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Optimization of critical parts of centrifugal blower by Modal & CFD Analysis

KUSEKAR S.K.
BMIT, SOLAPUR UNIVERSITY,
SOLAPUR, MAHARASTRA

PROF. LAVNIS A.K.
BMIT, SOLAPUR UNIVERSITY,
SOLAPUR, MAHARASTRA

ABSTRACT: Blowers are one of the types of turbo machinery which are used to move air continuously with in slight increase in static pressure. Blowers are widely used in industrial and commercial applications from shop ventilation to material handling, boiler applications to some of the vehicle cooling systems. The performance of the fan system may range from free air to several cfm (cubic feet per min.). Selection of fan system depends on various conditions such as airflow rates, temperature of air, pressures, airstream properties, etc. Although, the fan is usually selected for nontechnical reasons like price, delivery, availability of space, packaging etc. The blower is always analyzed by its performance curves which are defined as the plot of developed pressure and power required over a range of fan generated air flow. Also these fan characteristic curves can be used to data like fan bhp for selection of the motor being used. As per the discussion with concern person of the company Foodosavy solutions, Chinchwad, Pune, Maharashtra. It is one of the leading companies in the field of fruit juice. They are facing many problems regarding centrifugal blower. They are using centrifugal blower for air conditioning and ventilation purpose, also they are using blower to maintain the temperature of food storages (Pulp storage).The present centrifugal blower is made up of from M.S. material here corrosion is a major problem. The ingredients of the same are mixing with fruit pulps, which is harmful, also weight of the present blower is high and vibrations produced by the given centrifugal blower is more, discharge of the present blower is 10.84 m^3/s, which is somehow less as per the pulp area of the industry considered. This paper gives the solution to above some problems which are facing the industry i.e. Foodosavy solutions, Chinchwad, Pune. By optimization of critical parts of centrifugal blower by modal & CFD analysis using FEA. In this paper modal analysis is done for the material MS, SS, SS316L which is a food grade material and natural frequency of the material is compared, in order to reduce vibrations and failure of the centrifugal blower fan. CFD analysis is done for the same in order to enhance the discharge of the blower.

Keywords: Centrifugal Blower, Critical Parts, FEA, Modal Analysis, CFD Analysis Optimization, Static Analysis, SS316L.

1. INTRODUCTION:

The present work aims at examining the choice of material as an alternative for better vibration control. SS316L is well known for their superior damping characteristics are more promising in vibration reduction compared to metals. The modeling of the blower was done by using solid modeling software, CATIA V5 R20. The blower is meshed with a three dimensional hex8 mesh is done using HYPERMESH 10 and analysis using ANSYS14.5. Centrifugal blowers are used extensively for food industrial applications have high corrosion levels. The corrosion produced by a continues contact with water and air. The contemporary blades in naval applications are made up of aluminum or steel and generate noise that causes disturbance to the people working near the blower. Blowers are one of the types of turbo machinery which are used to move air continuously with in slight increase in static pressure. Blowers are widely used in industrial and commercial applications from shop ventilation to material handling, boiler applications to some of the vehicle cooling systems. The performance of the fan system may range from free air to several cfm (cubic feet per min.). Selection of fan system depends on various conditions such as airflow rates, temperature of air, pressures, airstream properties, etc. Although, the fan is usually selected for nontechnical reasons like price, delivery, availability of space, packaging etc. The blower is always analyzed by its performance curves which are defined as the plot of developed pressure and power required over a range of fan generated air flow. Also these fan characteristic curves can be used to data like fan bhp for selection of the motor being used. The centrifugal fans with impellers having blades of Airfoil section are considered as the high efficiency impellers among the six types Airfoil blades, Backward Inclined single thickness blades, Backward curved blades, forward curved blades, radial tip blades and radial blades. The present study gives the design methodology for these high efficiency impellers which include the numerical design procedure and the CFD analysis of it. The CFD part is used for improvement the results of Static Pressure generated at the entry to the impeller, static efficiency. The CFD optimization also helped to improve the flow pattern through the centrifugal fan system. Centrifugal turbo machines are commonly used in many air-moving devices due to their ability to achieve relatively high-pressure ratios in a compact configuration compared with axial fans. They are often found in gas turbine engines, heating ventilation and air conditioning systems, and hydraulic pumps. Because of their widespread use, the noise generated by these machines often causes serious environmental issues. The turbo machinery noise is often dominated by tones at blade passage frequency and its higher harmonics. This is mainly due to strong interactions

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between the flow discharged from the impeller and the cutoff of the casing. In addition to discrete tones, the broadband noise is also generated due to the separation, turbulence mixing, and the vortex interaction process. The idea of using splitter vanes in the blade passage of both impeller and diffuser is not new. Several works mostly experimental have been carried out to assess the suitability of the method. It is found that a numerical approach using a design analysis tool like CFD is of recent origin and the whole field flow analysis of the complex flow in a centrifugal fan has been the state of the art in the domain. Ogawa and Gopalakrishnan , Bhargava and Gopalakrishnan , Fabri performed computations on splittered centrifugal rotors based upon potential flow models. Millour examined the same configuration using a 3-D Euler analysis with simplified viscous forces. They observed that the primary effect of the splitters was to decrease the loading on the main blades, as well as to reduce the jet/wake effect at the rotor exit. Fradin performed an extensive set of experiments on the flow fields of two centrifugal rotors: one with splitters, and one without. In both cases the flow field was transonic. The geometry of the splitters was the same as the main blades. They were circumferentially positioned half way between the main blades. Their study showed that the flow field at the rotor (impeller) exit was more homogenous when the splitters were used. Gui et al. performed a series of incompressible flow regime experiments on two centrifugal fans: one with no splitter and one with variable geometry splitters. They examined the effects of splitter length, circumferential position, and stagger angle. Results indicated that while splitters do reduce the load and velocity gradients on the main blades, they also introduce additional losses that are greatly dependent upon their geometry. It was shown that the pressure coefficient increases when the splitter is placed closer to the suction side of the main blade. Increasing the length of the splitter can raise the pressure coefficient with little or no effect on efficiency.

2. LITERATURE REVIEW:

[1] Static and Dynamic Analysis of a Centrifugal Blower Using Fea Veeranjaneyulu Itha1, T.B.S.Rao2, International Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 8, October - 2012 ISSN: 2278-0181, pp. 1-11.-In this project work this paper is used to study static and dynamic analysis of blower so as to reduce vibrations & impact.

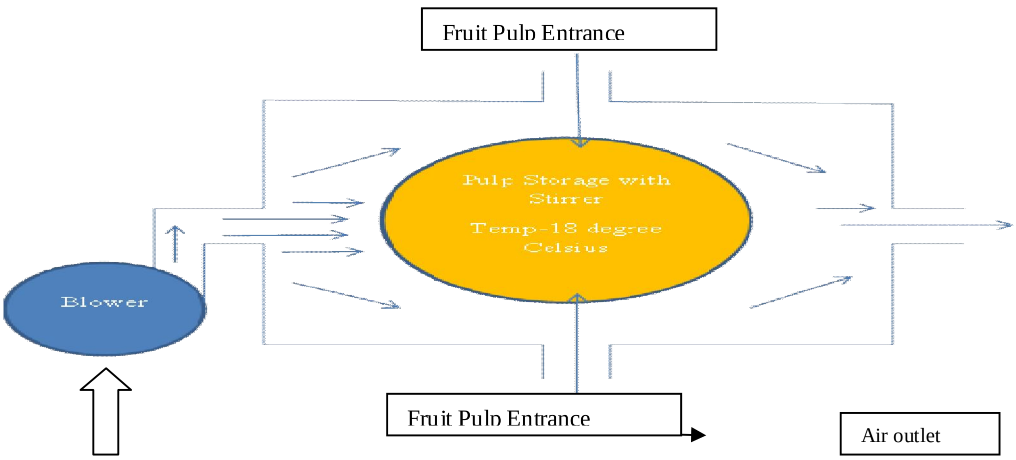
[2] Numerical Design and Parametric Optimization of Centrifugal Fans with Airfoil Blade Impellers Atre Pranav C. and Thundil Karuppa Raj R. School of Mechanical and Building Sciences, VIT University, Vellore-632014, Tamilnadu, INDIA.- In this project work this paper is used to know how Numerical Design and Parametric Optimization of Centrifugal Fans with Airfoil Blade impellers help to improve the efficiency of blades & optimize the weight.

[3] A numerical Study on the Acoustic Characteristics of a Centrifugal Impeller with a Splitter Wan-Ho Jeon1 1 Technical Research Lab., CEDIC Ltd., #1013, Byuksan Digital Valley II, Kasan- dong.-This paper is used to know Acoustic Characteristics of a Centrifugal Impeller with a Splitter

[4] Evaluation of Static & Dynamic Analysis of a Centrifugal Blower Using Fea Mohd Jubair Nizami, Ramavath Sunman, M.Guru Bramhananda Reddy, International Journal Of Advanced Trends in Computer Science and Engineering, Vol.2, Issue 7, January-2013, pp. - 316-321. -To study static and dynamic analysis of blower so as to reduce vibrations & impact.

[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.-In this project work this paper is used to Numerical Analysis of Internal Flow Field of Multi- Blade Centrifugal Fan for Floor Standing Air- Conditioner so as to improve discharge of the blower i.e. this paper is used to study the CFD analysis of the blower

3. PROBLEM IDENTIFICATION AND PROBLEM DEFINITION:



Problem Identified Fig (1): Plant Layout Where Problem Exist

Above fig (1) shows the plant layout of industry where the juice is produced. In this plant centrifugal blower is used for the ventilation purpose. As per the discussion with concern person of the company Foodosavy solutions, Chinchwad, Pune, it is found that it is one of the leading company in Maharashtra and they are producing different types of juice. They are facing many problems regarding centrifugal blower. They are using centrifugal blower for ventilation purpose, also they are using blower to maintain the temperature of food storages (Pulp storage).The present centrifugal blower is made up of from M.S. material here corrosion is a major problem. The ingredients of the same are mixing with food, which is harmful, also weight of the present blower is high and vibrations produced by the given centrifugal blower is more, discharge of the present blower is 10.84 m^3/s, which is somehow less as per the pulp area of the industry considered.

4. SCOPE OF WORK:

As per the discussion with concern person of the company Foodosavy solutions, Chinchwad, Pune, it is found that currently they are using Flanged Mounted type Centrifugal Blower (HBI-BL-0768). The specifications of the same are as follows:

- Type of blower: Flanged Mounted type Centrifugal Blower (HBI-BL-0768)
- Volume flow rate: 12000 cfm (cubic feet meter)
- Operating temperature: 16 degree centigrade
- Static pressure at operating temperature: 130 mm of Hg
- Size of blower/Wheel diameter(AISI316): 735 mm
- Fan RPM: 1440
- BHP at operating temperature: 13.91 HP
- Efficiency: 85%
- Motor Power: 12 HP, Torque: 6.91 kg-m
- Gas density at operating temperature: 1.21 kg/m3
- Static Load: 250 kg, Dynamic Load: 375 kg
- Noise Level at Site: 88 db

The scope of this paper is also mentioned below:

1. Study of present design of centrifugal Blower.
2. Identification and problem finding.
3. Collection of input data from Industry.
4. Study of weight-dimensional parameters
5. Study of Vibration and impact resistance.
6. Study of Keeping of service life at transportation and changes in climate

5. OBJECTIVES:

1. To reduce vibration problem of centrifugal blower by doing modal analysis for the material MS, SS316L (Food Grade Steel) using FEA.
2. To determine natural frequency of the MS, SS, SS316L (Food Grade Steel) material.
3. To check discharge of blower by CFD analysis.
4. To increase strength of centrifugal blower

6. METHODOLOGY:

6.1 STEPS INVOLVED IN ANALYSIS:

- Modeling by using CATIA V5 R20: Modeling of centrifugal blower is done by using CATIA V5 R20 using the standard drawing given by the company Hindustan Blowers Ltd, Bhosari ,Pune, Maharastra.

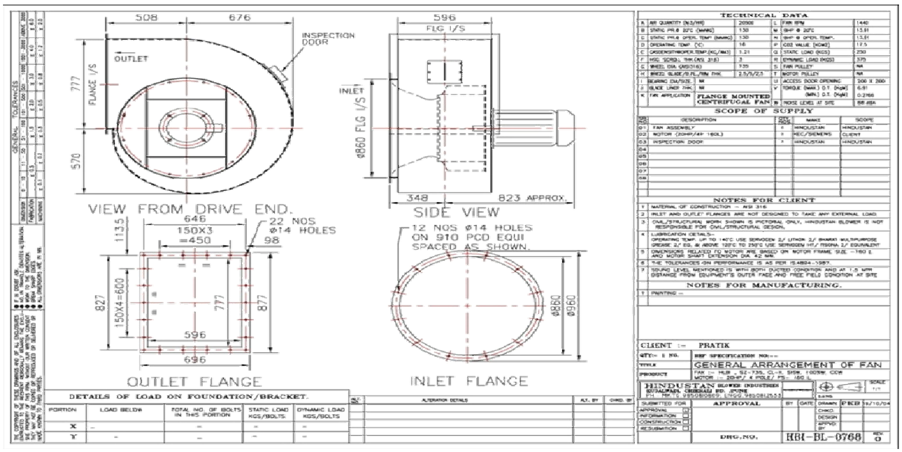


Fig (2): Drawing of centrifugal Blower

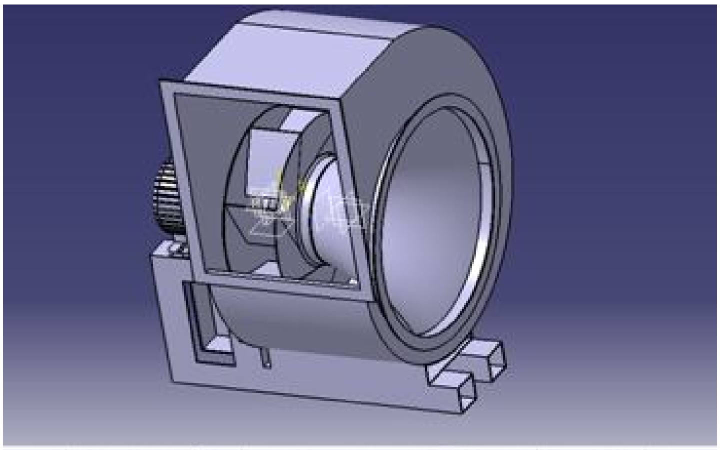


Fig (3): CAD model

- Meshing by using HYPERMESH 11.0: The solid model is imported to HYPERMESH 9.0 and hexahedral mesh is generated for the same. The meshed model is shown in figure 4. The meshing was done by splitting it into different areas and the 2D mapped mesh was done and then it was converted into 3D mesh using the tool linear solid. The number of elements and nodes are 20,837 and 42,177. Quality checks are verified for the meshed model. Jacobian, warpage and aspect ratio are within permissible limits. Then the meshed model is imported into the ANSYS.

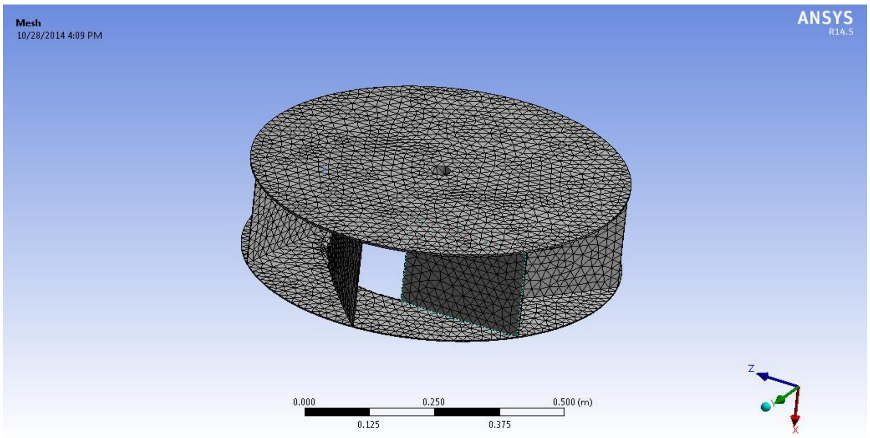


Fig (04): FEA model of centrifugal blower fan with meshing

6.2 MODAL ANALYSIS OF CENTRIFUGAL BLOWER FAN:

Procedure for modal analysis in ANSYS:

- Build the FE model explained in chapter 6.
- Define the material properties such as young's modulus and density etc
- Apply boundary conditions
- Enter the ANSYS solution processor in which analysis type is taken as modal analysis, and 'by taking mode extraction method, by defining number of modes to be extracted. Solution method is chosen as Block lanczos method.
- Solve the problem using current LS command from the tool bar.

6.3 MATERIAL PROPERTIES OF THE BLOWER:

The analysis is performed on (i) MS blower and (ii) SS316L blower

6.3.1 Material properties of MS blower:

- Young's modulus E= 210 MPa
- Poisson's ratio NUXY=0.303
- Mass density =7860 kg/m3
- Damping co-efficient =0.008

6.3.2 Material properties of SS316L (Food Grade Steel) blower:

- Yield stress 0.2 % proof (MPa) minimum- 170
- Elastic modulus- 193 GPa
- Mass density-8000 kg/m3
- Hardness B (HRB) max- 217
- Elongation (%)- 40 minimum

6.4 EIGEN VALUE ANALYSIS OF BLOWER:

Eigen value analysis results show that the first critical speed of MS blower is 30.532 Hz and that of SS316L blower is 31.656 Hz the reduction in natural frequency of MS blower is due to the high stiffness of the MS blower as per the equation below. This shows that both MS and SS316L blower are running with in the safe limits. The natural frequencies of the experimental results match with the natural frequency in the table.

$$F_1=\sqrt{\frac{\lambda 1}{2\pi}}$$

Table 6.4.1 Comparison of first six natural frequencies of MS and SS316L blower

No. of Modes	Natural frequencies of MS blower fan in Hz	Natural frequencies of SS316L blower fan in Hz	Natural frequencies of SS316L with1mm reduced thickness blower fan in Hz
1	30.532	31.656	25.172
2	30.643	31.772	25.348
3	48.683	50.476	43.99
4	144.63	149.96	124.08
5	159.58	186.2	147.68
6	159.64	165.46	148.08

The detail modal analysis which has been done in Ansys 14.5 with its sequential mode shape is as shown in following figures.

- **Material of Blower Fan: MS**

Tabular Data

	Mode	Frequency [Hz]
1	1.	30.532
2	2.	30.643
3	3.	48.683
4	4.	144.63
5	5.	159.58
6	6.	159.64

1st Mode

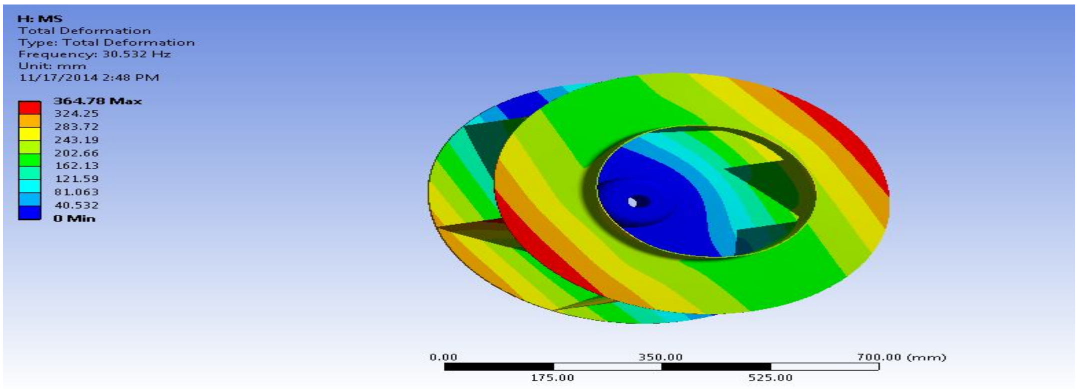


Fig.05. First mode shape of MS Blower Fan 2nd Mode

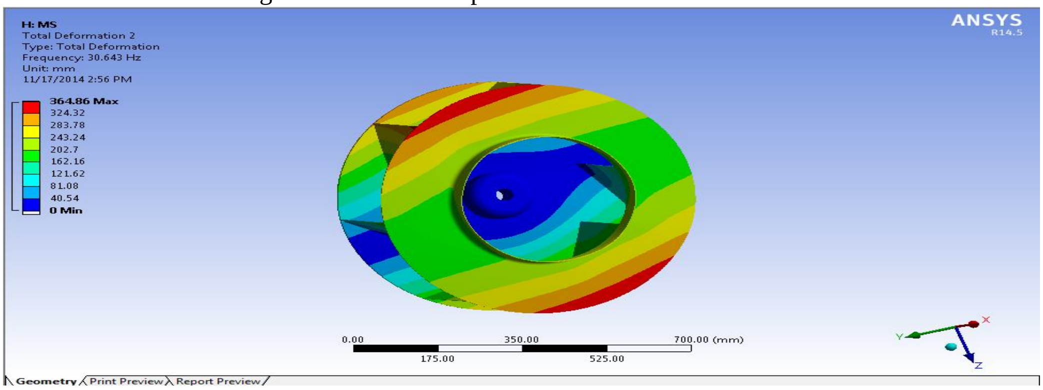


Fig.06. Second mode shape of MS Blower Fan

3rd Mode

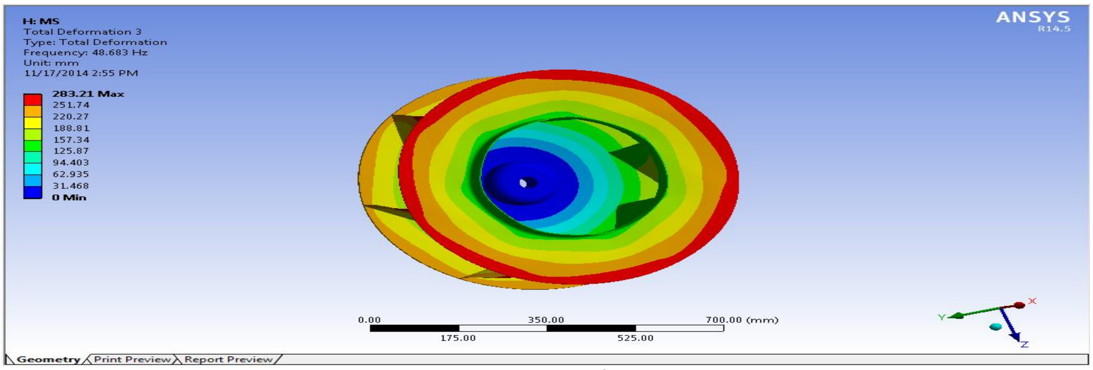


Fig.07. Third mode shape of MS Blower Fan

4th Mode

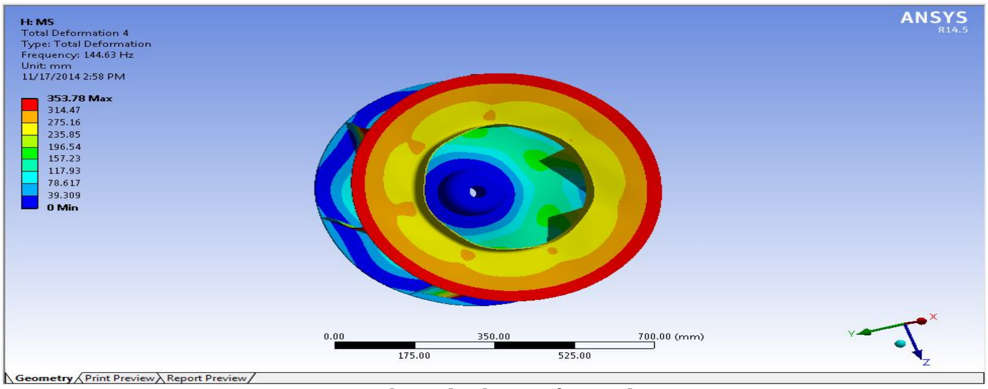


Fig.08. Fourth mode shape of MS Blower Fan

5th Mode

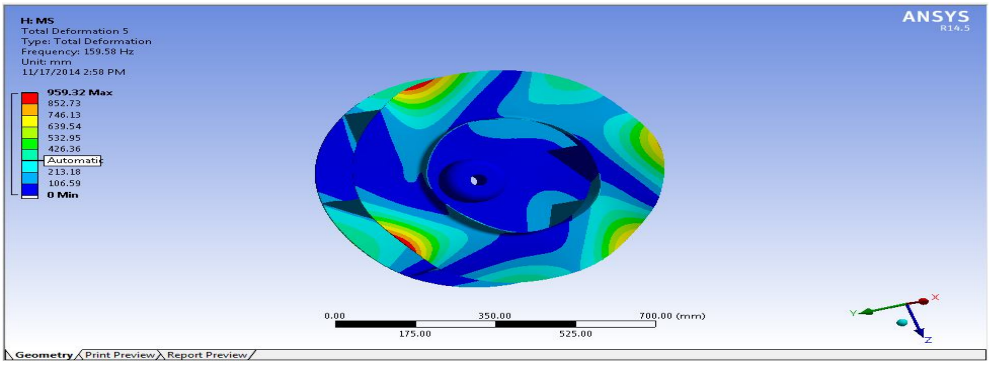


Fig.09. Fifth mode shape of MS Blower Fan

6th Mode

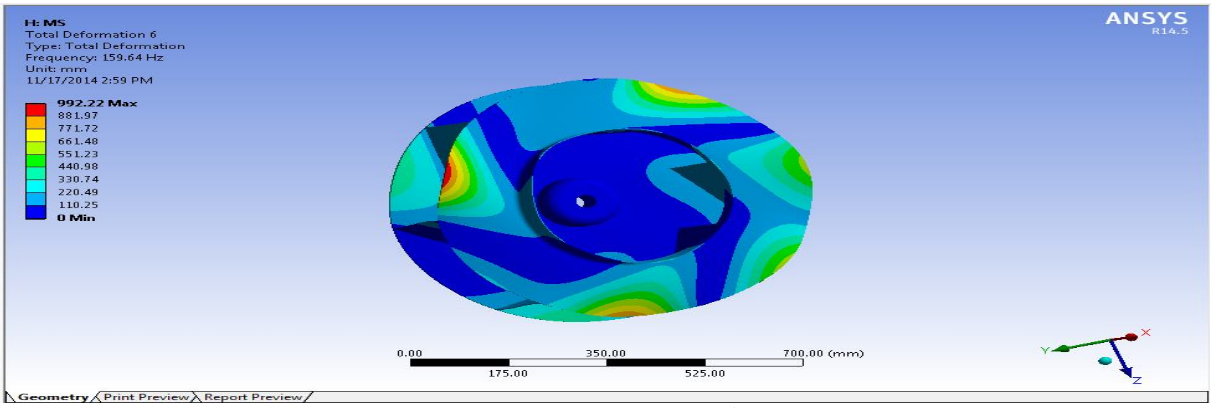


Fig.10. Sixth mode shape of MS Blower Fan

➢ **Material of the Blower Fan: SS316L (Food Grade Steel)**

	Mode	Frequency [Hz]
1	1.	31.656
2	2.	31.772
3	3.	50.476
4	4.	149.96
5	5.	165.46

1st Mode

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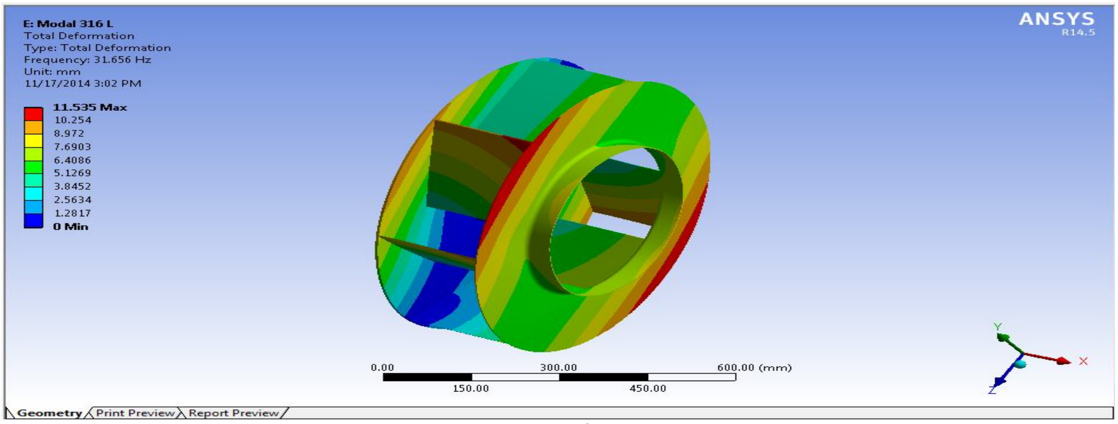


Fig.11. First mode shape of SS316L Blower Fan

2nd Mode

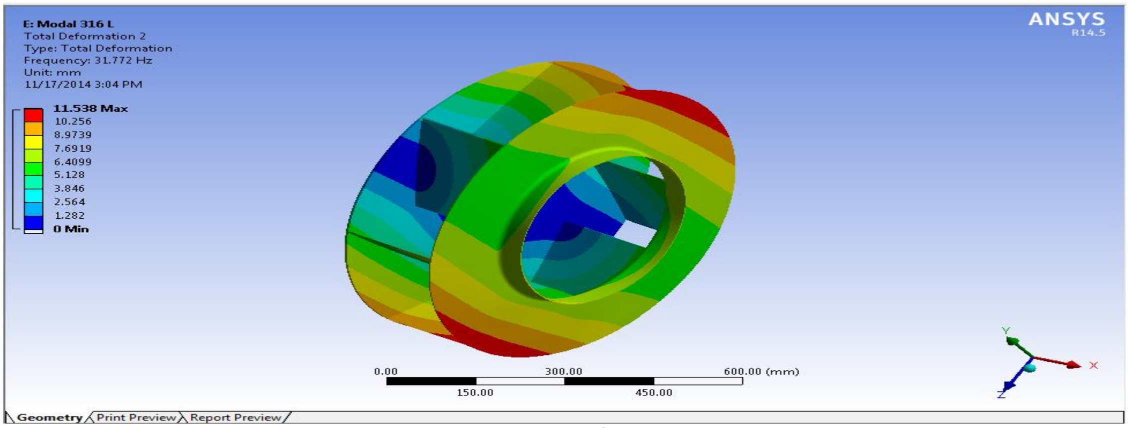


Fig.12. Second mode shape of SS316L Blower Fan

3rd Mode

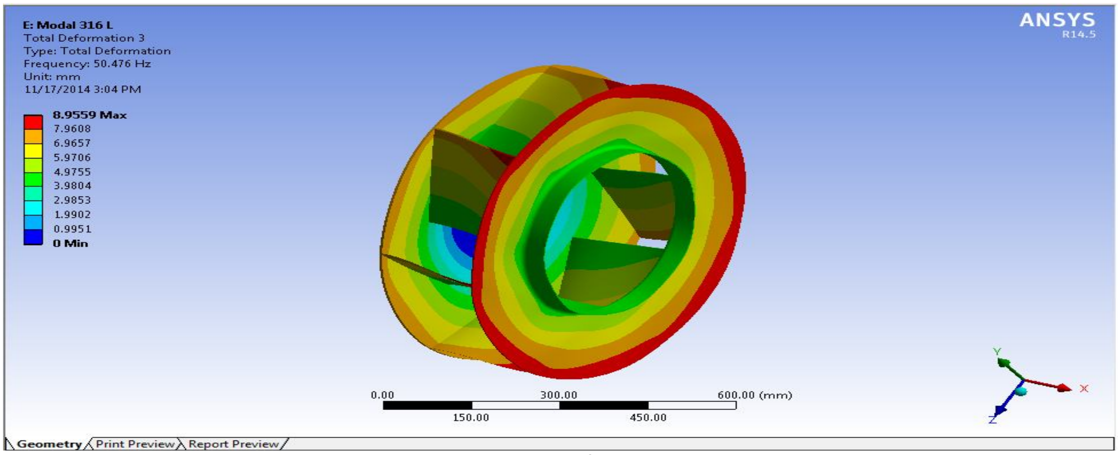
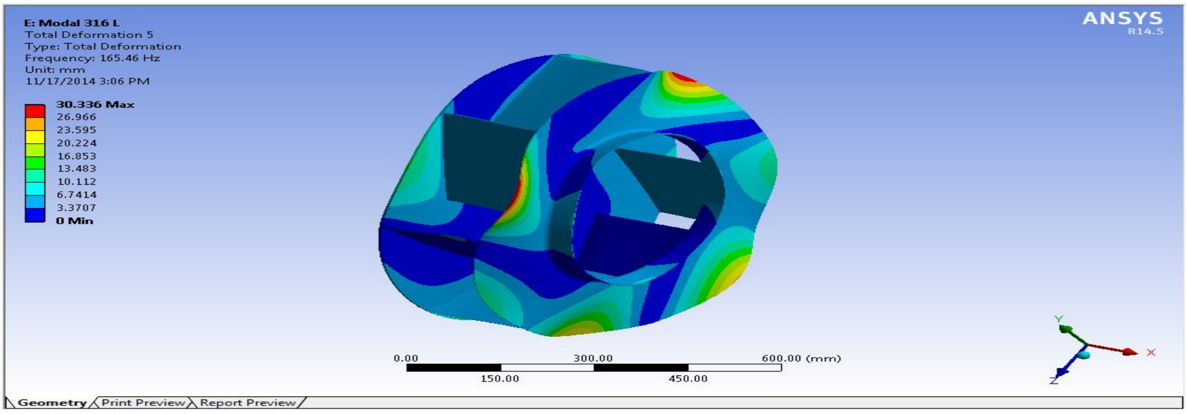
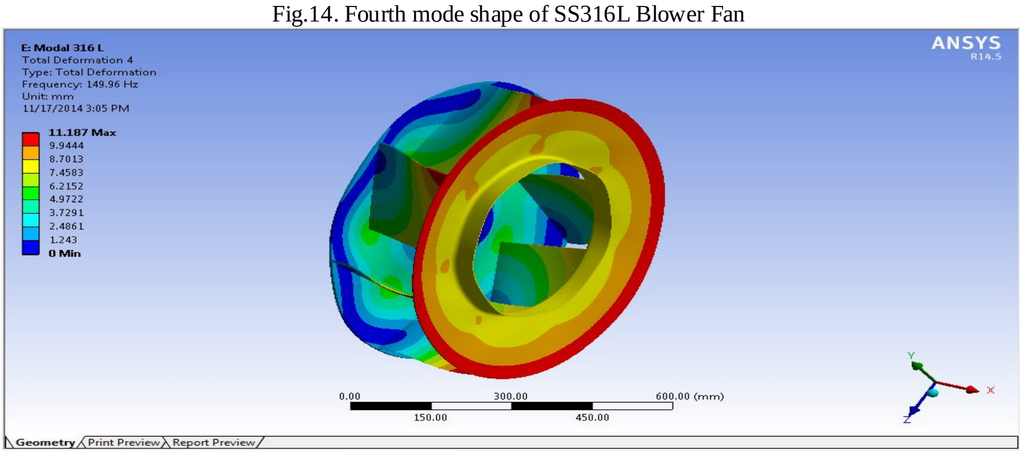


Fig.13. Third mode shape of SS316L Blower Fan



4th Mode

Fig.14. Fourth mode shape of SS316L Blower Fan



5th Mode

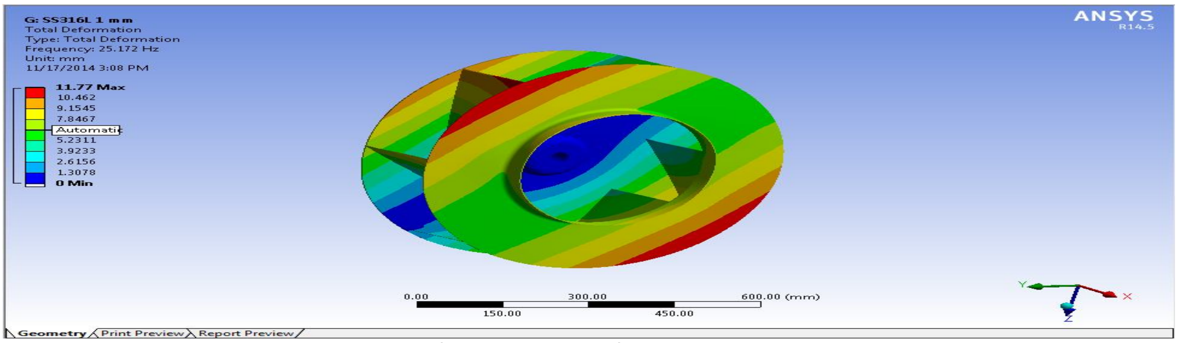


Fig.14. Fifth mode shape of SS316L Blower Fan

- **Material of the Blower Fan: SS316L with 1mm reduced thickness (Food Grade Steel)**

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Tabular Data

	Mode	Frequency [Hz]
1	1.	25.172
2	2.	25.348
3	3.	43.99
4	4.	124.08
5	5.	147.68
6	6.	148.08

1st Mode

Fig.15. Fist mode shape of SS316L-1mm less thickness Blower Fan

2nd Mode

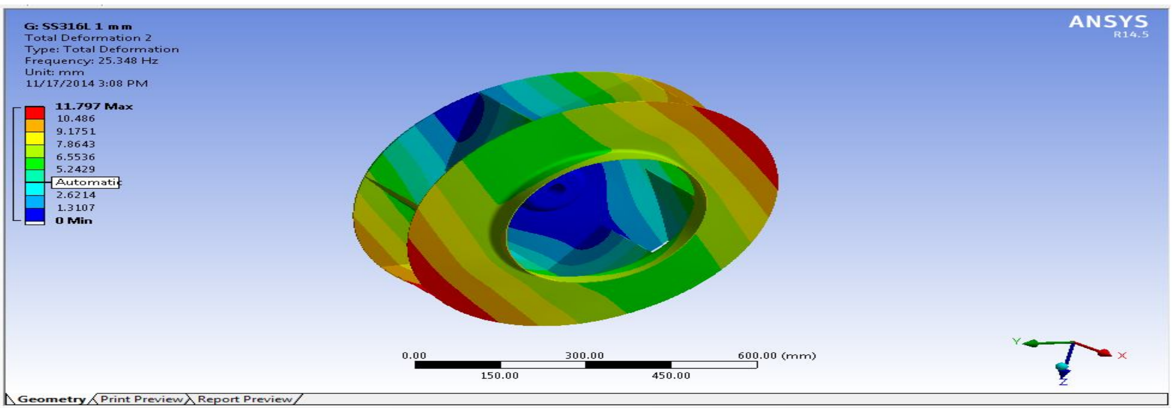

Fig.16. Second mode shape of SS316L-1mm less thickness Blower Fan

3rd Mode

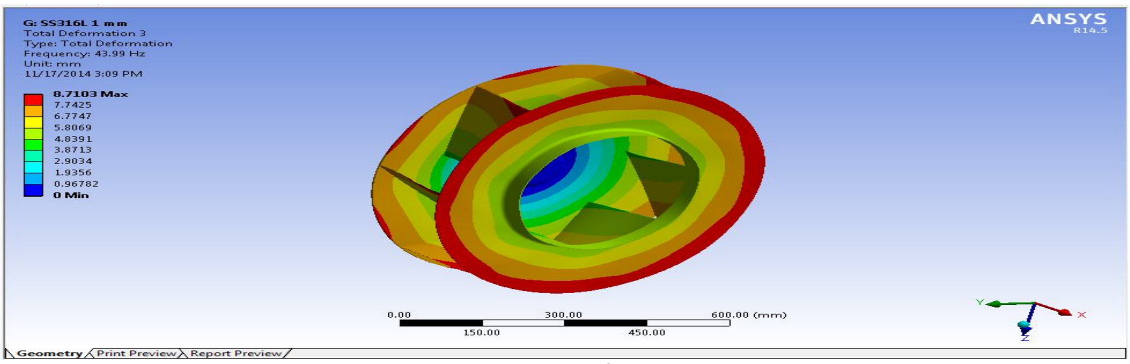

Fig.17. Third mode shape of SS316L-1mm less thickness Blower Fan

4th Mode

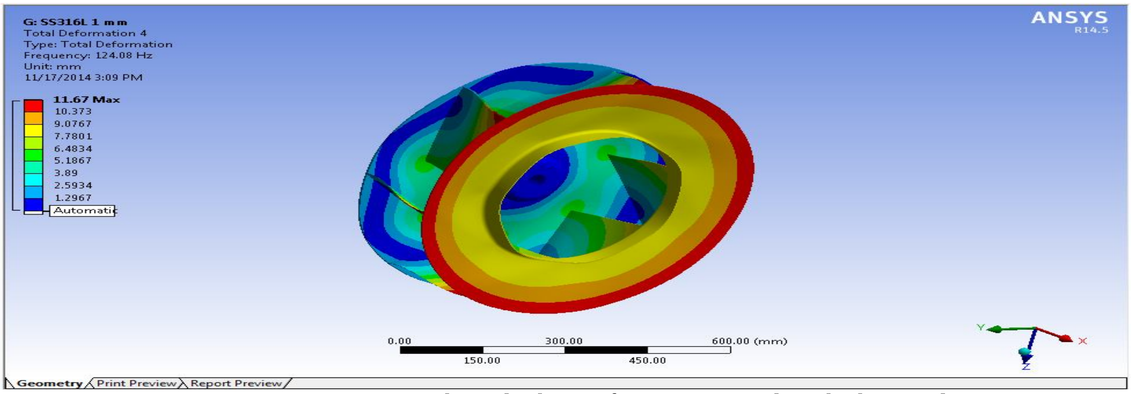

Fig.18. Fourth mode shape of SS316L-1mm less thickness Blower Fan

5th Mode

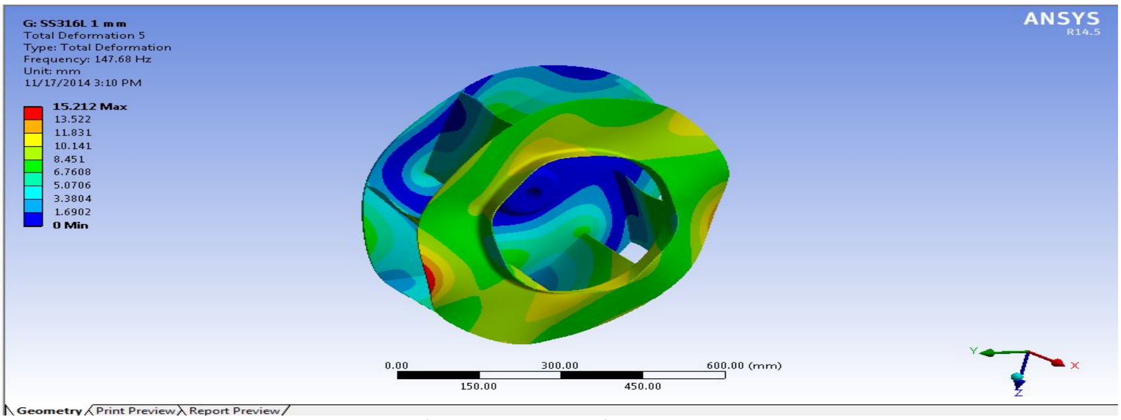

Fig.19. Fifth mode shape of SS316L-1mm less thickness Blower Fan

6th Mode

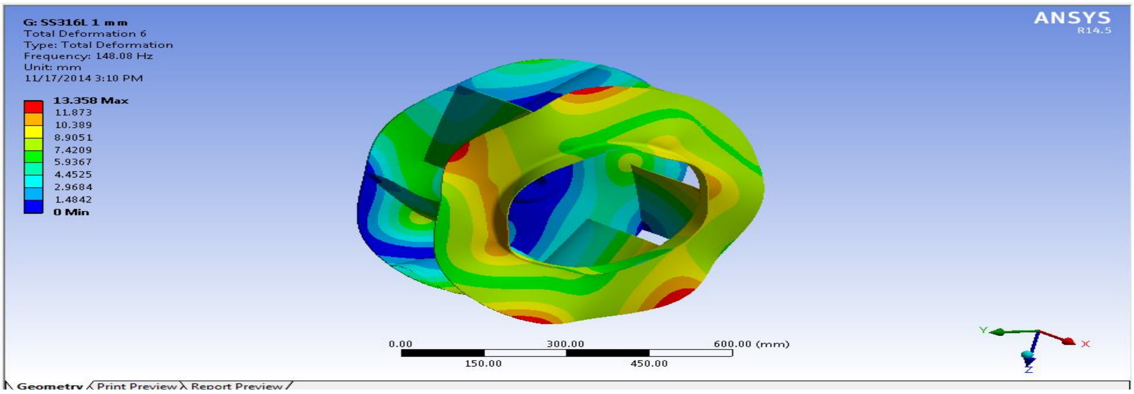

Fig.20. Sixth mode shape of SS316L-1mm less thickness Blower Fan

Table 6.4.2 Comparison of Deformations of MS and SS316L blower

Mode	MS Deformation	SS316L Deformation	SS316L-1mm less thickness Deformation
1	364.78	11.535	11.77
2	364.86	11.538	11.797
3	283.21	8.9559	8.7103
4	353.78	11.587	11.67
5	959.32	30.336	15.212
6	992.22	------	13.358

From above table it is clear that SS316L with 1mm reduced thickness have less deformation for 6 different modes. Therefore there are less chances of failure the material, also from table 6.4.1 it is clear that the natural frequency of SS316L with 1mm less thickness blower is reduced because of high stiffness and the layup sequence in the blower.

7. CFD ANALYSIS SS316L (FOOD GRADE STEEL) BLOWER:

7.1 Meshing:

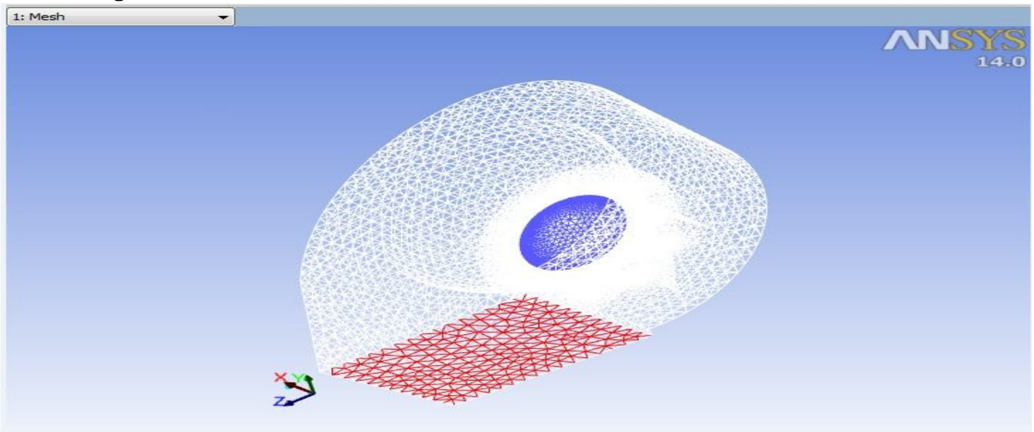

Fig.21. Meshing of Blower Casing

7.2 Velocity plot:

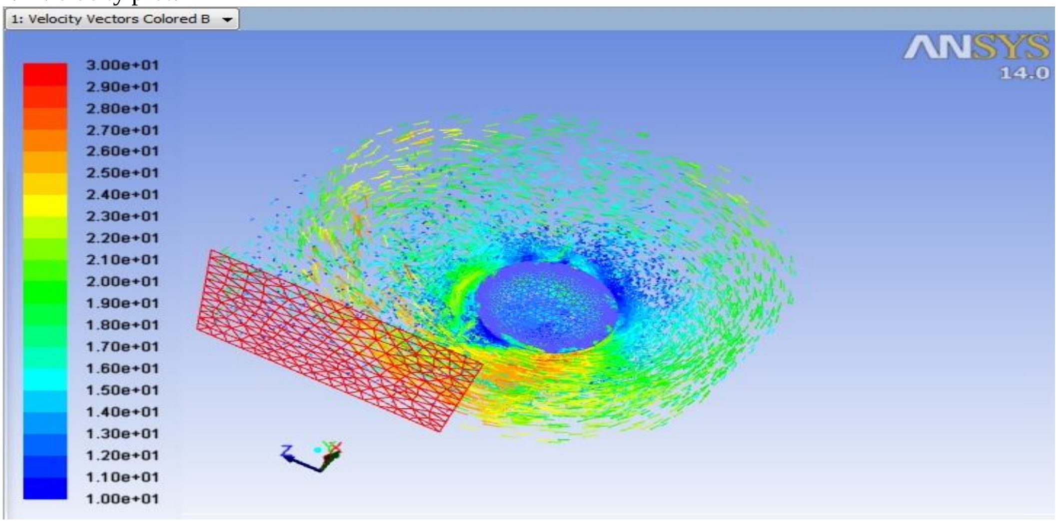

Fig.22. Velocity plot of SS316LBlower Casing

7.3 Difference in Velocity:

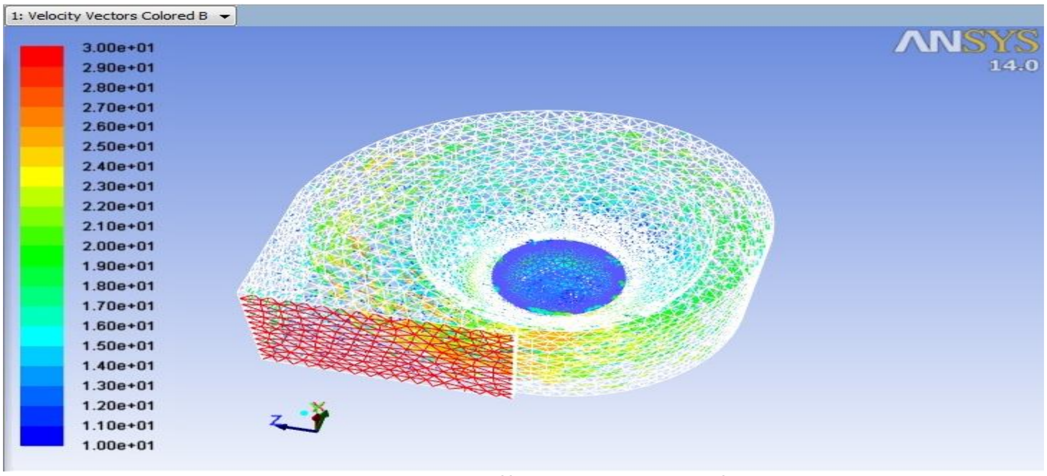

Fig.23. Difference in velocity of SS316LBlower Casing

7.4 Pressure plot:

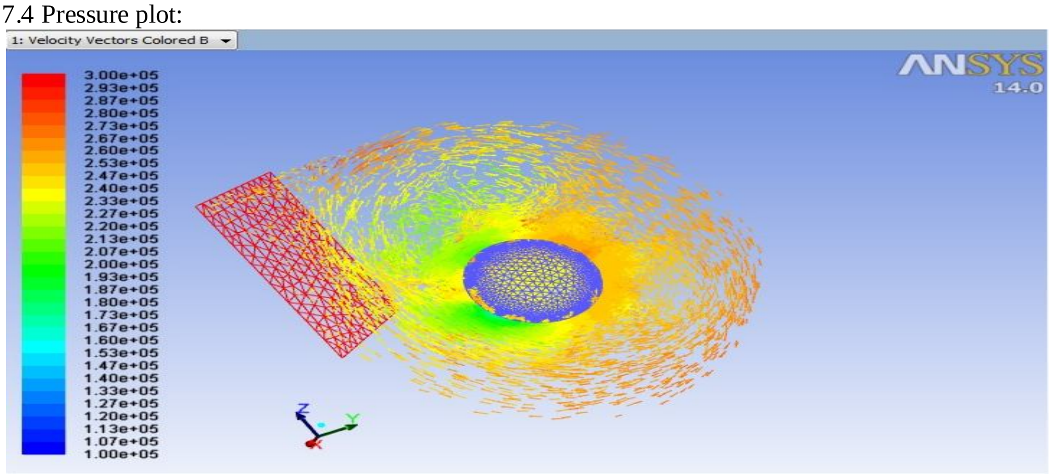

Fig.24. Pressure plot of SS316LBlower Casing

We get both result almost same because input parameters are same for both blower and volume is also same hence no much change in CFD, except velocity of air at duct outlet. That is velocity of air at duct outlet for MS material is 27 m/s, but it is for SS316L material is 30 m/s after the modification of design. The modified design parameters of SS316L blower duct outlet are as listed in following table.

Table 7 CFD Analysis Parameters of MS and SS316L blower

Sr. No	Material	Velocity	Pressure	Modified Design Parameters for Duct	Remark
1	MS	27 m/s	3.0 Bar	a-0.730 m b-0.550 m	Provide by the Company
2	SS316L	30 m/s	3.0 Bar	a-0.777 m b-0.596 m	Calculated

The flow rate or discharge of centrifugal blower is given by the following equation
Discharge (Q) = Area of duct × Velocity of air
i.e. $Q = A \times V$
As discharge is directly proportional to the velocity of air, hence velocity increases, discharge increases. In above analysis velocity of air increases for SS316L material (30 m/s) as compared to MS (27 m/s), so discharge of the blower increases by an amount

$$Q = a \times b \times V$$

$= 0.777 \times 0.596 \times 30 = 13.89\ m^3/s$
This is greater than MS blower (10.84 m3/s).

8.0 CONCLUSIONS:

1. Vibration problem of centrifugal blower reduced by using SS316L material because of its high stiffness and layup sequence in fan.
2. The natural frequency of SS316L blower is reduced because of high stiffness and the layup sequence in the blower.
3. The deformation of SS316L blower fan is less as compared to MS blower fan as listed in table 6.4.2.Therefore there are less chances of failure the material. Hence strength of centrifugal blower increases.
4. Discharge of centrifugal blower increases.

9.0 FUTURE SCOPE:

The present work gives only modal analysis of critical parts of centrifugal blower (i.e. blower fan) in order to reduce vibration problem & enhance strength of the blower also this paper provides solution to increase the discharge of blower by doing CFD analysis of blower casing. However this paper does not gives the static analysis of centrifugal blower, in future there is always scope of static analysis of blower, modal and CFD analysis of the blower casing & fan respectively, in order to increase performance of the given centrifugal blower.

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