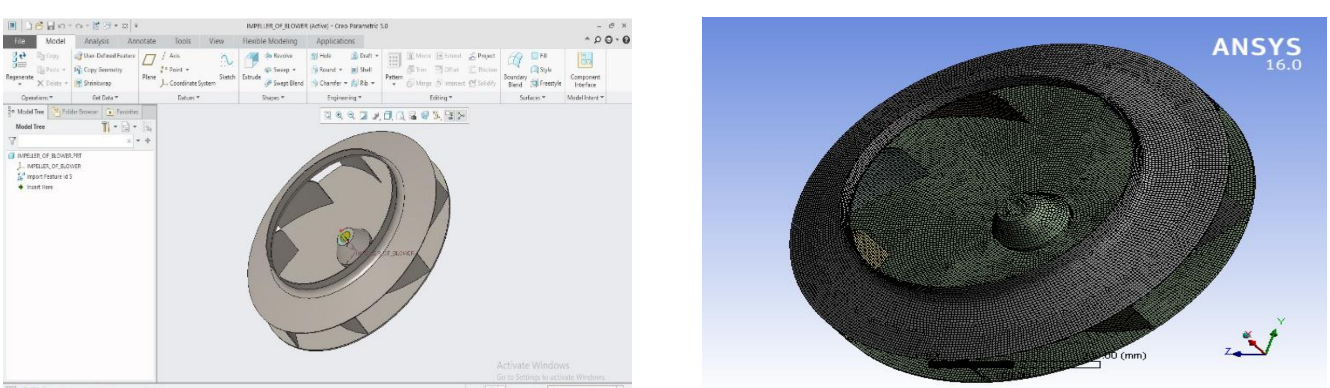

Fig. 2–(a) Creo Model; (b) Mesh Model in ANSYS

5.3 Harmonic Analysis of Present Blower

We build the FE model as shown in below diagram. Material properties such as Young's modulus and density are defined. Apply the constraints and pressure as explained as given. Enter the ANSYS solution processor in which new analysis is chosen as harmonic response and solution method. For this analysis the solution technique used is frontal solver. By defining the frequency range as 0-120 HZ with 10 sub-steps. Solve the problem using current LS command tool bar and obtain the results.

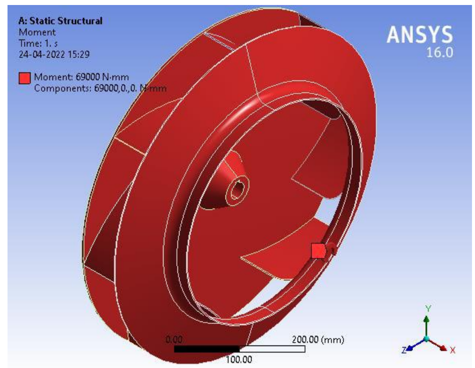

Fig. 3–Boundary Conditions in ANSYS for Harmonic Analysis

Case 1: Present Impeller
Material Mild Steel

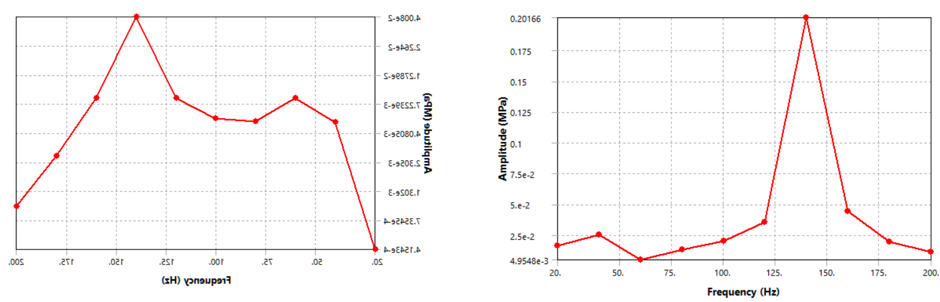

Fig. 4 – Stress Graph (a) X axis (b) Z axis

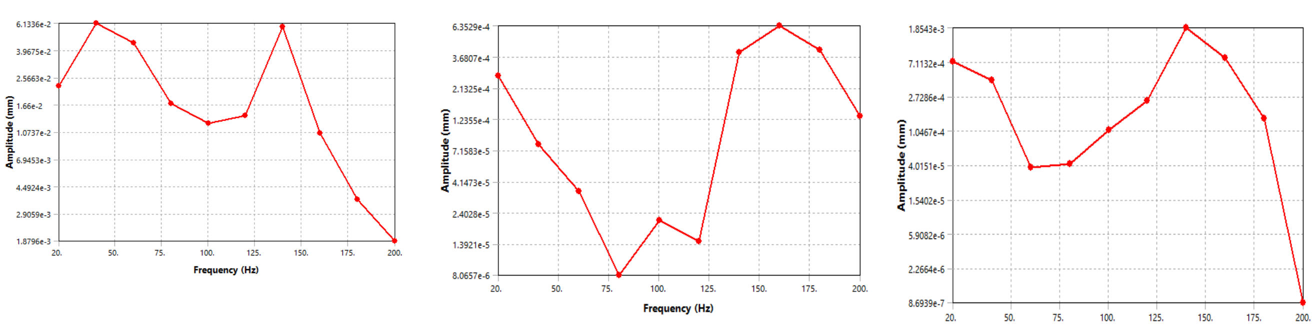

Fig. 5 – Deformation Graph (a) X axis (b) Y axis (c) Z axis

Material Aluminium Alloy 1060

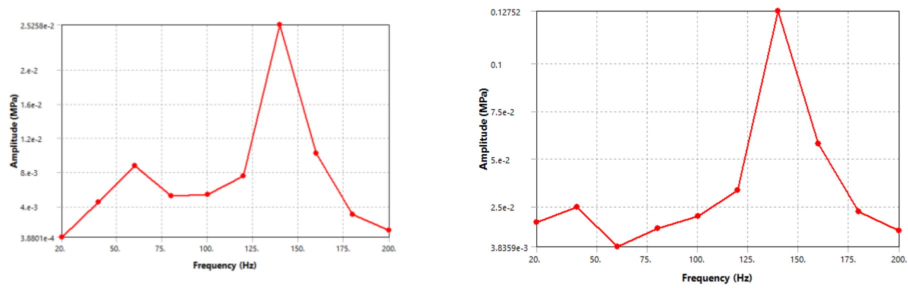

Fig. 6 – Stress Graph (a) X axis (b) Z axis

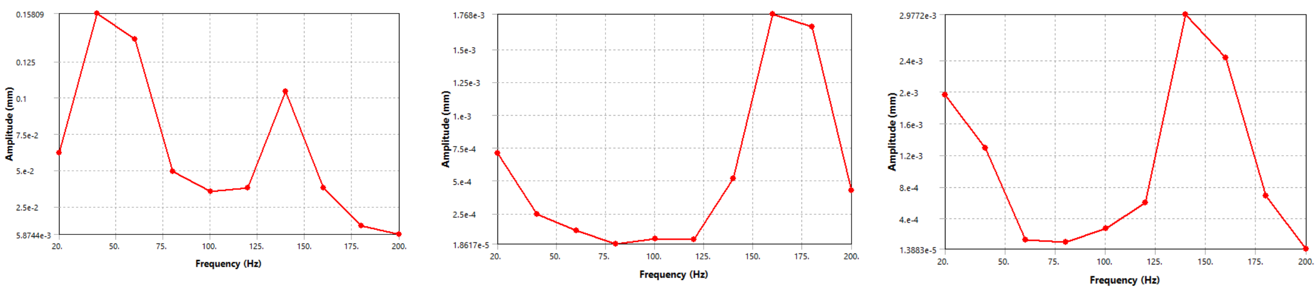

Fig. 7 – Deformation Graph (a) X axis (b) Y axis (c) Z axis

Material SS316L

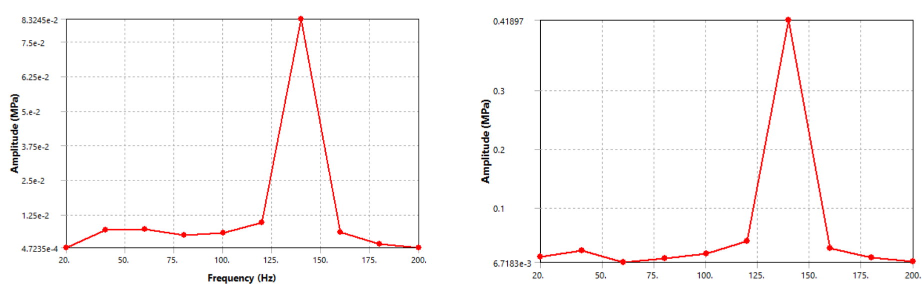

Fig. 8 – Stress Graph (a) X axis (b) Z axis

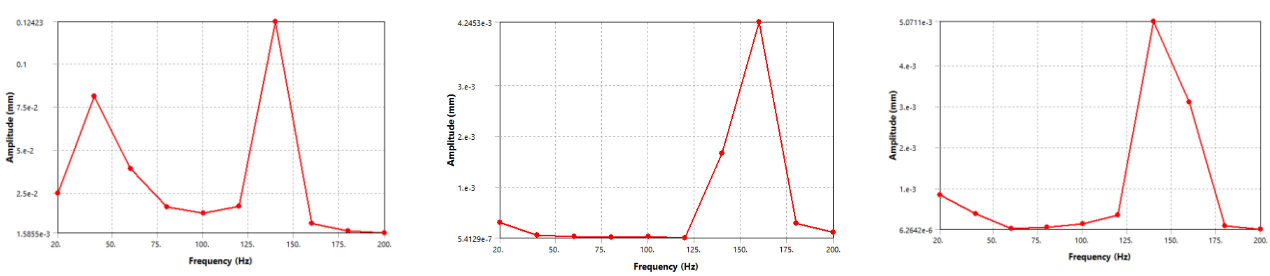

Fig. 9 – Deformation Graph (a) X axis (b) Y axis (c) Z axis

Case 2: Optimized Impeller

Material Mild Steel

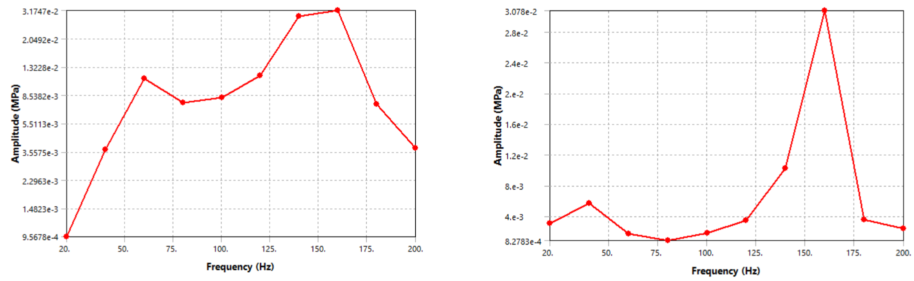

Fig. 10 – Stress Graph (a) X axis (b) Z axis

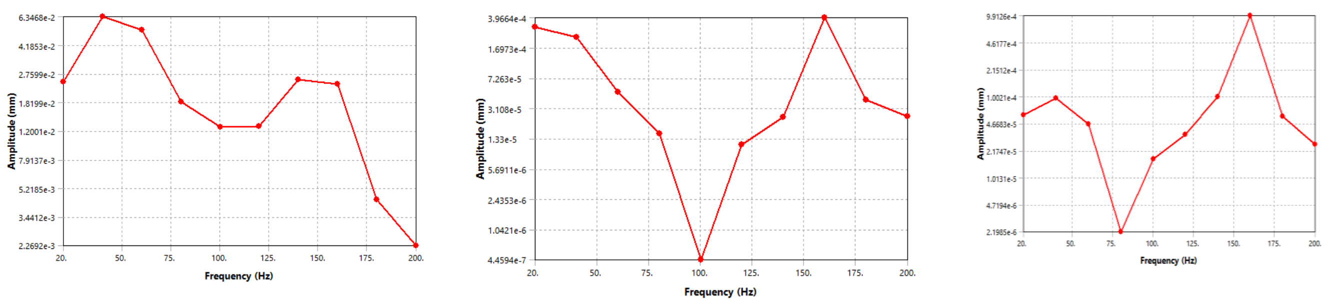

Fig. 11 – Deformation Graph (a) X axis (b) Y axis (c) Z axis

Material Aluminium Alloy 1060

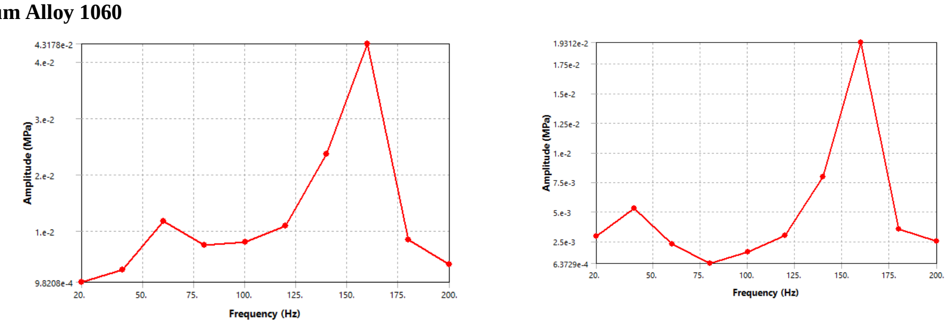

Fig. 12 – Stress Graph (a) X axis (b) Z axis

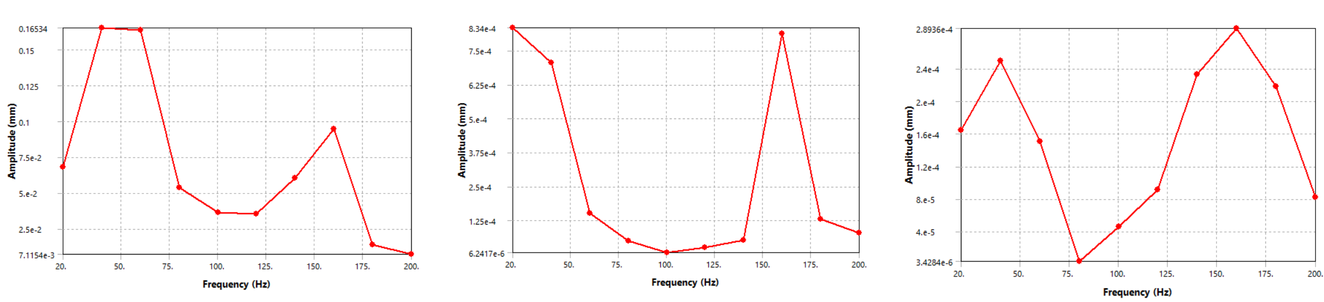

Fig. 13 – Deformation Graph (a) X axis (b) Y axis (c) Z axis

Material SS316L

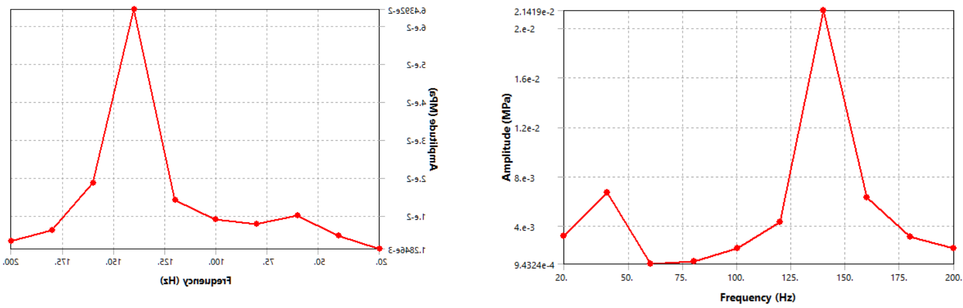

Fig. 14 – Stress Graph (a) X axis (b) Z axis

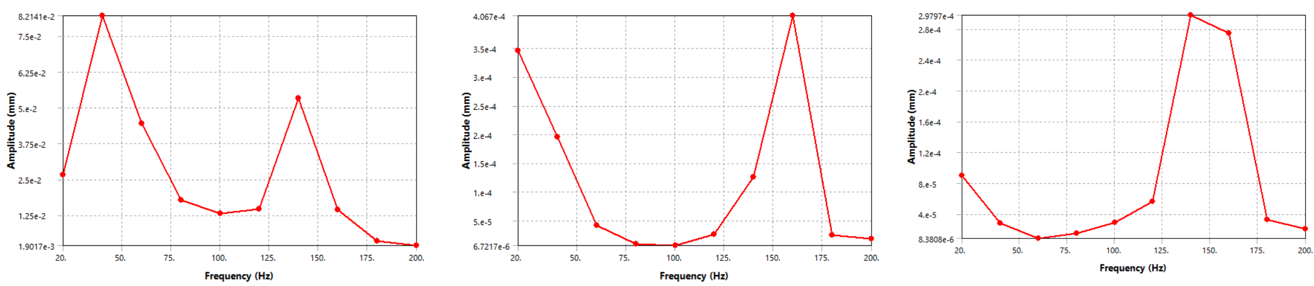

Fig. 15 – Deformation Graph (a) X axis (b) Y axis (c) Z axis

5.4 Result and discussion

Table 1 - Result table of Harmonic analysis of present impeller

HARMONIC ANALYSIS						
MATERIAL	**Mild Steel**					
FREQUENCY (HZ)	Stress (MPa)			Deformation (mm)		
	Along -X	Along -Y	Along -Z	Along -X	Along -Y	Along -Z
20	4.15E-04	1.74E-02	1.65E-02	2.24E-02	2.64E-04	7.29E-04
40	5.08E-03	2.71E-02	2.53E-02	6.13E-02	7.92E-05	4.25E-04
60	8.10E-03	4.38E-03	4.95E-03	4.49E-02	3.49E-05	3.81E-05
80	5.13E-03	1.36E-02	1.35E-02	1.69E-02	8.07E-06	4.21E-05
100	5.47E-03	2.04E-02	2.01E-02	1.24E-02	2.10E-05	1.07E-04
120	8.06E-03	3.59E-02	3.54E-02	1.40E-02	1.47E-05	2.44E-04
140	4.01E-02	0.20419	0.20166	5.82E-02	3.98E-04	1.85E-03
160	8.16E-03	4.79E-02	4.45E-02	1.06E-02	6.35E-04	8.06E-04
180	2.62E-03	1.90E-02	1.95E-02	3.67E-03	4.19E-04	1.47E-04
200	9.58E-04	1.05E-02	1.10E-02	1.88E-03	1.31E-04	8.69E-07
MATERIAL	**Al 1060**					
FREQUENCY (HZ)	Stress (MPa)			Deformation (mm)		
	Along -X	Along -Y	Along -Z	Along -X	Along -Y	Along -Z
20	3.88E-04	1.77E-02	1.68E-02	6.19E-02	7.11E-04	1.96E-03
40	4.50E-03	2.65E-02	2.48E-02	1.58E-01	2.47E-04	1.29E-03
60	8.74E-03	3.19E-03	3.84E-03	1.40E-01	1.19E-04	1.30E-04
80	5.19E-03	1.34E-02	1.33E-02	4.93E-02	1.86E-05	1.02E-04
100	5.39E-03	2.00E-02	1.97E-02	3.52E-02	5.82E-05	2.75E-04
120	7.59E-03	3.39E-02	3.34E-02	3.79E-02	5.09E-05	6.00E-04
140	2.53E-02	0.129	0.12752	1.05E-01	5.16E-04	2.98E-03
160	1.02E-02	5.96E-02	5.78E-02	3.77E-02	1.77E-03	2.43E-03
180	3.01E-03	2.18E-02	2.24E-02	1.18E-02	1.67E-03	6.86E-04
200	1.19E-03	1.19E-02	1.24E-02	5.87E-03	4.27E-04	1.39E-05

MATERIAL	**SS316L**					
FREQUENCY (HZ)	Stress (MPa)			Deformation (mm)		
	Along -X	Along -Y	Along -Z	Along -X	Along -Y	Along -Z
20	4.72E-04	1.70E-02	1.59E-02	2.44E-02	3.05E-04	8.46E-04
40	6.82E-03	2.95E-02	2.72E-02	8.10E-02	6.13E-05	3.81E-04
60	7.10E-03	6.29E-03	6.72E-03	3.88E-02	2.44E-05	2.52E-05
80	5.05E-03	1.40E-02	1.39E-02	1.65E-02	1.14E-05	5.67E-05
100	5.71E-03	2.15E-02	2.12E-02	1.30E-02	2.21E-05	1.36E-04
120	9.62E-03	4.29E-02	4.22E-02	1.70E-02	5.41E-07	3.52E-04
140	8.32E-02	0.42517	0.41897	0.12423	1.66E-03	5.07E-03
160	6.10E-03	2.99E-02	3.04E-02	7.19E-03	4.25E-03	3.10E-03
180	1.81E-03	1.45E-02	1.53E-02	2.96E-03	2.93E-04	8.95E-05
200	4.97E-04	7.94E-03	8.50E-03	1.59E-03	1.04E-04	6.26E-06

Table 2 - Result table of Harmonic analysis of optimized impeller

HARMONIC ANALYSIS

MATERIAL	**Mild Steel**					
FREQUENCY (HZ)	Stress (Mpa)			Deformation (mm)		
	Along -X	Along -Y	Along -Z	Along -X	Along -Y	Along -Z
20	9.57E-04	2.44E-03	3.02E-03	2.45E-02	3.06E-04	6.03E-05
40	3.67E-03	4.96E-03	5.63E-03	6.35E-02	2.27E-04	9.52E-05
60	1.11E-02	2.36E-03	1.70E-03	5.22E-02	4.94E-05	4.63E-05
80	7.60E-03	6.28E-05	8.28E-04	1.84E-02	1.54E-05	2.20E-06
100	8.28E-03	8.96E-04	1.84E-03	1.28E-02	4.46E-07	1.72E-05
120	1.16E-02	2.06E-03	3.41E-03	1.29E-02	1.12E-05	3.47E-05
140	2.88E-02	7.33E-03	1.02E-02	2.54E-02	2.46E-05	1.00E-04
160	3.17E-02	3.15E-02	3.08E-02	2.37E-02	3.97E-04	9.91E-04
180	7.48E-03	2.02E-03	3.51E-03	4.43E-03	3.92E-05	5.72E-05
200	3.77E-03	1.84E-03	2.41E-03	2.27E-03	2.47E-05	2.61E-05
MATERIAL	**Al 1060**					
FREQUENCY (HZ)	Stress (Mpa)			Deformation (mm)		
	Along -X	Along -Y	Along -Z	Along -X	Along -Y	Along -Z
20	9.82E-04	2.39E-03	2.94E-03	6.80E-02	8.34E-04	1.64E-04
40	3.10E-03	4.64E-03	5.28E-03	1.65E-01	7.04E-04	2.50E-04
60	1.18E-02	2.87E-03	2.24E-03	1.64E-01	1.50E-04	1.50E-04
80	7.60E-03	8.94E-05	6.37E-04	5.38E-02	4.86E-05	3.43E-06
100	8.10E-03	7.36E-04	1.62E-03	3.65E-02	6.24E-06	4.59E-05
120	1.09E-02	1.77E-03	3.00E-03	3.55E-02	2.39E-05	9.16E-05
140	2.37E-02	5.57E-03	7.96E-03	6.04E-02	5.10E-05	2.33E-04
160	4.32E-02	1.69E-02	1.93E-02	9.48E-02	8.13E-04	2.89E-04
180	8.43E-03	1.79E-03	3.53E-03	1.39E-02	1.29E-04	2.18E-04
200	4.15E-03	1.95E-03	2.52E-03	7.12E-03	7.96E-05	8.19E-05
MATERIAL	**SS316L**					
FREQUENCY (HZ)	Stress (Mpa)			Deformation (mm)		
	Along -X	Along -Y	Along -Z	Along -X	Along -Y	Along -Z
20	1.28E-03	2.53E-03	3.17E-03	2.67E-02	3.45E-04	9.01E-05
40	4.69E-03	5.89E-03	6.73E-03	8.21E-02	1.95E-04	2.80E-05
60	1.00E-02	1.56E-03	9.43E-04	4.45E-02	4.11E-05	8.38E-06
80	7.88E-03	3.31E-04	1.11E-03	1.78E-02	9.73E-06	1.49E-05
100	9.14E-03	1.21E-03	2.22E-03	1.32E-02	6.72E-06	2.89E-05
120	1.41E-02	2.80E-03	4.35E-03	1.47E-02	2.59E-05	5.60E-05
140	6.44E-02	1.97E-02	2.14E-02	5.32E-02	1.26E-04	2.98E-04
160	1.87E-02	1.04E-02	6.30E-03	1.44E-02	4.07E-04	2.75E-04
180	6.12E-03	2.07E-03	3.11E-03	3.59E-03	2.44E-05	3.31E-05
200	3.23E-03	1.73E-03	2.18E-03	1.90E-03	1.86E-05	2.05E-05

Harmonic response analysis is carried out on optimized impeller with all three selected material; it was observed that stress in optimized impeller is much less than the present impeller due to it has much better damping. The other observation is that aluminium blower is performing well compared to other two blower as we seen previous case. In aluminium blower the stress along x axis is near to MS impeller and lower than SS316L impeller also much lower along other two axis compare to MS and SS.

5.5Conclusion

In this work, the geometry of impeller is modelled, optimized and mesh is generated successfully. FEA is applied for the Harmonic analysis of the impeller. Contours of total deformation and equivalent stress are plotted. Modal analysis is done to determine the vibration characteristics of as structure or a machine component while it is being designed. Based on the model predictions of FEA and modal analysis the following conclusions are drawn:

1. Both present and optimized blowers are safe according to analytic calculations as the analytical natural frequency is not matching with blower working frequency.
2. Also the working frequency does not matches with mode shapes of modal analysis so resonance will not occur, so the impeller is safe
3. In Harmonic Analysis we observed that Stress levels are further reducing in optimized blower.
4. The maximum displacements are lesser in aluminium blower than MS and SS.

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