Design and Simulation of Centrifugal Blower Using with Different Composite Materials

P. Srinivasulu[1], N. Sai Kumar[2], K. Gowtham Kumar[3],

[1] *Assistant Professor, Department of Mechanical Engineering, JBIET, Moinabad, Telangana.*
[2,3] *Research Scholar, Department of Mechanical Engineering, JBIET, Moinabad, Telangana.*

ABSTRACT

A centrifugal blower is a mechanical device for moving air or other gases. The terms "blower" and "squirrel cage fan" (because it looks like a hamster wheel) are frequently used as synonyms. Rotating impellers increase the speed of the air blowing from another end. Centrifugal blowers are used in naval applications and motors. The Contemporary blades in Centrifugal Blower used in naval applications are made up of Aluminum1060 or Steel now we replaced the composite material (carbon fiber).In this thesis the centrifugal blower modeling in Solid works software and analysis in ANSYS software with different materials in static analysis and different velocities in CFD analysis to find the fluid flow .In this thesis the static analysis to determine the stress, deformation and strain with different materials (aluminum alloy, graphite and carbon fiber)CFD analysis to determine the pressure drop, velocity, heat transfer coefficient and mass flow rate at different velocities (14, 16, 18, 20 and 22m/s).

Keyword – ***Design and Simulation, Centrifugal Blower, Composite Materials*.**

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1. INTRODUCTION

Centrifugal blowers look more like centrifugal pumps than fans. The impeller is typically gear-driven and rotates as fast as 15,000 rpm. In multi-stage blowers, air is accelerated as it passes through each impeller. In single-stage blower, air does not take many turns, and hence it is more efficient. Centrifugal blowers typically operate against pressures of 0.35 to 0.70 kg/cm2, but can achieve higher pressures. One characteristic is that airflow tends to drop drastically as system pressure increases, which can be a disadvantage in material conveying systems that depend on a steady air volume. Centrifugal pumps are very common equipment used in residence, agriculture and industrial applications. It is essential for a pump manufactured at low cost and consuming less power with high efficiency. The overall performance is based on the impeller parameters and it is essential to identify the optimized design parameter of the impeller. R. Ragoth Singh, and M. Natarajstudy the performance of centrifugal pump impeller by developing the vane profile by circular arc method and point by point method and perform CFD analysis of the impeller vane profile for forward and backward curved vane. Adgale Tushar Balkrishna, G.R.Gogate and R.V. Bajaj work on pump reducing vibration levels below permissible levels in Centrifugal blower. Karthik Matta, Kode Srividya and Inturi Prakash are change the material of centrifugal pump impeller and study the effect on the performance of pump by static and modal analysis of same. Energy Efficiency Guide for Industry in Asia study the performance of pump and suggest the energy saving parameter for pump design and design overall pump. C. Kundera and V.A. Martsinkovsky are done static analysis and deriving relationships between the impeller geometry and the basic performance parameters of the pump. A numerical example was used to show the calculation procedure of static characteristics for the predetermined parameters of an impeller for a single-stage pump. Shardul Sunil KulkarniCFD analysis is currently being used in the design and construction stage of various pump types, the use of which reduces significantly the new pump development time and costs. The scope of present work is to investigate the performance of impeller by developing the vane profile by changing vane outlet angle from standard range 16 to 35 and inlet angle calculate as per design of given data of pump. After designing the pump, pump design check by reverse Designing method for pump mathematically validation method then after check same by using software result and then manufacturing model of same design data and check the same data by experimental method.

Air blowers generally use centrifugal force to propel air forward. Inside a centrifugal air blower is a wheel with small blades on the circumference and a casing to direct the flow of air into the center of the wheel and out toward the edge.

Blower

A centrifugal fan also known as a centrifugal air blower is a mechanical device for moving air or other gases in a direction at an angle to the incoming fluid. The centrifugal blowers are used in industries where there is a requirement for larger volumes of airflow with high pressure. They are highly useful in industrial processes like conveying material in dust collector systems, combustion air for burners, drying and cooling, general ventilation, and circulation of air.

Centrifugal blowers differ based on their airflow capacity, blower type, blower dimension, and maximum operating pressure. Based on the requirement, blowers of various types are customized and installed to serve the needs of diverse and varied industrial applications. The Aero Foil Designs are also available by Blowers Manufacturers on request for extra high efficiencies.

Common blower types include the following:

1. Positive Displacement Blowers
    - o Rotary Lobe Blowers
    - o Helical Screw Blowers
2. Centrifugal Blowers
3. Multistage Centrifugal Blowers
4. High-Speed Blowers
5. Regenerative Blowers

Different Blower Types

There are four main types of blowers. Each of these have their various advantages and disadvantages, and are used for specific functions:

1. Positive Displacement Blowers

Positive displacement blowers, which are suitable for applications which involve either air or neutral gas, operate in a relatively simplistic fashion. Air or gas enters through a section on one side of the blower which increases in size and exits through the other side which decreases in size. Due to the difference in proportion between the entry and exit points, positive displacement of the air occurs as it is released through the contracting side, increasing air pressure. A particular feature of this kind of blower is that regardless of pressure changes, the speed of airflow remains consistent.

Figure: Positive Displacement Blower

Rotary Lobe Blowers

One specific kind of positive displacement blower is the rotary lobe blower. This operates by way of dual rotors which rotate in opposing directions. The blower draws in air, and the lobes spin the air around before impelling it outward.

Due to the rotary lobe function, these blowers produce a high volume of air, and thus are useful for larger vacuum systems. As these types of blowers are used for applications such as aeration tank deoxygenating, the air pressure generated is quite moderate (roughly 15 psi).

Figure: Rotary Lobe Blower

Helical Screw Blowers

Helical screw blowers, much like centrifugal blowers, are able to produce air at higher pressures than rotary lobe blowers. Helical screw blowers utilize two rotors, which are each equipped with lobes (usually two or three). The main rotor fits into the flute of a second rotor.

A helical rotor is designed to give higher and more precise pressure due to the unique helical shape of the lobes on the rotor; the helical geometry works in such a way that it squeezes the air between the rotors. These rotors are also carefully aligned to avoid any contact between the lopes.

Figure: Helical Screw Blower

2. Centrifugal Blowers

Centrifugal blowers are typically used in applications where there is a need for high pressure and variable flow. These blowers have rotating impellers, which increase the speed of the air (or gas) as it passes through. Additionally, as the air enters the blower’s fan wheel, it rotates 90 degrees and exits the blower at a faster rate than it entered. This type of blower is ideal for maintaining continual gas transfer. As gas passes through, kinetic energy is increased, and thus as the gas is discharged from the blower, gas enters to level out the pressure.

A commonly used type of centrifugal blower is the multistage centrifugal blower. Multistage centrifugal blowers are rotating machines able to increase the pressure of air or gasses, by means of the centrifugal force normally transmitted by an electric motor. It has a high pressure tolerance and high flow rates, thus is well equipped for applications which involve the creation of high pressure from small air volume. It is used for a variety of applications such as: aeration in the wastewater treatment industry, landfill gas boosting and powering artificial lungs in the medical sector.

Figure: Centrifugal Blower

3. High-Speed Blowers

Designed for high-pressure (up to 25 psi) and high-flow (up to 15,000 m3 per hour) demands, high-speed blowers are powered by a motor. Similar to centrifugal blowers, high-speed blowers have impellers at each side which provide dual suction. These direct-coupled impellers are directly connected to a permanent magnet synchronous motor operated by a variable frequency drive (VFD) which allows for high-speeds while maintaining control of flow.

Figure: High-Speed Blower

4. Regenerative Blowers

Regenerative blowers are designed for applications where a large volume of air is needed to be moved at a low pressure. Often regenerative blowers have oil-free components, which mean that they are not only easy to maintain but safe, especially in environments in the food and beverage industry and in the medical industry.

Regenerative blowers create pressure through the displacement of air molecules. The impeller spins, which draws in air which is then captured between the blades. As the impeller continues to rotate, the air is pushed forward, where it returns to the base of the impeller. The blower conveys the air by using non-positive displacement, which traps air which is then forced to move.

Figure: Regenerative Blower

Industrial applications of Centrifugal blower

The centrifugal blowers can be of importance in a plethora of applications. Many applications like chemical processing, corrosive gas handling, dust collection, dryers, fume control, process cooling, and process heating. The few most common applications across industries are-

- Clean Air Handling- In any kind of industrial operations and facilities air movement is a crucial part of the process. Industrial air handling operations support the processes as well as maintain clean air in the vicinity. Centrifugal fans come as very important in handling clean air at bigger volumes.
- Material handling- Centrifugal force material handling can process particles like sand, plastic pellets, sawdust, wood chips, grain paper trim, and many others. They range from smaller particles to heavier and more abrasive materials.
- High-temperature processes- Many processes are dependent on high-temperature or heat systems. Chambers use a heat convection system to circulate heat and these processes require carefully designed centrifugal fans.
- Saturated Air treatment- Most centrifugal fans more than often process saturated air and these applications require heavy-duty material and moisture resistant coating. This is sometimes very crucial to maintain the quality of the product and efficient industrial fans make the process smoother.
- Dust loading operations- The industrial processes also make use of these fans as a part of the dust collection system for the maintenance of air quality. The various parts of the system can move small particles along with the dust and can include air filtration

2. LITERATURE

Anderson J.D. [1]. The performance of the fan obtained by different fan laws Hence lot of emphasis is given to understand the basic theory of fans, their types and their working. The selection of critical parameters is very essential and determining the performance of the fans. The basic equations mainly continuity equation, momentum equations and energy equations need to be considered while following the computational fluid dynamics approach. While considering any practical problem the best turbulence model and order of accuracy needs to be selected for good results.

AtrePranav C. and ThundilKaruppa Raj R et al [2] Numerical Design and Parametric Optimization of Centrifugal Fans with Airfoil Blade Impellers 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. Fans are one of the types of turbo machinery which are used to move air continuously with in slight increase in static pressure. Fans 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.

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

Chunxi, Li, Wang Song Ling, and Jia Yakui et al [4]. Provide influence of the increased impeller on a spiral without changes in the performance of the centrifugal fan G4-73 is investigated. Comparisons are made between the fan with the original impeller and two larger impellers with impeller diameter increments of 5% and 10% respectively in the numerical and experimental studies. The internal properties are determined by numerical simulation, suggesting that with a larger impeller more volute loss occurs in the fan. The results of the experiment show that the flow, the increase in total pressure, the power of the shaft and the sound pressure level have increased, while the efficiency has decreased when the fan works with a larger impeller. Variation equations are suggested in the performance of the operating points for the fan with enlarged wheels. Comparisons between the results of the experiment and the clipping laws show that the clipping laws for the ordinary situation can predict the performance of the extended lower error fan wheel for a higher flow rate, although the situation of the application does not match. The noise frequency analysis shows that a higher noise level with the larger impeller fan is due to the reduction in the distance between impeller and volute. The influence of the impeller extension is evaluated numerically and experimentally. The equations of variation of the operating points for the enlarged wheels are derived. The expansion of the impeller causes a higher noise of the fan as the distance between the impeller and the spiral is reduced.

Datong, Qi, Mao Yijun, Liu Xiaoliang, and Yuan Minjian et al [5] Investigation focused on the sound of the backward curved blades (BC) and the multi-bladed centrifugal fans forward (FC). In this article, an experimental study was conducted to investigate the noise reduction of a centrifugal industrial FC fan. First, the performance and noise characteristics of the FC centrifugal fan were tested to compare the similarities and differences with those of the BC blades and the FC multi-blade centrifugal fans. Subsequently, several different geometric configurations of the spiral were made to examine the effects of the inclined spiral tongue, the pitch of the impeller blade, the passage of the hub coil and its coupling effect on the performance and noise of the centrifugal fan FC.

Jia Bing Wang Huazhong et al [6] Numerical Analysis of Internal Flow Field of Multi- Blade Centrifugal Fan for Floor Standing Air- Conditioner 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. The flow field in a centrifugal fan is highly complex with flow reversal taking place on the suction side of impeller and diffuser vanes. Generally, performance of the centrifugal fan could be enhanced by judiciously introducing splitter vanes so as to improve the diffusion process. An extensive numerical whole field analysis on the effect of splitter vanes placed in discrete regions of suspected separation points is possible using CFD. This paper examines the effect of splitter vanes corresponding to various geometrical locations on the impeller and diffuser. The analysis shows that the splitter vanes located near the diffuser exit improves the static pressure recovery across the diffusing domain to a larger extent.

Kshirsagar S.R* MaheshShinde1 et al [7] Blower is used to deliver the air or gas with an appreciable rise in pressure again the flow resistance. It is an important role in various industries for air-conditioning systems, furnaces and dust or fume extraction systems Based on the input data the design calculations have been carried out and modeled using SOLIDWORKS. The cleanup and meshing are carried out in CFD Analysis the Main Aim Behind these Project for increase energy efficiency & constant air flow delivery that enable them generate energy of up to 84% efficiency. Done the CFD investigation for getting improved parameter blend utilizing prepare. This will provide optimized design of centrifugal blower This paper gives the solution to above problems by optimization of centrifugal blower impeller by static and modal analysis using FEA for the material MS.

3. METHODOLOGY

Centrifugal blowers are widely used in different industrial applications, which are proficient of as long as restrained to high-pressure rise and flow rates. Centrifugal blowers are mainly two main parts, namely, the casing and the impeller. The impeller is often considered an integral part of the suction motor since its housings and the motor are assembled as a unit. The impeller, driven by the blower shaft adds the velocity component to the fluid by centrifugally casting the fluid away from the impeller vane tips. The key idea here is that the energy created is kinetic energy.

The principle involved in the design of a blower is similar in virtually every important aspect as that of a centrifugal pump except for the fact that the term “centrifugal pump” is often associated with liquid as its working fluid while the blower is meant to work on air The effects of centrifugal force acting upon the spinning air within the impeller create the suction. As the impeller rotates, the spinning air moves outward away from the hub, creating a partial vacuum which causes more air to flow into the impeller Air enters the impeller axially through the inlet nozzle which provides slight acceleration to the air before its entry to the impeller. The action of the impeller swings the air from a smaller to a larger radius and delivers the air at a high pressure and velocity to the casing. The centrifugal energy also contributes to the stage pressure rise. The flow from the impeller blades is collected by a spirally-shaped casing known as scroll or volute. It delivers the air to the exit of the blower.

Design of Impeller:

The blower design is analyzed single stage centrifugal blower. Input data for design calculations are taken from industrial zone, used for separate the wheat and the defect for wheat mill factory. The details of an impeller specification are provided in table 1

Table: Specification of impeller

Parameter	Dimension
Air flow rate, Q	1.2 m^3/s
Rotational speed, N	3800rpm
Inlet air pressure, P_a	101.353 kPa
Inlet air temperature, T_a	30°C
Discharge air pressure, P_d	11kPa
Gravitational acceleration, g	9.81m/s^2
Air constant, R	287 J/kgK

The design of centrifugal blower involves a large number of interdependent variables so there are several possible designs for the same duty. To calculate the power input, flow rate and total adiabatic head must be known. As a result, to provide a certain amount of power to the air a larger amount of power must be provided to the blower shaft. This power is called brake horsepower. The power input to the blower is determined from the relationship

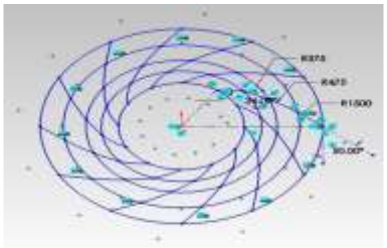


Figure: 2D Drawing of Impeller

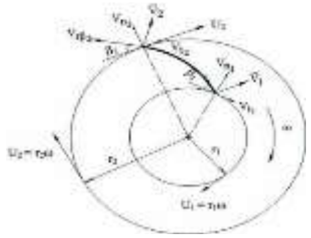


Figure: Velocity Vector Diagram of Impeller

In all of these approaches the same basic procedure is followed.

- **During preprocessing**

The geometry (physical bounds) of the problem is defined.

The volume occupied by the fluid is divided into discrete cells (the mesh). The mesh may be uniform or non-uniform.

The physical modeling is defined – for example, the equations of motion + enthalpy + radiation + species conservation Boundary conditions are defined. This involves specifying the fluid behavior and properties at the boundaries of the problem. For transient problems, the initial conditions are also defined.

The simulation is started and the equations are solved iteratively as a steady-state or transient.

finally a postprocessor is used for the analysis and visualization of the resulting solution.

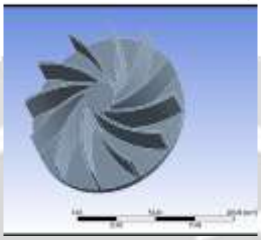
Static Analysis Centrifugal Blower Propeller Blade Material -Aluminum Alloy

Save creo Model as .iges format

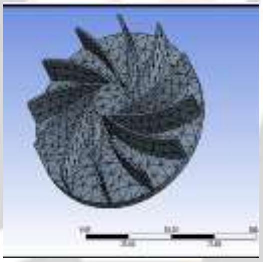
→Annoys → Workbench→ Select analysis system → static structural → double click

→Select geometry → right click → import geometry → select browse →open part → ok

→ Select mesh on work bench → right click →edit Double click on geometry → select MSBR → edit material →



Select mesh on left side part tree → right click → generate mesh →



Select static structural right click → insert → select rotational velocity and fixed support → Select displacement → select required area → click on apply → put X,Y,Z component zero →Select force → select required area → click on apply → enter force valve Select solution right click→ solve →Solution right click → insert → deformation → total → Solution right click → insert → strain→ equivalent (von-mises) →Solution right click → insert → stress → equivalent (von-mises) → Right click on deformation → evaluate al result

Design of Graphite material component: Graphite is one of the three crystalline forms of the element carbon; the other two being diamond and fullerenes (which include carbon nanotubes and graphene). Graphite occurs naturally in the earth and, under standard conditions, is the most stable form of carbon.

Material -Graphite:

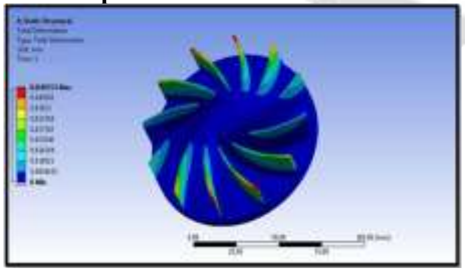


Figure: Total deformation

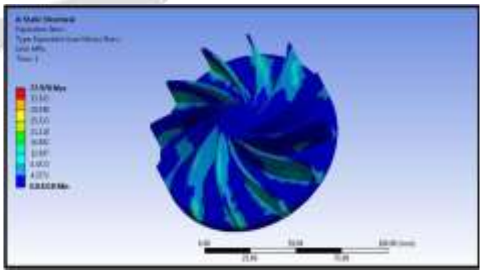


Figure: Stress

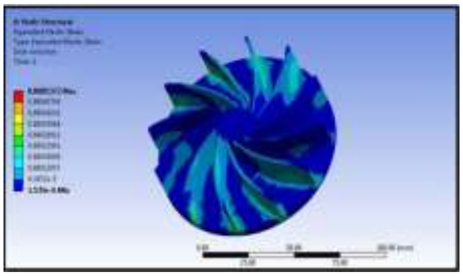


Figure: Strain

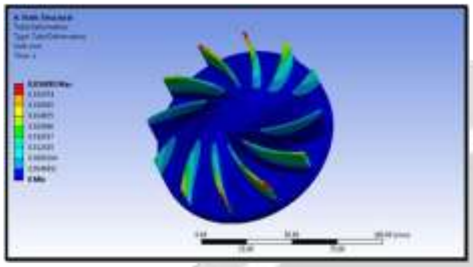


Figure: Total deformation

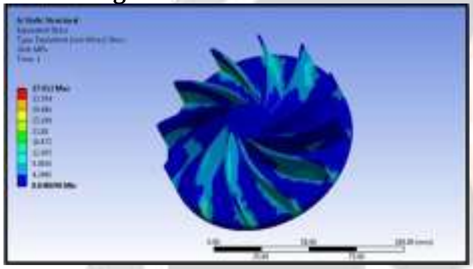


Figure: Stress

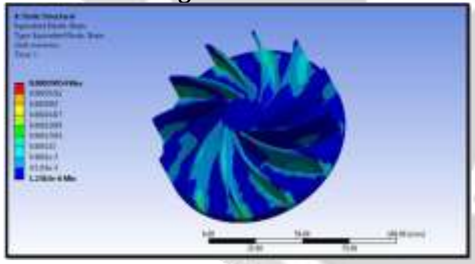


Figure: Strain

Material -Carbon Fiber:

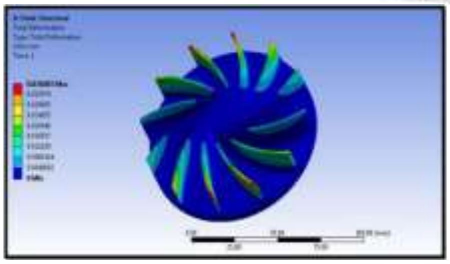


Figure: Material -Carbon Fiber Deformation

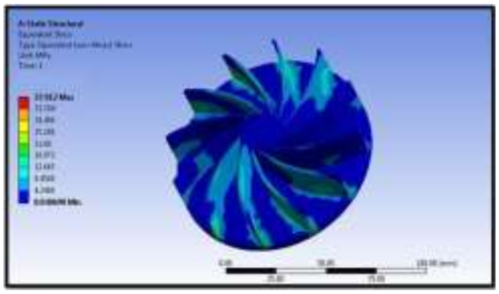


Figure: Stress

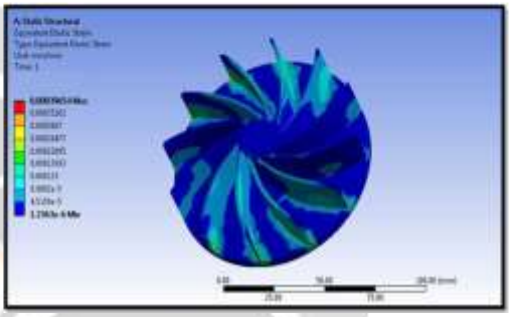


Figure: Strain

Cfd Analysis of Centrifugal Blower at Velocity-14m/s

→→Ansys → workbench→ select analysis system → fluid flow fluent → double click →→Select geometry → right click → import geometry → select browse →open part → ok

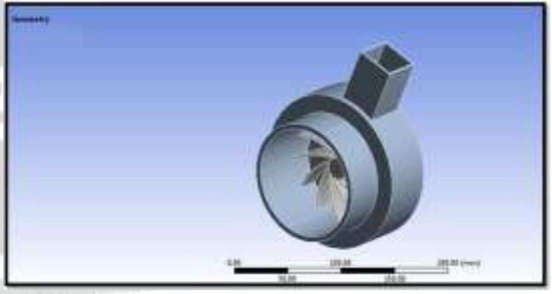
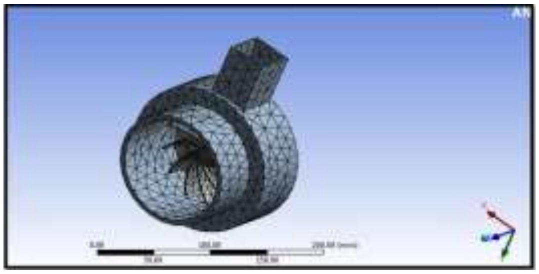


Figure: Cfd Analysis of Centrifugal Blower At Velocity-14m/s

→→ select mesh on work bench → right click →edit → select mesh on left side part tree → right click→ generate mesh →

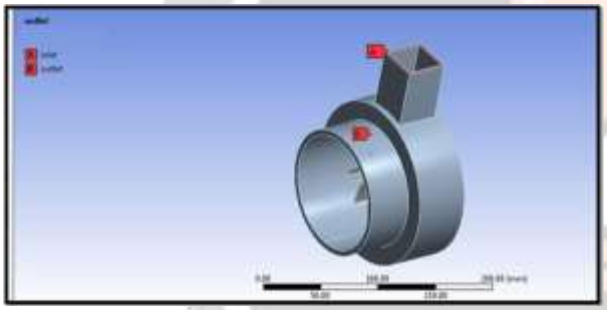


Select faces → right click → create named section → enter name → water inlet

Select faces → right click → create named section → enter name → water outlet

Meshing:

Total Nodes	101635
Total Elements	60032
Maximum Aspect Ratio	7.8925
% of elements with Aspect Ratio < 3	99.1
% of elements with Aspect Ratio > 10	0
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:13



Model → energy equation → on. Viscous → edit → k-epsilon Enhanced Wall Treatment → ok Materials → new → create or edit → specify fluid material or specify properties → ok Select air and water Solution Boundary conditions → select water inlet → Edit → Enter Water Flow Rate → 2Kg/s and Inlet Temperature –→ Solution Initialization → Hybrid Initialization →done Run calculations → no of iterations = 50 → calculate→ calculation complete →→ Results → graphics and animations → contours → setup

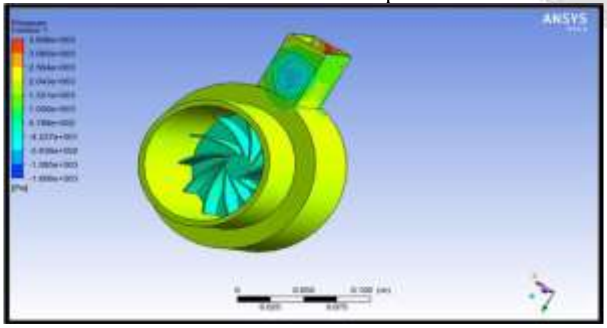


Figure: Pressure

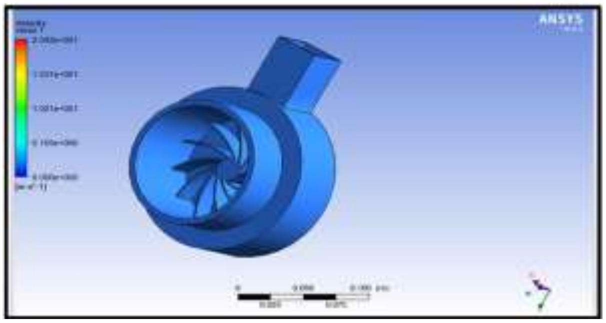


Figure: Velocity

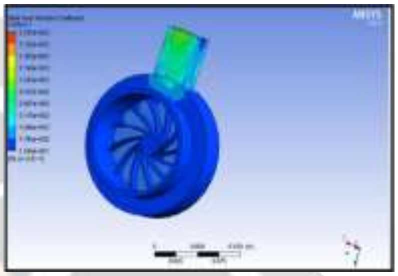
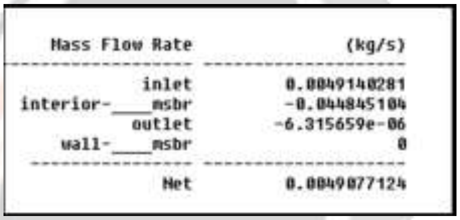


Figure: Heat Transfer Coefficient



```
        Mass Flow Rate                   (kg/s)
-------------------------------- --------------------
                  inlet             0.0049140281
     interior-____msbr             -0.044845104
                 outlet            -6.315659e-06
         wall-____msbr                         0
-------------------------------- --------------------
                    Net             0.0049077124
```

Figure: Mass Flow Rate

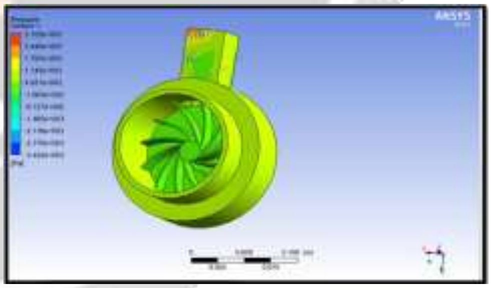


Figure: At Velocity-16m/s Pressure

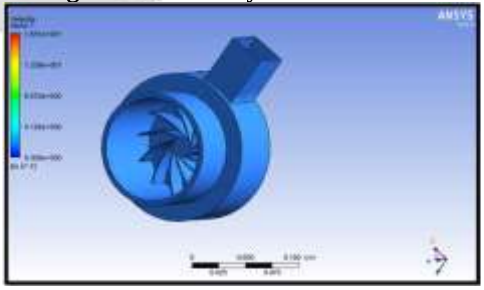


Figure: Velocity

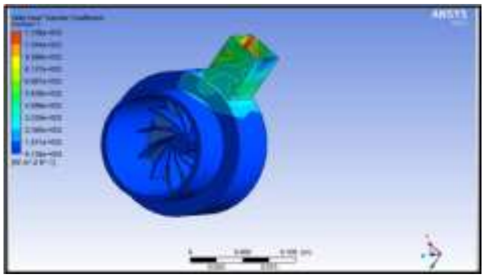
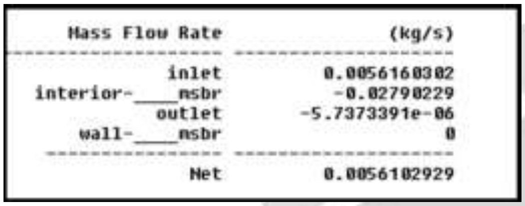


Figure: Heat Transfer Coefficient



```
    Mass Flow Rate                 (kg/s)
-------------------- --------------------
             inlet         0.0056160302
interior-____msbr         -0.02790229
            outlet        -5.7373391e-06
       wall-____msbr                  0
 ---------------- --------------------
               Net         0.0056102929
```

Figure: Mass Flow Rate

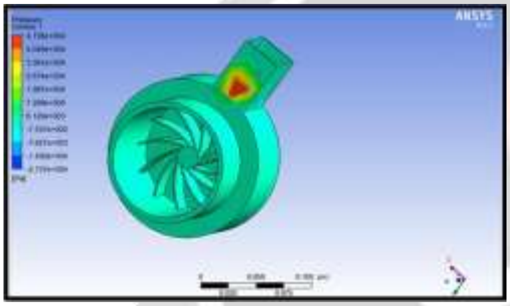


Figure: At Velocity-18m/s Pressure

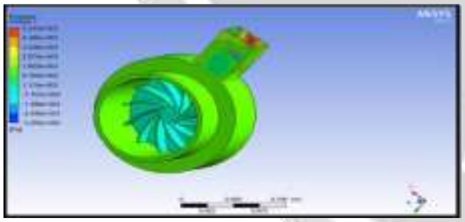


Figure: At Velocity-20m/S Pressure

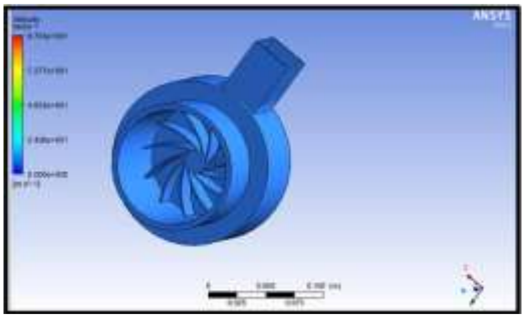


Figure: Velocity

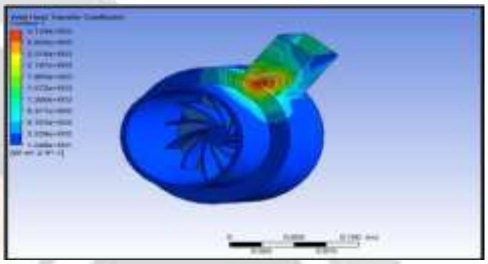
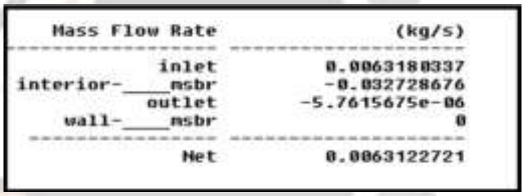
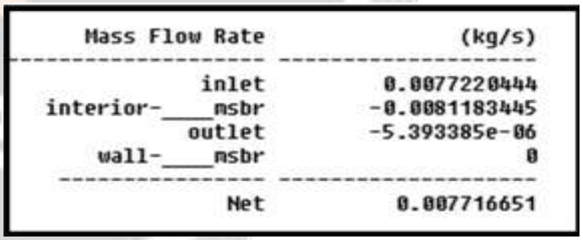


Figure: Heat Transfer Coefficient



```
    Mass Flow Rate                 (kg/s)
-------------------- --------------------
             inlet         0.0063180337
interior-____msbr         -0.032728676
            outlet        -5.7615675e-06
       wall-____msbr                  0
 ---------------- --------------------
               Net         0.0063122721
```

Figure: Mass Flow Rate



```
    Mass Flow Rate                 (kg/s)
-------------------- --------------------
             inlet         0.0077220444
interior-____msbr         -0.0081183445
            outlet        -5.393385e-06
       wall-____msbr                  0
 ---------------- --------------------
               Net         0.007716651
```

Table: Static structural Analysis results

Material	Deformation (mm)	Stress (N/mm^2)	Strain
Aluminum alloy	0.049153	37.978	0.0005372
Carbon fiber	0.036083	37.912	0.00039654
Graphite	0.0073159	37.966	7.94e-5

Table: CFD Analysis results

Inlet Velocity(M/S)	Pressure (Pa)	Heat Transfer Coefficient(W/M^{2}k)	Velocity (M/S)	Mass Flow Rate (Kg/Sec)
14	3.606e+03	1.701e+03	2.04e+01	0.0049077
16	3.10e+03	1.158e+03	1.65e+01	0.00561029
18	4.73e+004	3.13e+03	9.703e+01	0.0063122
20	5.233e+03	1.036e+03	2.35e+01	0.007018

22	6.0523e+04	1.673e+03	3.166e+01	0.0077166

5. CONCLUSIONS

Modeling and simulation of centrifugal blower fan has done using Solid Works software.

1. After observing the static and dynamic analysis values we can conclude that e-epoxy has the better stress bearing capacity compared with the other materials except titanium deformation values by showing its better strength values to the applied loads.
2. During Flow simulation at impeller output velocity is decreased compared to inlet velocity, whereas output pressure is increased compared to inlet pressure.
3. By using cost analysis methods, the material cost of each metal is noted shown in graphs and we can observe that cost of e-epoxy is slightly more than aluminum and this can be reduced in long run of manufacturing.
4. E-glass/Epoxy material is non-metallic component so, the chattering noise will be low compared to other materials during the functioning process.
5. For manufacturing the centrifugal blower impeller, we can proceed with Epoxy/E-glass material because it has high stress bearing capacity and reasonable manufacturing cost.

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