Modeling & Analysis of Centrifugal Blower using Composite Material

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Abstract: *Centrifugal blowers are used extensively for on-board naval applications which have high noise levels. The noise generated by a rotating component is mainly due to random loading force on the blades and periodic iteration of incoming air with the blades of the rotor. The Contemporary blades in naval applications are made up of Aluminium or Steel and generate noise that causes disturbance to the people working near the blower.*

The present work aims at observing the choice of E-Glass as an alternative to metal for better vibration control. E-Glass, known for their superior damping characteristics are more promising in vibration reduction compared to metals. The modeling of the blower was done by CATIA V5 R19. The blower is meshed with a three dimensional hex8 mesh is done using HYPERMESH 10.

It is proposed to design blower with Epoxy glass, analyze its strength and deformation using FEM technique. In order to evaluate the effectiveness of E-Glass and metal blower using FEA packaged (ANSYS). Modal analysis is performed on both Aluminium and E-Glass blower to find out first five natural frequencies.
Keywords: *CATIA V5 R19, HYPERMESH 10, ANSYS*

I.   Introduction

Blowers are one of the mechanisms used regularly in submarines. They are installed in ventilation and air conditioning systems in almost all submarine compartments. Ventilation systems usually presented by central systems include supply and exhaust fans, serve for ventilation of accommodation and other than accommodation areas with atmospheric air with simultaneous ventilation of storage batteries and for air cooling and purification from harmful and smelling impurities. Air conditioning systems are presented by local, compartment group and single duct systems. These systems are used to provide comfortable conditions in terms of air temperature and humidity for the crew in accommodation areas, air purification in galleys, provision rooms, and sanitary areas and also for air mixing in compartments.

All blowers are intended for submarine installation differs from industrial ones not only for their reliability and strength under dynamic impacts but also for low noise and vibration levels. As blower represents a large part of submarine mechanisms, they should naturally meet the following compulsory requirements for all mechanisms:
1.   Minimum weight-dimensional parameters
2.   Reliable operation at submarine motions.
3.   Vibration and impact resistance.
4.   Convenience of mountings, repairs and easy access to lubrication points.
5.   Keeping of service life at transportation and changes in climate.

1.1 REASONS OF NOISE GENERATION IN CENTRIFUGAL BLOWER

Whole noise is due to rotational frequency and fan Blade passing frequency (BPF) and their harmonics. These are usually dominant noise source. Broadband aerodynamic noise generated by airflow at the inlet and outlet of the cooling fan. Mechanical noise caused by friction in bearings and seals, vibration due to motor fan static and dynamic unbalanced rotating masses, resonant vibration of motor fan casings, motor fan mounting and misalignment, etc. Due to Electro magnetically produced noise caused by changing of electromagnetic field in the electric motor.

1.2 NOISE CONTROL METHODS

Environmental noise usually does not affect directly from the energy source rather, it transmitted along mechanical or liquid streams before it finally radiates from some vibrating surface into the surrounding environment. The approaches to treating pump noise generally include in the following:
1.   Modify the basic design or operating condition to minimize the generation of acoustic energy.

2.   Prevent sources from generating airborne noise by interrupting the stream between the energy source and the listener. This approach may range from isolation mounts at the source physically removing the listener.

1.3 ROLE OF EPOXY GLASS IN NOISE GENRATION CONTROL

E-Glass material is a system that is created by the synthetic assembly of two or materials. The material consists of fiber of high strength and modulus embedded in a resin with distinct interfaces between them. They produce a combination of properties that cannot be achieved with either of the constituents acting alone. E-Glass materials have high strength, modulus.

The most common form in which reinforced composites are used in structural application is called a laminate and it is obtained by stacking a number of thin layers of fibers and matrix and consolidating them into the desired thickness. Fiber orientation in each layer and stacking sequence of various layers can be controlled to obtain a wide range of physical and mechanical properties for the composite laminate.

These materials are found to have high damping co-efficient. The damping property of a material represents its capacity to reduce transmission of vibration caused by mechanical disturbances to a structure. The measure of damping of a material is its damping factor. Increasing the value of efficiency is desirable for reducing the resonance amplitude of vibration in a structure. Damping factor value depends on a number of factors, including fiber orientation angle, and stacking sequence.

II.   Principle Of Centrifugal Blower

Operating principle is a combination of two effects: Centrifugal force which produces more static pressure and again deflection of the air flow by the blades, but here the deflection is from a radial outward direction in to a spiral flow pattern. In case of forward curved blades the air deflections have a strong influence on the flow pattern on the performance.

2.2 PROBLEM DEFINITION

In the present work, metal blower is used for air conditioning and ventilation purpose in naval defense applications causes vibration and noise during its operation which causes mental imbalance to the people working near the blower on ship. Therefore reducing vibration from a source is very important and critical task. Hence the objective of this project is to reduce the vibration level produced by metal air blower. It can be effectively reduced by the modifying the shape of blades.

2.3 BREIF NOTES ON THE PRESENT WORK:

Finite element method is the most versatile of all numerical techniques available. Hence the blowers have been analyzed by the Finite element Analysis technique (FEA). For the purpose of finite element analysis, the commercially available finite element package, ANAYS 11 has been used. The study of centrifugal blowers includes modeling and analysis.

III.   Steps In Project Work

3.1 MODELING BY USING CATIA V5 R19

A centrifugal blower with rearwardly curved impeller blades positioned in housing between two housing faces that are spaced apart along the impeller axis. One of the housing faces defines a housing inlet called bell mouth. The housing is substantially closed off with the exception of the inlet and an outlet. Modeling of the Centrifugal blower is done using CATIA V5 R 19. In order to model the centrifugal blower it is necessary to model the parts of the blower which are Spiral Casing, Impeller and the suction plate then it was assembled to get the total component. The solid model of the centrifugal blower is shown in the figure 3.1.
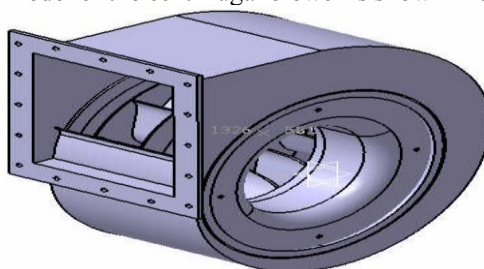
Fig. 3.1 Solid model of the centrifugal blower

3.2 MESHING BY USING HYPERMESH 10

The solid model is imported to HYPERMESH 10 and hexahedral mesh is created for the same. The meshed model is shown in figure 3.2. 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 27388 and 52412. 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.
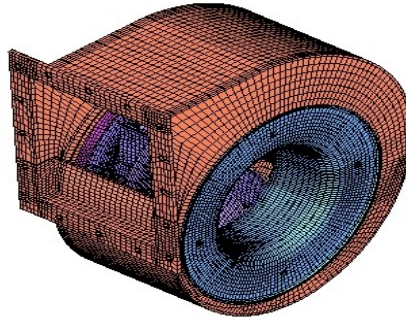

Fig. 3.2 Centrifugal Blower FE model in Hypermesh 10.0

3.3 ANALYSIS OF CENTRIFUGAL BLOWER
The analysis of centrifugal blower has been carried out by using ANSYS 11.0 general purpose FEM software. The following analysis was done on the blower.
1)   Static analysis
2)   Modal analysis
3)   Harmonic analysis

Procedure for Static analysis in ANSYS
Build the FE model as shown fig.3.1. Define the material properties such as young's modulus and density etc., Apply boundary condition and pressures as given. Solve the problem using current LS command from the tool bar.

Procedure for modal analysis in ANSYS
Build the FE model explained in fig.3.1. Define the material properties such as young's modulus and density etc., Apply boundary condition as given. 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 LS command tool bar.

Procedure for harmonic analysis in ANSYS
Build the FE model explained in fig.3.1. 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 0-500 HZ with 150 sub-steps. Solve the problem using current LS command tool bar and obtain the results.

IV.   Orientation
4.1 MATERIAL PROPERTIES OF THE BLOWER
The analysis is performed on (i) Metallic blower and (ii) Composite blower
i) Material properties of metallic blower :(aluminium)
Young's modulus E=70 GPa
Poisson's ratio NUXY   = 0.34
Mass density $= 2700 kg/_{m^3}$
Damping co-efficient   =0.006
ii) Material properties of composite blower : (E-Glass/Epoxy)
Young's modulus $E_X = E_Y = 14000\ MPa, E_Z = 8800 MPa$
Poisson's ratio NUXY=0.13, NUYZ=NUZX=0.39
Shear modulus $G_{XY} = 4700 MPa, G_{YZ} = G_{ZX} = 4200 MPa$
Mass density $= 1750\ kg/_{m^3}$
Damping co-efficient = 0.02

V.   Results & Discussions

5.1 STATIC ANALYSIS OF ALUMINIUM BLOWER

The deformation of aluminium blower is shown in figure5.1 and the maximum deflection was found as 0.0914mm. The maximum normal stress obtained is $3.483 N/_{mm}{}^2$. The stress and displacements are shown in figures 5.2 to 5.5. Table 5.1 shows induced deformations and stresses in aluminium blower.

Table 5.1   Static analysis results of Aluminium blower

Aluminium Blower	Results
Deflection in mm	0.09147 mm
Max. Normal stress, N/mm^2	3.483 N/mm^2
1st principal stress, N/mm^2	13.234N/mm^2
2nd principal stress, N/mm^2	1.345N/mm^2
3rd principal stress, N/mm^2	0.9047N/mm^2

The maximum deflection induced in metallic blower is 0.0914 mm, which is in safe limits. Hence based on rigidity the design is safe. The maximum induced stress 13000 KPa which is less than the allowable stress (160000KPa). Hence the design is based on strength.
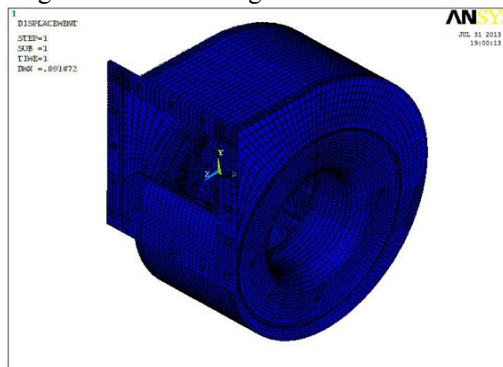
Fig. 5.1 Deformation of Aluminium blower, mm
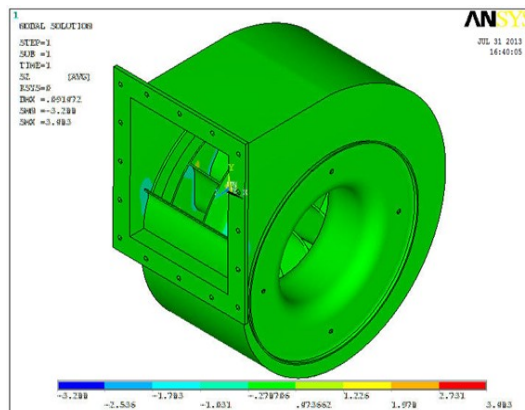
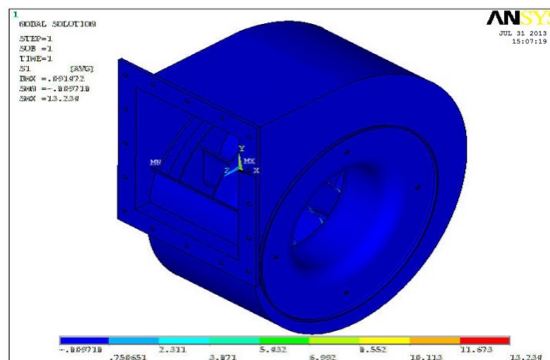**Fig. 5.2 Stress of Aluminium blower in Z-direction, N/mm^2**

Fig.5.3. 1st Principal Stress of Aluminium blower, N/mm^2
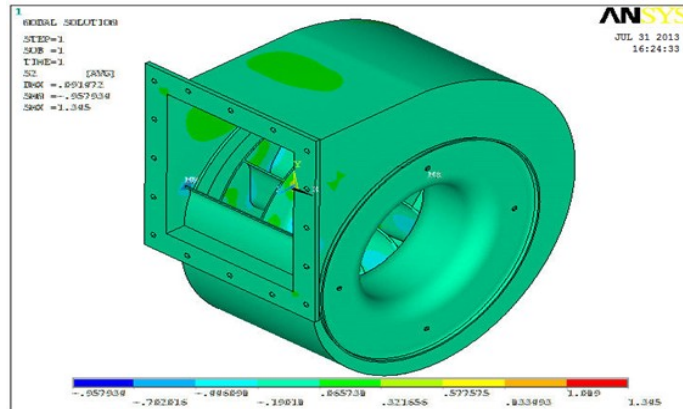
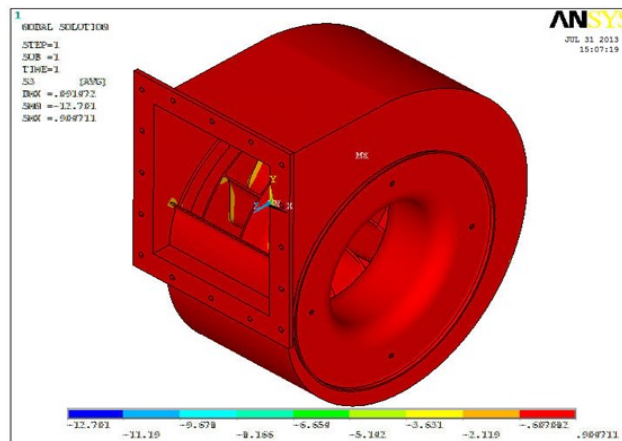**Fig.5.4. 2nd Principal Stress of Aluminium blower,** N/mm²

Fig.5.5. 3rd Principal Stress of Aluminium blower, N/mm²

5. 2 STATIC ANALYSIS OF COMPOSITE BLOWER

Static analysis of composite blower is carried out so as to check the bonding strength between various layers of composite blower and Inter-laminar shear stresses are calculated.

Maximum deflection for composite blower with 27 layers was found to be 1.018 mm as shown in figure 5.6. The maximum normal stress was found to be 4.534 $N/_{mm^2}$ in z-direction as shown in figure 5.7 and the maximum inter –laminar shear stress as 8.669$N/_{mm^2}$ and is shown in figure 5.8. Table 5.2 shows induced deformations and stresses in composite blower.

The deflection for composite blower was found to be around 1.018 mm for all layers which is more than that of Aluminium blower i.e., 0.09147mm. Inter laminar shear stresses were calculated for composite blower for 27 layers and the maximum inter laminar shear stress is found on the layer 27.

Table 5.2 Static analysis results of composite blower

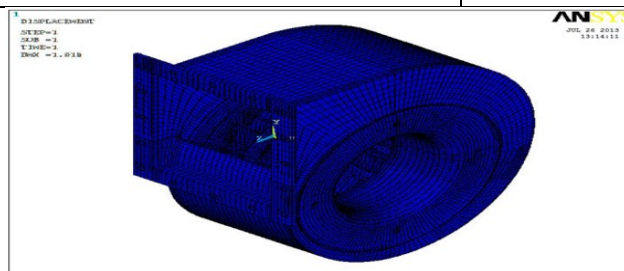| Composite blower (27 layers)	Results
Max deflection in mm	1.018mm
Max. normal stress, N/mm²	4.534N/mm²
Maximum Inter-laminar shear stress, N/mm²	8.669N/mm²

Fig. 5.6 Deformation of composite blower, mm

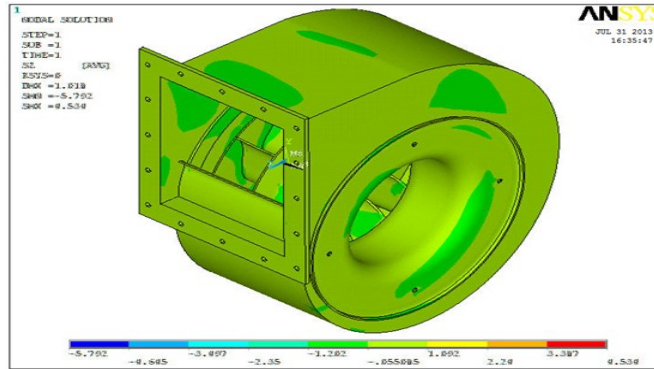**Fig. 5.7. Stress of composite blower in Z-direction,** N/mm^2
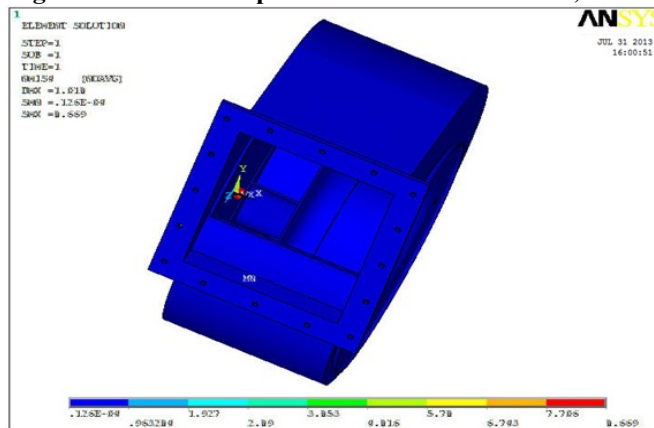

Fig. 5.8 Maximum interlaminar shear stress (occurs between LN1 and LN2), N/mm^2
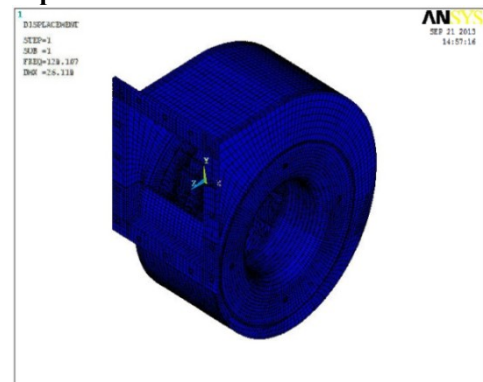
5.3 MODAL ANALYSIS OF BLOWER

Eigen value analysis results show that the first critical speed of composite blower is 94 Hz and that of aluminium blower is 128.11 the reduction in natural frequency of composite blower is due to high stiffness of the composite blower as per the equation below. This shows that both composite and aluminium blower are running in the safe limits. The natural frequencies of the experimental results match with the natural frequency in the table
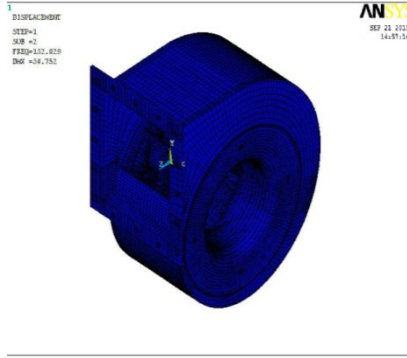
$$f_i = \frac{\sqrt{\lambda_i}}{2\pi}.$$

Table 5.3 Comparison of natural frequency of Aluminum and composite blower

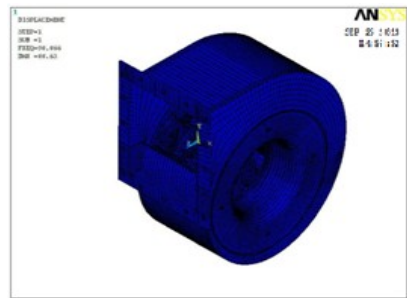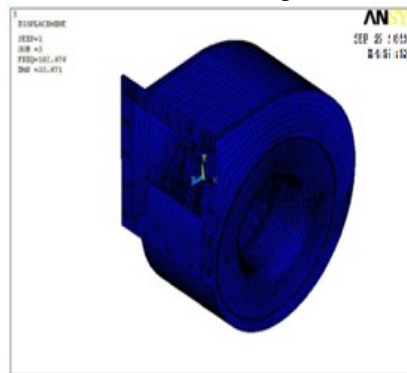| No. of modes	Natural frequencies of Aluminum blower in Hz	Natural frequencies of Composite blower in Hz	%Variation
1	128.11	94.466	26.261
2	132.03	94.498	28.42
3	132.16	102.67	22.31
4	199.67	106.40	46.71
5	249.07	132.05	46.98

First mode shape

Second mode shape
Fig. 5.9 Mode shapes of Aluminium blower

First mode shape

Second mode shape
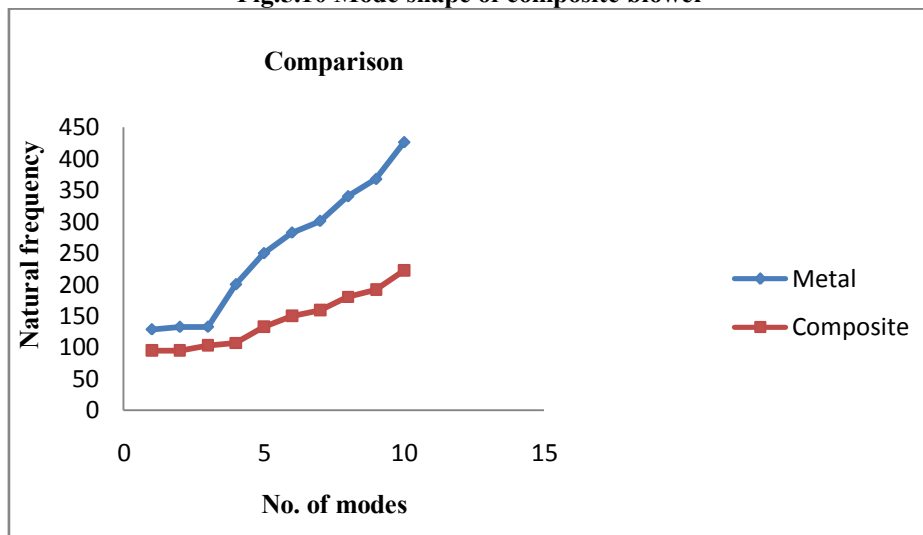**Fig.5.10 Mode shape of composite blower**

Fig.5.11. Natural frequency of Aluminum and composite blower

5.4 HARMONIC ANALYSIS OF ALUMINUM BLOWER

Harmonic response analysis is carried out on both aluminum and composite blower; it was observed that composite blower is performing well compared to aluminum blower. We can observe peaks at the natural frequency in both aluminum and composite blower. In composite blower the displacements are reduced when compared to the aluminum blower which shows that the acceleration of composite blower is less that causes lesser vibration in composite blower because in composite blower the damping controls the vibrations.

The following advantages were observed from harmonic response analysis of composite blower over Aluminum blower:

1. Vibration levels are less in composite blower compared to aluminum at higher frequency range.
2. The maximum displacements are lesser in composite blower than Aluminium.
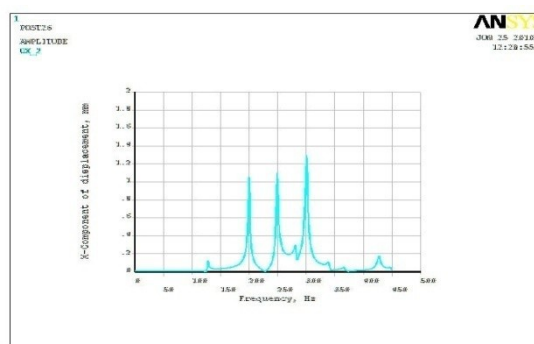3. The mass of the composite blower is much less than Aluminium.

Fig.5.12. X-Component of Displacement versus Frequency response graph of aluminum blower
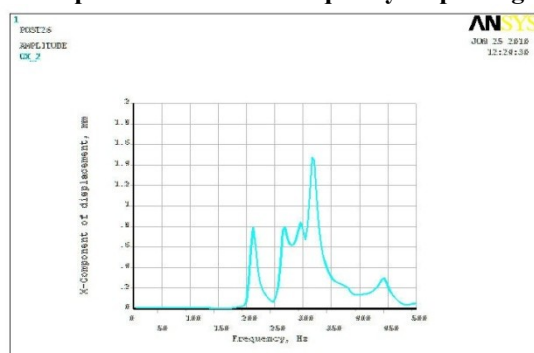

Fig.5.13. X-Component of Displacement versus Frequency response graph of Composite blower

VI.   Conclusions

The Stresses of E-Glass/Epoxy blower obtained in static analysis are within the allowable stress limits. The natural frequency of E-Glass blower is reduced by 26.6% to 47.7% because of high stiffness and the lay-up sequence in the blower. The weight of the E-Glass blower is 15 kg which is less than the Aluminium blower with a weight of 20 kg. From the results of harmonic analysis, damping effect is more in E-Glass blower which controls the vibration levels. From the above results we can conclude that E-Glass blower is preferable than Aluminium blower and based up on frequency values can be reduced.

6.1. SCOPE OF THE WORK

In present work the harmonic analysis is carried out for both aluminum and Epoxy blower and response is compared. The aerofoil blade profile may be used for impeller and further solution is required.

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