Major Project Report

On

DESIGN AND ANALYSIS OF AIRCRAFT ENGINE COOLING FAN

Submitted in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

in

MECHANICAL ENGINEERING

By

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MALLA REDDY COLLEGE OF ENGINEERING

(Approved by AICTE- Permanently Affiliated to JNTU Hyderabad)

Accredited by NBA & NAAC, Recognized under section 2(f) &12(B) of UGC New Delhi: ISO 9001:2015 certified Institution

Maisammaguda, Dhulapally (Post via Kompally), Secunderabad- 500100

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CERTIFICATE

This is to certify that the major project report on **"DESIGN AND ANALYSIS OF AIRCRAFT ENGINE COOLING FAN "** is successfully done by the following students of Department of Mechanical Engineering of our college in partial fulfillment of the requirement for the award of B.Tech degree in the year 2020-21.The results embodied in this report have not been submitted to any other University for the award of any diploma or degree.

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Internal Examiner **External Examiner**

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DECLARATION

We hereby declare that project report entitled **"DESIGN AND ANALYSIS OF AIRCRAFT ENGINE COOLING FAN "** is a genuine project work carried out by us, in B.Tech (Mechanical Engineering, Malla Reddy College of Engineering, Kompally, Hyderabad) degree course of Jawaharlal Nehru Technological University, Hyderabad and has not been submitted to any other courses or university for award of any degree by us.

Project Associate

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ABSTARCT

An internal combustion engine produces power by burning fuel within the cylinders; therefore, it is often referred to as a heat engine. Engines that produce their energy by heat and combustion have a problem of maintaining safe operating temperatures. Thirty to thirty five percent of the heat produced in the combustion chambers by the burning fuel is dissipated by the cooling system along with the lubrication and fuel systems. Forty to forty-five percent of the heat produced passes out with the exhaust gases. If this heat were not removed quickly, valves would burn and warp,

Engine cooling fans are an essential component of the engine cooling system which is used to dissipate the excess heat generated by the combustion of fuels inside the engine. This project consists of designing the fan and analyzing it for its strength in structure using the Finite Element Method (FEM) approach. In this project complete design with calculation developed by using cad tool solid works and analyzed with cae tool Ansys workbench. By using static and dynamic analysis we can understand the maximum strength and stress values for different materials.

Tools were used:

CAD TOOL: SOLID WORKS

CAE TOOL: Ansys workbench

Keywords: solid works, Ansys ,, static analysis, dynamic analysis.

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ABBREVIATIONS

TDC	Top dead center
BDC	Bottom dead center
RPM	Revolution per minute
OHV	Overhead valve
DOHV	Dual over head valve
SOHC	Single overhead valve
VTEC	Variable Valve Timing and Lift Electronic Control
CAD	Computer aided design
CAE	Computer aided engineering
MPA	Mega pascals

CHAPTER 1

INTRODUCTION

1.1 JET ENGINES

Components of jet engines

Cold section:

1.1.1 Air intake (inlet) for subsonic aircraft, the inlet is a duct which is required to ensure smooth airflow into the engine despite air approaching the inlet from directions other than straight ahead. This occurs on the ground from cross winds and in flight with aircraft pitch and yaw motions. The duct length is minimize to reduce drag and weight. Air enters the compressor at about half the speed of sound so at flight speeds lower than this the flow will accelerate along the inlet and at higher flight speeds it will slow down. Thus the internal profile of the inlet has to accommodate both accelerating and diffusing flow without undue losses. For supersonic aircraft, the inlet has features such as cones and ramps to produce the most efficient series of shockwaves which form when supersonic flow slows down. The air slows down from the flight speed to subsonic velocity through the shockwaves, then to about half the speed of sound at the compressor through the subsonic part of the inlet. The particular system of shockwaves is chosen, with regard to many constraints such as cost and operational needs, to minimize losses which in turn maximizes the pressure recovery at the compressor.

1.1.2 Compressor or fan The compressor is made up of stages. Each stage consists of rotating blades and stationary stators or vanes. As the air moves through the compressor, its pressure and temperature increase. The power to drive the compressor comes from the turbine (see below), as shaft torque and speed.

1.1.3 Bypass ducts deliver the flow from the fan with minimum losses to the bypass propelling nozzle. Alternatively the fan flow may be mixed with the turbine exhaust before entering a single propelling nozzle. In another arrangement an afterburner may be installed between the mixer and nozzle.

1.1.4 Shaft — The shaft connects the turbine to the compressor, and runs most of the length of the engine. There may be as many as three concentric shafts, rotating at independent speeds, with as many sets of turbines and compressors. Cooling air for the turbines may flow through the shaft from the compressor.

1.1.5 Diffuser section: - The diffuser slows down the compressor delivery air to reduce flow losses in the combustor. Slower air is also required to help stabilize the combustion flame and the higher static pressure improves the combustion efficiency

1.2 Hot section:

1.2.1 Combustor or combustion chamber: Fuel is burned continuously after initially being ignited during the engine start.

1.2.2 Turbine : the turbine is a series of bladed discs that act like a windmill, extracting energy from the hot gases leaving the combustor. Some of this energy is used to drive the compressor. Turboprop, turboshaft and turbofan engines have additional turbine stages to drive a propeller, bypass fan or helicopter rotor. In a free turbine the turbine driving the compressor rotates independently of that which powers the propellor or helicopter rotor. Cooling air, bled from the compressor, may be used to cool the turbine blades, vanes and discs to allow higher turbine entry gas temperatures for the same turbine material temperatures

A blade with internal cooling as applied in the high-pressure turbine

1.2.3 Afterburner or reheat (British) (mainly military) Produces extra thrust by burning fuel in the jetpipe. This reheating of the turbine exhaust gas raises the propelling nozzle entry temperature and exhaust velocity. The nozzle area is increased to accommodate the higher specific volume of the exhaust gas. This maintains the same airflow through the engine to ensure no change in its operating characteristics.

1.2.4 Exhaust or nozzle Turbine exhaust gases pass through the propelling nozzle to produce a high velocity jet. The nozzle is usually convergent with a fixed flow area.

1.2.5 Supersonic nozzle For high nozzle pressure ratios (Nozzle Entry Pressure/Ambient Pressure) a convergent-divergent (de Laval) nozzle is used. The expansion to atmospheric pressure and supersonic gas velocity continues downstream of the throat and produces more thrust.

The various components named above have constraints on how they are put together to generate the most efficiency or performance. The performance and efficiency of an engine can never be taken in isolation; for example fuel/distance efficiency of a supersonic jet engine maximises at about Mach 2, whereas the drag for the vehicle carrying it is increasing as a square law and has much extra drag in the transonic region. The highest fuel efficiency for the overall vehicle is thus typically at Mach ~0.85.

For the engine optimisation for its intended use, important here is air intake design, overall size, number of compressor stages (sets of blades), fuel type, number of exhaust stages, metallurgy of components, amount of bypass air used, where the bypass air is introduced, and many other factors. For instance, let us consider design of the air intake.

1.3 Compressors

Axial compressors rely on spinning blades that have aerofoil sections, similar to aeroplane wings. As with aeroplane wings in some conditions the blades can stall. If this happens, the airflow around the stalled compressor can reverse direction violently. Each design of a compressor has an associated operating map of airflow versus rotational speed for characteristics peculiar to that type (see compressor map).

At a given throttle condition, the compressor operates somewhere along the steady state running line. Unfortunately, this operating line is displaced during transients. Many compressors are fitted with anti-stall systems in the form of bleed bands or variable geometry stators to decrease the likelihood of surge. Another method is to split the compressor into two or more units, operating on separate concentric shafts.

Another most design consideration is the average stage loading. This can be kept at a sensible level either by increasing the number of compression stages (more weight/cost) or the mean blade speed (more blade/disc stress).

Although large flow compressors are usually all-axial, the rear stages on smaller units are too small to be robust. Consequently, these stages are often replaced by a single centrifugal unit. Very small flow compressors often employ two centrifugal compressors, connected in series. Although in isolation centrifugal compressors are capable of running at quite high pressure ratios impeller stress considerations limit the pressure ratio that can be employed in high overall pressure ratio engine cycles.

Increasing overall pressure ratio implies raising the high-pressure compressor exit temperature. This implies a higher high-pressure shaft speed, to maintain the datum blade tip Mach number on the rear compressor stage. Stress considerations, however, may limit the shaft speed increase, causing the original compressor to throttle-back aerodynamically to a lower pressure ratio than datum.

The 17-stage axial compressor of the General Electric J79

1.4 Combustors

Flame fronts generally travel at just Mach 0.05, whereas airflows through jet engines are considerably faster than this. Combustors typically employ structures to give a sheltered combustion zone called a flame holder. Combustor configurations include can, annular, and can-annular.

Great care must be taken to keep the flame burning in a moderately fast moving airstream, at all throttle conditions, as efficiently as possible. Since the turbine cannot withstand stoichiometric temperatures (a mixture ratio of around 15:1), some of the compressor air is used to quench the exit temperature of the combustor to an acceptable level (an overall mixture ratio of between 45:1 and 130:1 is used). Air used for combustion is considered to be primary airflow, while excess air used for cooling is called secondary airflow. The secondary airflow is ported through many small holes in the burner cans to create a blanket of cooler air to insulate the metal surfaces of the combustion can from the flame. If the metal were subjected to the direct flame for any length of time, it would eventually burn through.

Rocket engines, being a non 'duct engine' have quite different combustor systems, and the mixture ratio is usually much closer to being stoichiometric in the main chamber. These engines generally lack flame holders and combustion occurs at much higher temperatures, there being no turbine downstream. However, liquid rocket engines frequently employ separate burners to power turbopumps, and these burners usually run far off stoichiometric so as to lower turbine temperatures in the pump.

1.5 Turbines

Because a turbine expands from high to low pressure, there is no such thing as turbine surge or stall. The turbine needs fewer stages than the compressor, mainly because the higher inlet temperature reduces the deltaT/T (and thereby the pressure ratio) of the expansion process. The blades have more curvature and the gas stream velocities are higher.

Designers must, however, prevent the turbine blades and vanes from melting in a very high temperature and stress environment. Consequently, bleed air extracted from the compression system is often used to cool the turbine blades/vanes internally. Other solutions are improved materials and/or special insulating coatings. The discs must be specially shaped to withstand the huge stresses imposed by the rotating blades. They take the form of impulse, reaction, or combination impulse-reaction shapes. Improved materials help to keep disc weight down.

1.6 Afterburners (reheat)

Due to temperature limitations with the gas turbines, jet engines do not consume all the oxygen in the air ('run stoichiometric'). Afterburners burn the remaining oxygen after exiting the turbines, but usually do so inefficiently due to the low pressures typically found at this part of the jet engine make the subsequent nozzle inefficient at extracting the heat energy; however afterburners still gain significant thrust, which can be useful. Engines intended for extended use with afterburners often have variable nozzles and other details.

1.7 Nozzle

The propelling nozzle converts a gas turbine or gas generator into a jet engine. Power available in the gas turbine exhaust is converted into a high speed propelling jet by the nozzle. The power is defined by typical gauge pressure and temperature values for a turbojet of 20 psi (140 kPa) and 1,000 °F (538 °C).

1.8 Thrust reversers

These either consist of cups that swing across the end of the exhaust nozzle and deflect the jet thrust forwards (as in the DC-9), or they are two panels behind the cowling that slide backward and reverse only the fan thrust (the fan produces the majority of the thrust). Fan air redirection is performed by devices called "blocker doors" and "cascade vanes". This is the case on many large aircraft such as the 747, C-17, KC-10, etc. If you are on an aircraft and you hear the engines increasing in power after landing, it is usually because the thrust reversers are deployed. The engines are not actually spinning in reverse, as the term may lead you to believe. The reversers are used to slow the aircraft more quickly and reduce wear on the wheel brakes.

1.9 Cooling systems

All jet engines require high temperature gas for good efficiency, typically achieved by combusting hydrocarbon or hydrogen fuel. Combustion temperatures can be as high as 3500K (5841F) in rockets, far above the melting point of most materials, but normal airbreathing jet engines use rather lower temperatures.

Cooling systems are employed to keep the temperature of the solid parts below the failure temperature

1.10 Air systems

A complex air system is built into most turbine based jet engines, primarily to cool the turbine blades, vanes and discs.

Air, bled from the compressor exit, passes around the combustor and is injected into the rim of the rotating turbine disc. The cooling air then passes through complex passages within the turbine blades. After removing heat from the blade material, the air (now fairly hot) is vented, via cooling holes, into the main gas stream. Cooling air for the turbine vanes undergoes a similar process.

Cooling the leading edge of the blade can be difficult, because the pressure of the cooling air just inside the cooling hole may not be much different from that of the oncoming gas stream. One solution is to incorporate a cover plate on the disc. This acts as a centrifugal compressor to pressurize the cooling air before it enters the blade. Another solution is to use an ultra-efficient turbine rim seal to pressurize the area where the cooling air passes across to the rotating disc.

Seals are used to prevent oil leakage, control air for cooling and prevent stray air flows into turbine cavities.

A series of (e.g. labyrinth) seals allow a small flow of bleed air to wash the turbine disc to extract heat and, at the same time, pressurize the turbine rim seal, to prevent hot gases entering the inner part of the engine. Other types of seals are hydraulic, brush, carbon etc.

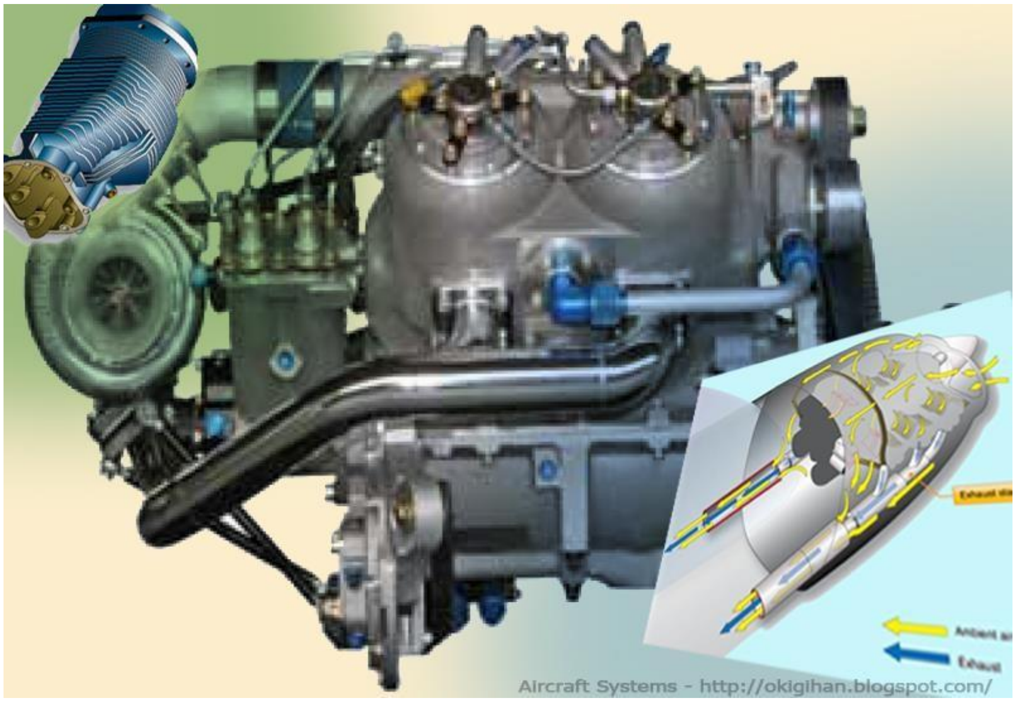
Small quantities of compressor bleed air are also used to cool the shaft, turbine shrouds, etc. Some air is also used to keep the temperature of the combustion chamber walls below critical. This is done using primary and secondary airholes which allow a thin layer of air to cover the inner walls of the chamber preventing excessive heating.

Exit temperature is dependent on the turbine upper temperature limit depending on the material. Reducing the temperature will also prevent thermal fatigue and hence failure. Accessories may also need their own cooling systems using air from the compressor or outside air.

Air from compressor stages is also used for heating of the fan, airframe anti-icing and for cabin heat. Which stage is bled from depends on the atmospheric conditions at that altitude.

1.11 Engine Cooling Systems

Excessive heat is always undesirable in both reciprocating and turbine aircraft engines. If means were not available for its control or elimination, major damage or complete engine failure would occur. Although the vast majority of reciprocating engines are air cooled, some diesel liquid-cooled engines are being made available for light aircraft. In a liquid-cooled engine, around the cylinder are water jackets, in which liquid coolant is circulated and the coolant takes away the excess heat. The excess heat is then dissipated by a heat exchanger or radiator using air flow. Turbine engines use secondary airflow to cool the inside components and many of the exterior components.



1.12 Reciprocating Engine Cooling Systems

An internal-combustion engine is a heat machine that converts chemical energy in the fuel into mechanical energy at the crankshaft. It does not do this without some loss of energy, however, and even the most efficient aircraft engines may waste 60 to 70 percent of the original energy in the fuel. Unless most of this waste heat is rapidly removed, the cylinders may become hot enough to cause complete engine failure. Excessive heat is undesirable in any internal-combustion engine for three principal reasons:

It affects the behavior of the combustion of the fuel/ air charge.

It weakens and shortens the life of engine parts.

It impairs lubrication.

If the temperature inside the engine cylinder is too great, the fuel-air mixture is preheated, and combustion occurs before the desired time. Since premature combustion causes detonation, knocking, and other undesirable conditions, there must be a way to eliminate heat before it causes damage.

One gallon of aviation gasoline has enough heat value to boil 75 gallons of water; thus, it is easy to see that an engine that burns 4 gallons of fuel per minute releases a tremendous amount of heat. About one-fourth of the heat released is changed into useful power. The remainder of the heat must be dissipated so that it is not destructive to the engine. In a typical aircraft powerplant, half of the heat goes out with the exhaust and the other is absorbed by the engine. Circulating oil picks up part of this soaked-in heat and transfers it to the airstream through the oil cooler. The engine cooling system takes care of the rest. Cooling is a matter of transferring the excess heat from the cylinders to the air, but there is more to such a job than just placing the cylinders in the airstream. A cylinder on a large engine is roughly the size of a gallon jug. Its outer surface, however, is increased by the use of cooling fins so that it presents a barrel-sized exterior to the cooling air. Such an arrangement increases the heat transfer by radiation. If too much of the cooling fin area is broken off, the cylinder cannot cool properly, and a hotspot develops. Therefore, cylinders are normally replaced if a specified number of square inches of fins are missing.

Cowling and baffles are designed to force air over the cylinder cooling fins. [Figure 1] The baffles direct the air close around the cylinders and prevent it from forming hot pools of stagnant air while the main streams rush by unused. Blast tubes are built into the baffles to direct jets of cooling air onto the rear spark plug elbows of each cylinder to prevent overheating of ignition leads.

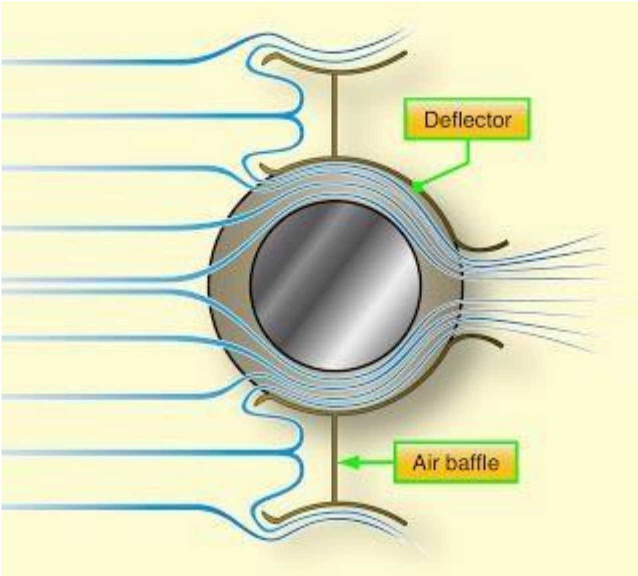


Figure 1. Cylinder baffle and deflector system

An engine can have an operating temperature that is too low. For the same reasons that an engine is warmed up before takeoff, it is kept warm during flight. Fuel evaporation and distribution and oil circulation depend on an engine being kept at its optimum operating temperature. The aircraft engine has temperature controls that regulate air circulation over the engine. Unless some controls are provided, the engine could overheat on takeoff and get too cold in high altitude, high-speed and low-power letdowns.

The most common means of controlling cooling is the use of cowl flaps. [Figure 2] These flaps are opened and closed by electric motor-driven jackscrews, by hydraulic actuators, or manually in some light aircraft. When extended for increased cooling, the cowl flaps produce drag and sacrifice streamlining for the added cooling. On takeoff, the cowl flaps are opened only enough to keep the engine below the red-line temperature. Heating above the normal range is allowed so that drag is as low as possible. During ground operations, the cowl flaps should be opened wide since drag does not matter and cooling needs to be set at maximum. Cowl flaps are used mostly with older aircraft and radial engine installations.

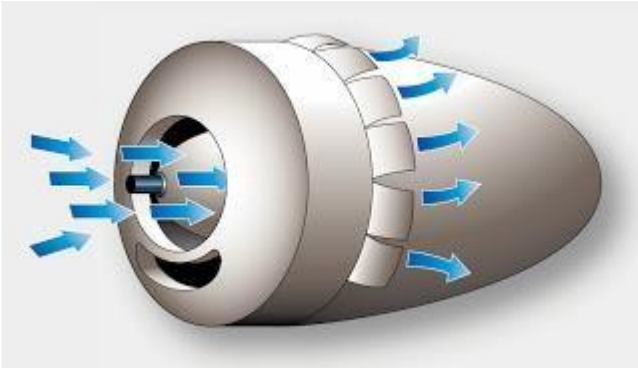


Figure 2. Regulating the cooling airflow

Some aircraft use augmentors to provide additional cooling airflow. [Figure 3] Each nacelle has two pairs of tubes running from the engine compartment to the rear of the nacelle. The exhaust collectors feed exhaust gas into the inner augmentor tubes. The exhaust gas mixes with air that has passed over the engine and heats it to form a high-temperature, low-pressure, jet-like exhaust. This low-pressure area in the augmentors draws additional cooling air over the engine. Air entering the outer shells of the augmentors is heated through contact with the augmentor tubes but is not contaminated with exhaust gases. The heated air from the shell goes to the cabin heating, defrosting, and anti-icing system.

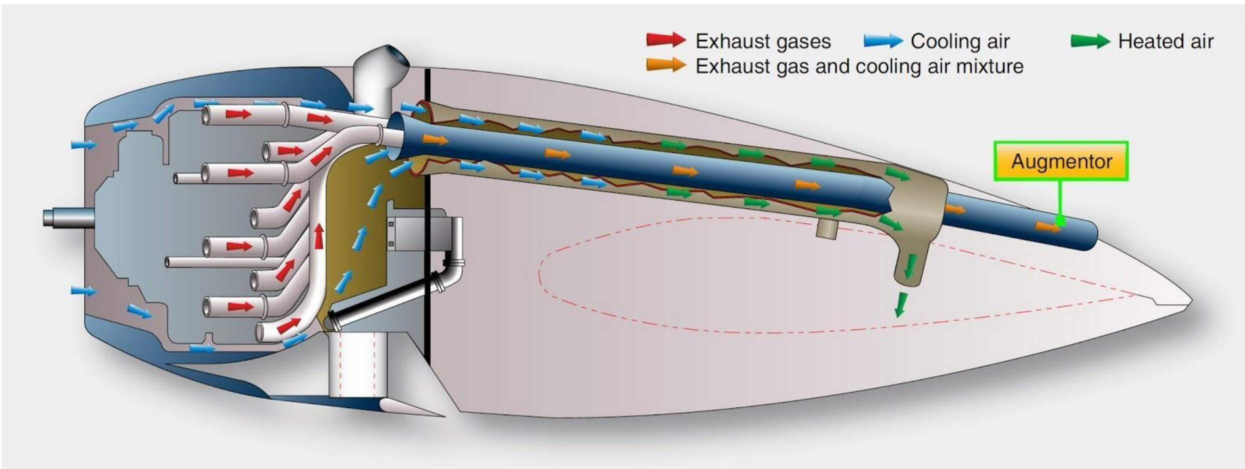


Figure 3. Augmentor

Augmentors use exhaust gas velocity to cause airflow over the engine so that cooling is not entirely dependent on the prop wash. Vanes installed in the augmentors control the volume of air. These vanes are usually left in the trail position to permit maximum flow. They can be closed to increase the heat for cabin or anti-icing use or to prevent the engine from cooling too much during descent from altitude. In addition to augmentors, some aircraft have residual heat doors or nacelle flaps that are used mainly to let the retained heat escape after engine shutdown. The nacelle flaps can be opened for more cooling than that provided by the augmentors. A modified form of the previously described augmentor cooling system is used on some light aircraft. [Figure 4] Augmentor systems are not used much on modern aircraft.

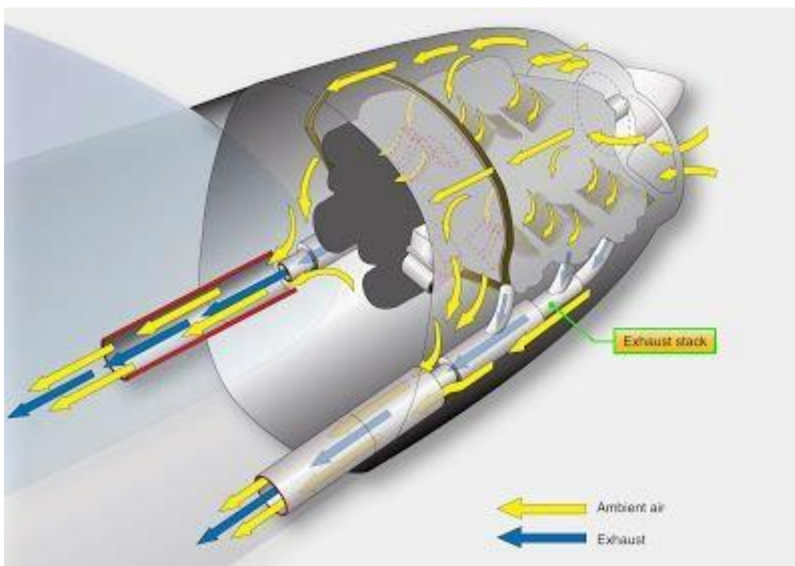


Figure 4. Engine cooling and exhaust system

As shown in Figure 4, the engine is pressure cooled by air taken in through two openings in the nose cowling, one on each side of the propeller spinner. A pressure chamber is sealed off on the top side of the engine with baffles properly directing the flow of cooling air to all parts of the engine compartment. Warm air is drawn from the lower part of the engine compartment by the pumping action of the exhaust gases through the exhaust ejectors. This type of cooling system eliminates the use of controllable cowl flaps and assures adequate engine cooling at all operating speeds.

1.13 Turbine Engine Cooling

The intense heat generated when fuel and air are burned necessitates that some means of cooling be provided for all internal combustion engines. Reciprocating engines are cooled either by passing air over fins attached to the cylinders or by passing a liquid coolant through jackets that surround the cylinders. The cooling problem is made easier because combustion occurs only during every fourth stroke of a fourstroke-cycle engine.

The burning process in a gas turbine engine is continuous, and nearly all of the cooling air must be passed through the inside of the engine. If only enough air were admitted to the engine to provide an ideal air/fuel ratio of 15:1, internal temperatures would increase to more than 4,000 °F. In practice, a large amount of air in excess of the ideal ratio is admitted to the engine. The large surplus of air cools the hot sections of the engine to acceptable temperatures ranging from 1,500° to 2,100 °F. Because of the effect of cooling, the temperatures of the outside of the case are considerably less than those encountered within the engine. The hottest area occurs in and around the turbines. Although the gases have begun to cool a little at this point, the conductivity of the metal in the case carries the heat directly to the outside skin.

The secondary air passing through the engine cools the combustion-chamber liners. The liners are constructed to induce a thin, fast-moving film of air over both the inner and outer surfaces of the liner. Can-annular-type burners frequently are provided with a center tube to lead cooling air into the center of the burner to promote high combustion-efficiency and rapid dilution of the hot combustion gases while minimizing pressure losses. In all types of gas turbines, large amounts of relatively cool air join and mix with the burned gases aft of the burners to cool the hot gases just before they enter the turbines.

Cooling-air inlets are frequently provided around the exterior of the engine to permit the entrance of air to cool the turbine case, the bearings, and the turbine nozzle. Internal air is bled from the engine compressor section and is vented to the bearings and other parts of the engine. Air vented into or from the engine is ejected into the exhaust stream. When located on the side of the engine, the case is cooled by outside air flowing around it. The engine exterior and the engine nacelle are cooled by passing fan air around the engine and the nacelle. The engine compartment frequently is divided into two sections. The forward section is referred to as the cold section and the aft section (turbine) is referred to as the hot section. Case drains drain almost potential leaks overboard to prevent fluids from building up in the nacelle.

1.14 Accessory Zone Cooling

Turbine powerplants can be divided into primary zones that are isolated from each other by fireproof bulkheads and seals. The zones are the fan case compartment, intermediate compressor case compartment, and the core engine compartment. [Figure 5] Calibrated airflows are supplied to the zones to keep the temperatures around the engine at levels that are acceptable. The airflow provides for proper ventilation to prevent a buildup of any harmful vapors. Zone 1, for example, is around the fan case that contains the accessory case and the electronic engine control (EEC). This area is vented by using ram air through an inlet in the nose cowl and is exhausted through a louvered vent in the right fan cowling.

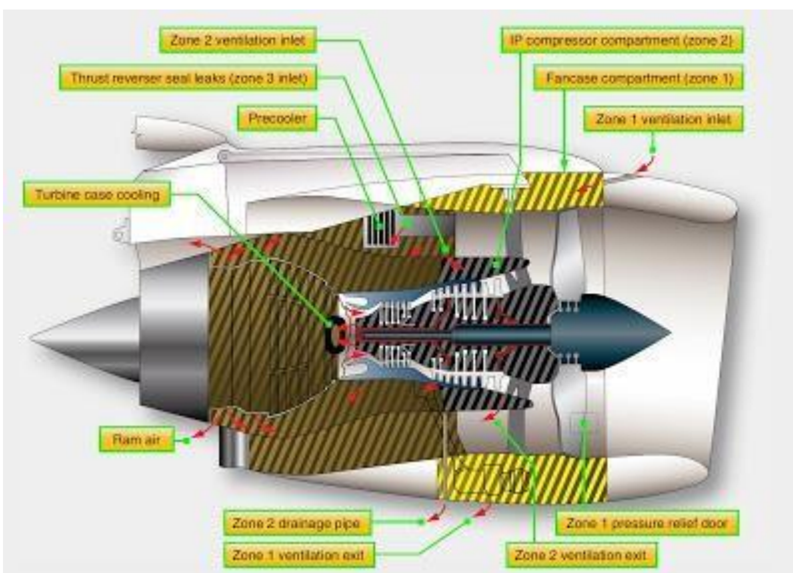


Figure 5. Accessory zone cooling

If the pressure exceeds a certain limit, a pressure relief door opens and relieves the pressure. Zone 2 is cooled by fan air from the upper part of the fan duct and is exhausted at the lower end back into the fan air stream. This area has both fuel and oil lines, so removing any unwanted vapors would be important.

Zone 3 is the area around the high-pressure compressor to the turbine cases. This zone also contains fuel and oil lines and other accessories. Air enters from the exhaust of the precooler and other areas and is exhausted from the zone through the aft edge of the thrust reverser inner wall and the turbine exhaust sleeve.

1.15 Engine Cooling Systems Evolution & Its Necessity

An internal combustion engine produces power by burning fuel within the cylinders; therefore, it is often referred to as a heat engine. Engines that produce their energy by heat and combustion have a problem of maintaining safe operating temperatures. Thirty to thirty five percent of the heat produced in the combustion chambers by the burning fuel is dissipated by the cooling system along with the lubrication and fuel systems. Forty to forty-five percent of the heat produced passes out with the exhaust gases. If this heat were not removed quickly, valves would burn and warp, lubricating oil would break down, pistons and bearing would overheat and seize, and the engine would soon stop. The necessity for cooling may be emphasized by considering the total heat developed by an ordinary six-cylinder engine. It is estimated that such an engine operating at ordinary speeds generates enough heat to warm a six-room house in freezing weather. Also, peak combustion temperatures in a gasoline engine may reach as high as 4500°F, while that of a diesel engine may approach 6000°F.The valves, pistons, cylinder walls, and cylinder head, all of which must be provided some means of cooling to avoid excessive temperatures, absorb some of this heat. Even though heated gases may reach high temperatures, the cylinder wall temperatures must not be allowed to rise above 400°F to 500°F. Temperatures above this result in serious damage as already indicated. The cooling system has four primary functions. These functions are as follows:

1. Remove excess heat from the engine.

2. Maintain a constant engine operating temperature.

3. Increase the temperature of a cold engine as quickly as possible.

4. Provide a means for heater operation.

CHAPTER 2

LITERATURE REVIEW

- Dwivedi et al. [1] deals with axial flow fans that are primarily used for cooling towers for air-conditioning Skewed blade profile carried out using CFD software FLUENT 6.3 and the results are compared with the experimental results from literature. The CFD analysis is done by modeling the axial fan in GAMBIT 2.2 and using Standard k-є model with the Standard wall function for modeling turbulence. The analysisis carried out with blade stagger angle of 25o, Skewed angle of 8.3o and at 1440 rpm and 1800 rpm. Jain et al.
- [2] used an axial flow fan augments the transfer of heat from the engine mounted on the APT T4. CFD analysis was performed for an area weighted average static pressure difference at the inlet and outlet of the fan.
- Ambdekar et al. [3] Observed that engine cooling fans are an essential component of the engine cooling system which is used to dissipate the excess heat generated by the combustion of fuels inside the engine.
- Bala subramanaiam et al. [4] presented the static analysis of the radiator fan and at the outcome we analyze the failure of the entire blade taking into design consideration. The analysis of the radiator fan is executed to different types of materials to check and evaluate the material and process conditions which withstand the dynamic and structural loads. In the paper design of the blade is done through reverse engineering.
- Udawant et al. [5] developed a methodology for design and development of radiator cooling fan with an objective to improve under hood thermal management. For this purpose an Axial Fan Design Software has been developed which is based on Arbitrary Vortex Flow theory. A Rapid Prototype sample of the optimized fan design is manufactured and tested in a fan test rig made as per AMCA 210-99 standard to evaluate the fan performance curve and the power consumption

2.1 Design considerations

Design

Select operational speed.

Designing the fan at rated engine speed: [engine rpm = 1650]

Fan Speed = 1.3 * engine rpm…(assumed)

= 1.3 * 1650

= 2145 rpm

By calculating all the designing parameters such as Number of Blades, Blade Angle, Noise, Solidity of Blade,

Blade Width for design of blade by taking assumptions

we have got the following Blade angles.

	At hub	**At mid**	**At tip**
= Φ	$.5^{0}$	$.2^{0}$	^{0}
= θ	3^{0}	4.6^{0}	6^{0}

2.2 The Model

A blade has mean section area A and length αR, where α is the fraction of the fan radius ρ which is blade (the rest is hub). Its volume is αRA and the angular acceleration is ω2R, so the centrifugal force at the blade root is

$$F = \rho(\alpha R A)\omega^2 R \qquad \text{(M7.1)}$$

The force is carried by the section A, so the stress at the root of the blade is

$$\sigma = \frac{F}{A} = \alpha \rho \omega^2 R^2 \qquad \text{(M7.2)}$$

.

This stress must not exceed the failure stress σf divided by a safety factor (typically about 3) which does not affect the analysis and can be ignored. The stress at which fast fracture will occur is:

$$\sigma_f = \frac{K_{IC}}{\sqrt{\pi a}}$$

,

where KIC is the fracture toughness of the material of the blade and α is the length of the largest defect it contains. Non-destructive testing can ensure that this is less than some detection limit, a*. Thus, for safety:

$$\alpha \rho \omega^2 R^2 < \frac{K_{IC}}{\sqrt{\pi a^*}}$$

,

or

$$\omega < \frac{1}{R}\left(\frac{1}{\alpha\sqrt{\pi a^*}}\right)^{1/2}\left(\frac{K_{IC}}{\rho}\right)^{1/2} \qquad \text{(M7.3)}$$

.

The lengths R and a* are fixed, as is α. The safe rotational velocity ω is maximized by selecting materials with large values of

$$\boxed{M_1 = \frac{K_{IC}}{\rho}} \qquad \text{(M7.4)}$$

.

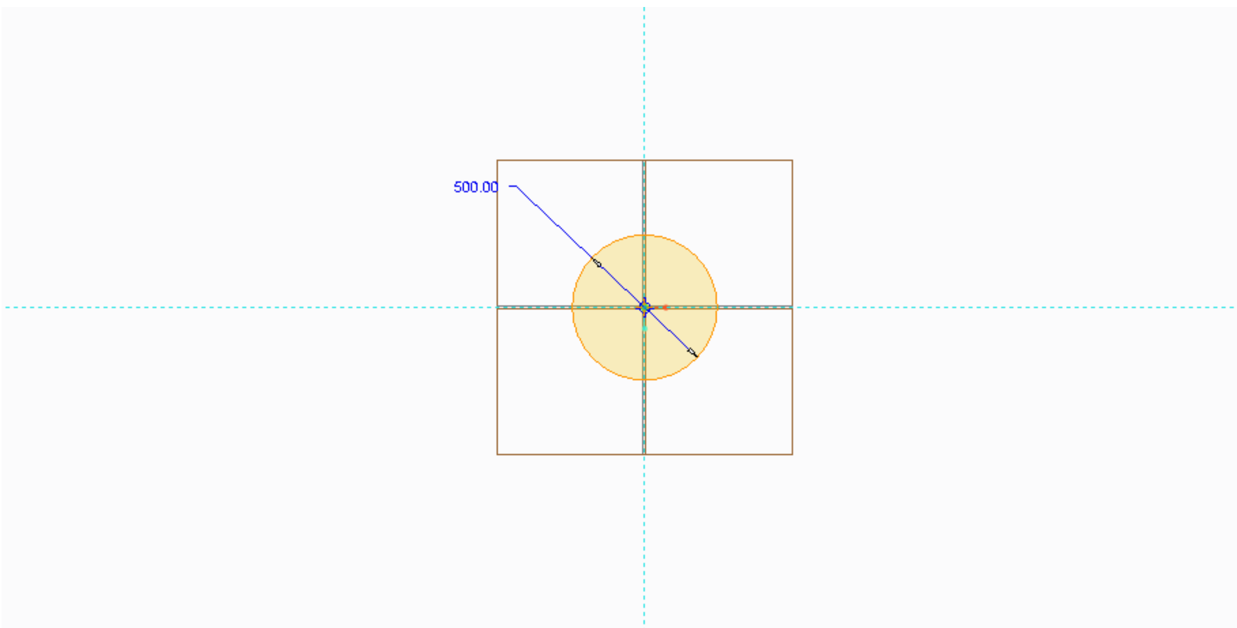
The material cost of the fan is

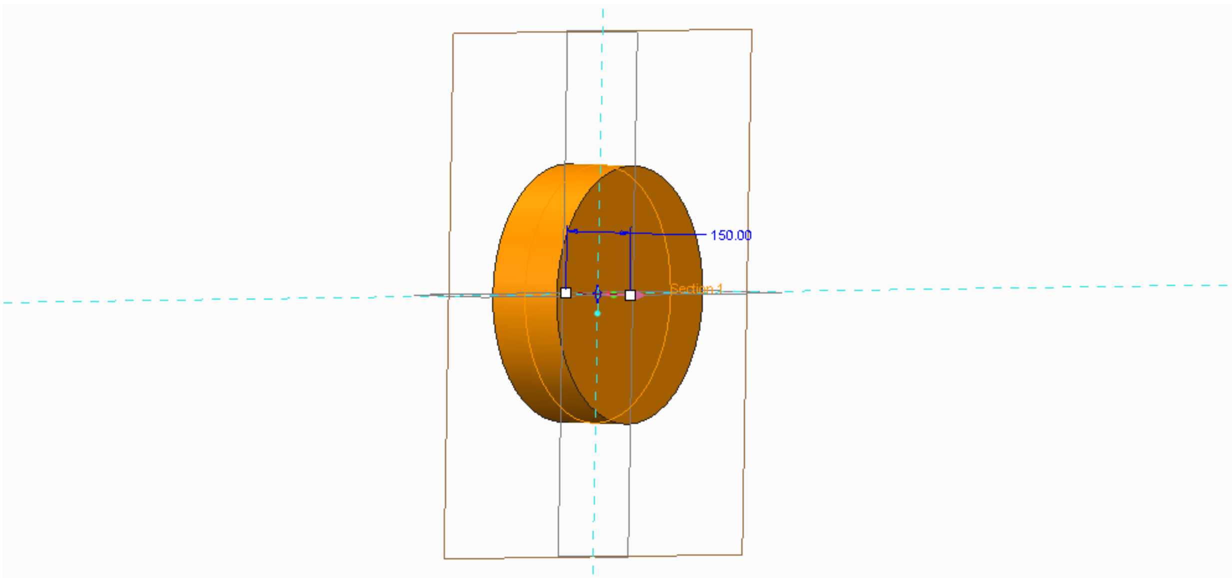
$$C = C_m \rho V$$

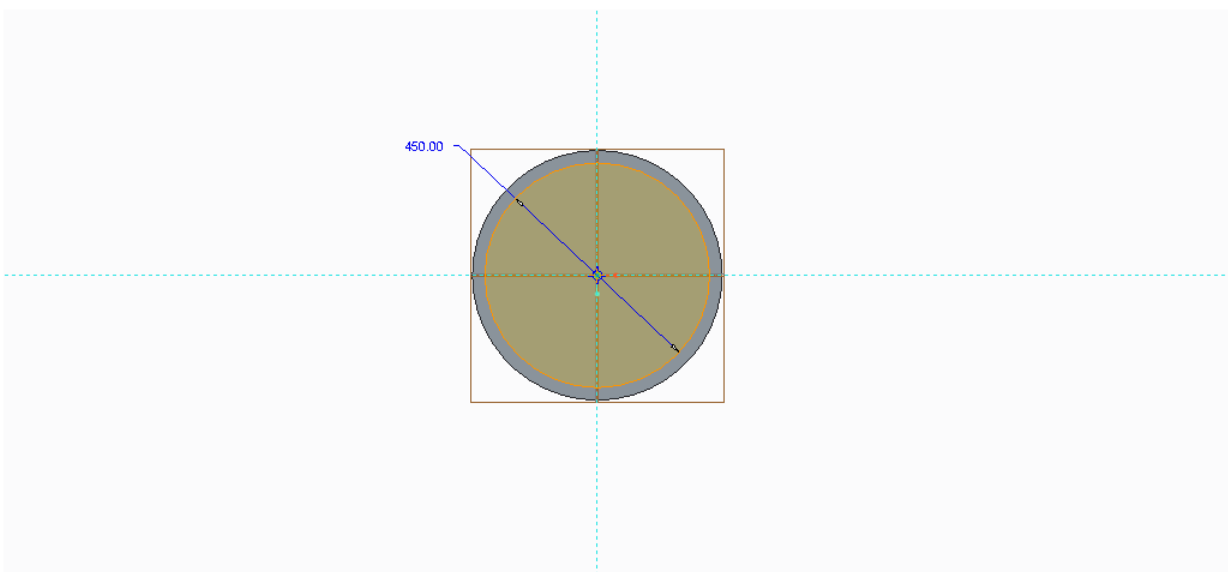
where Cm is the cost/kg of the material, ρ its density and V the volume of material in the fan. The volume is essentially fixed by the radius R, which is a constraint on the selection. Thus the material cost is minimized by selecting materials with large values of the volume per unit cost:

$$\boxed{M_2 = \frac{1}{C_m \rho}}.$$

2.3 Design process step by step




150.00
Section 1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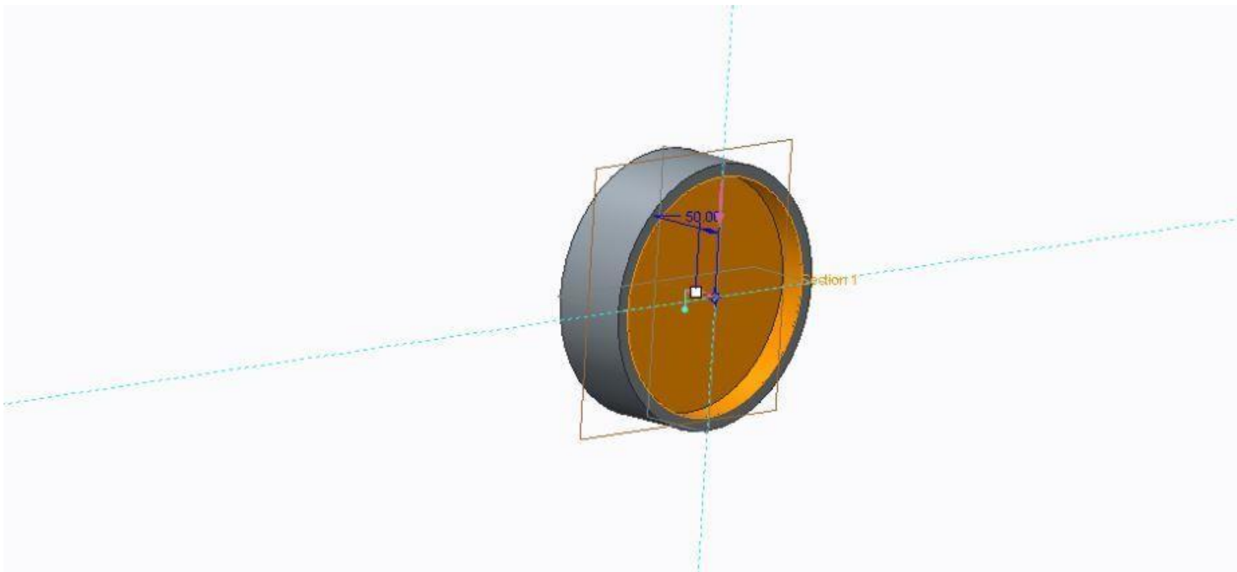
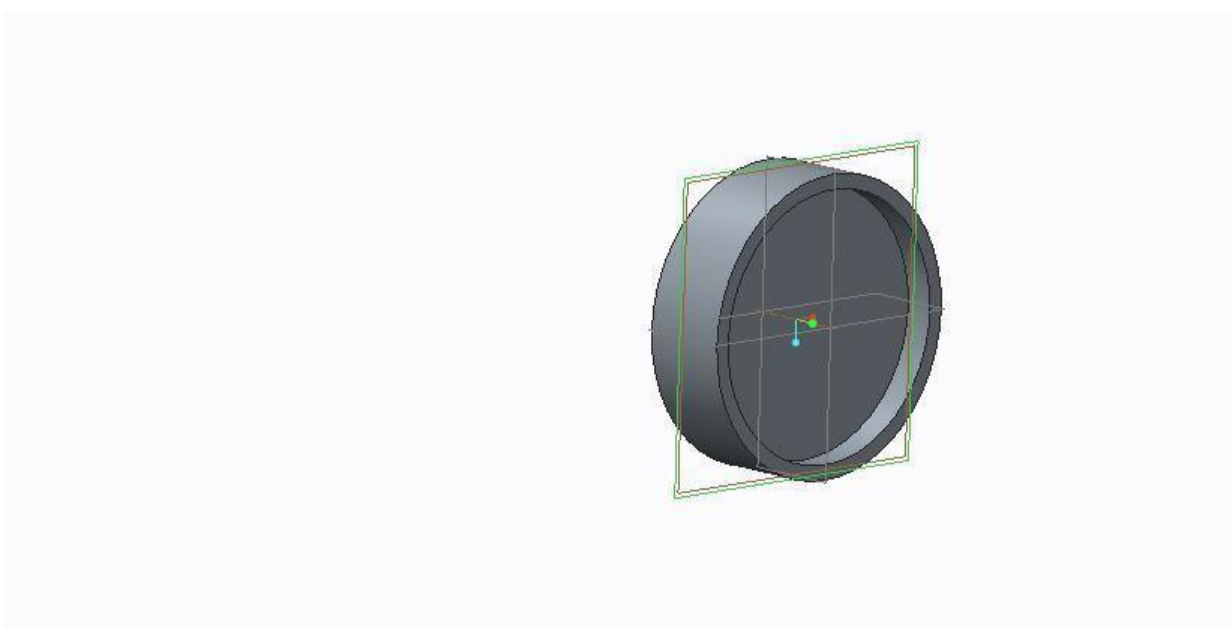
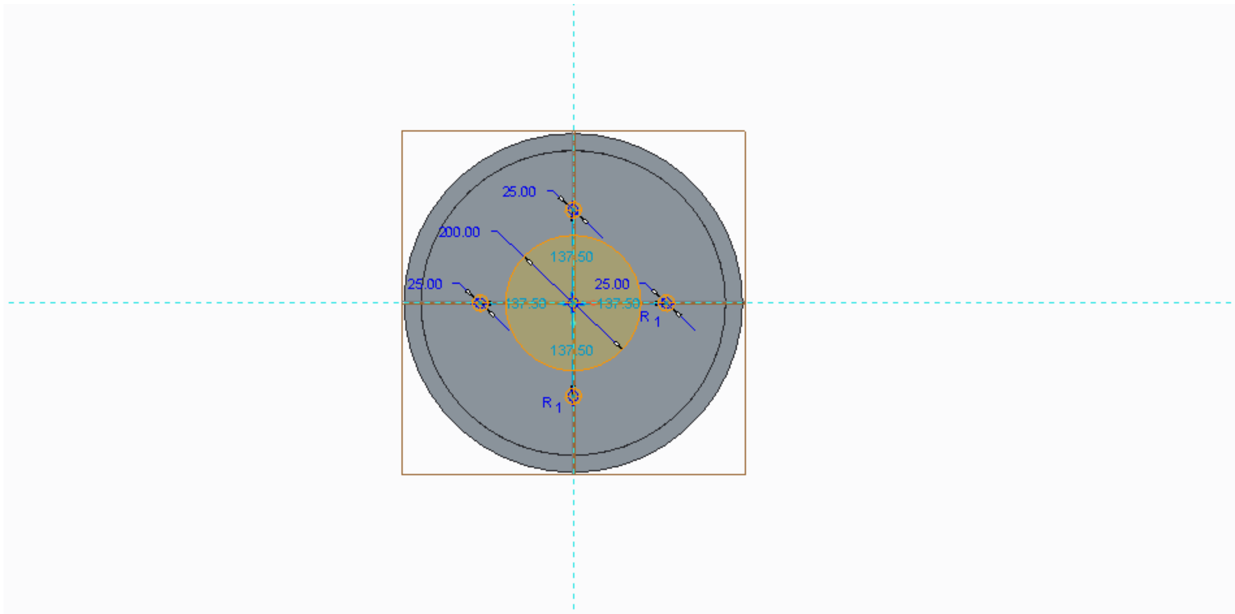
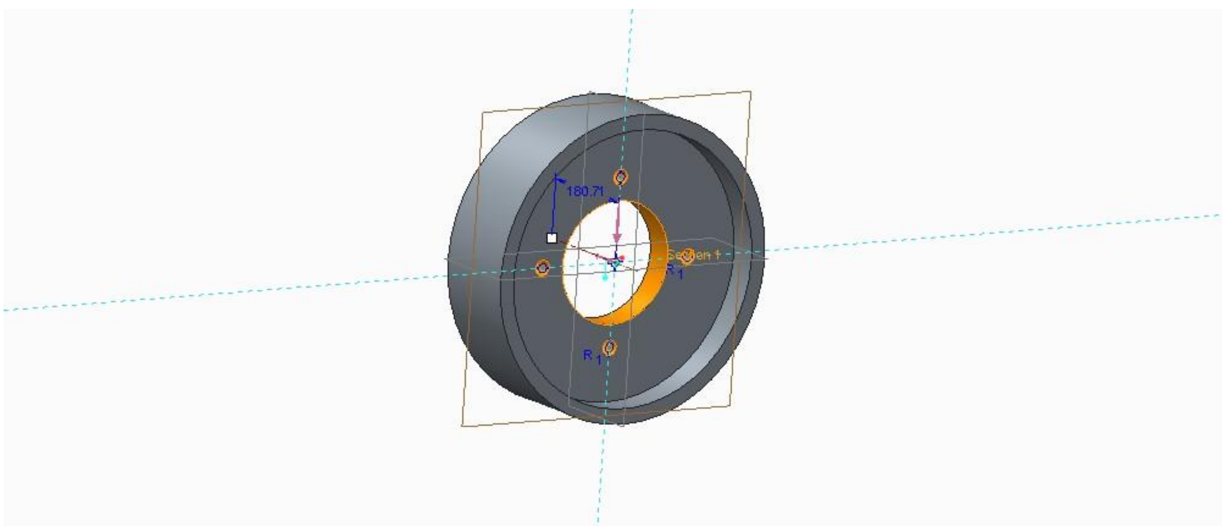
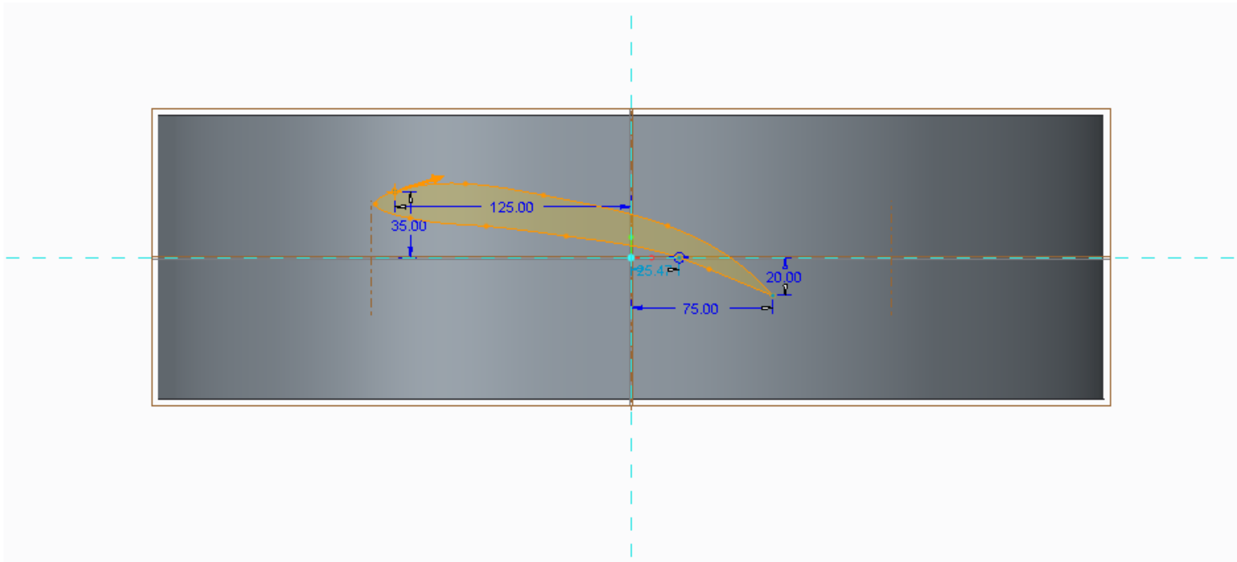

50.00
Section 1

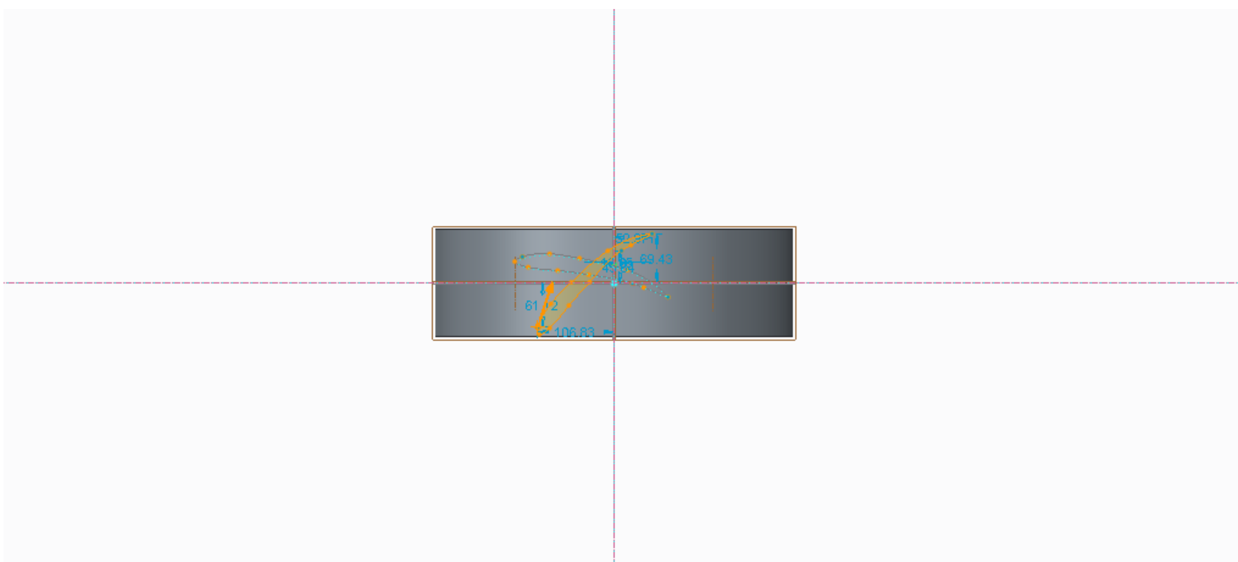


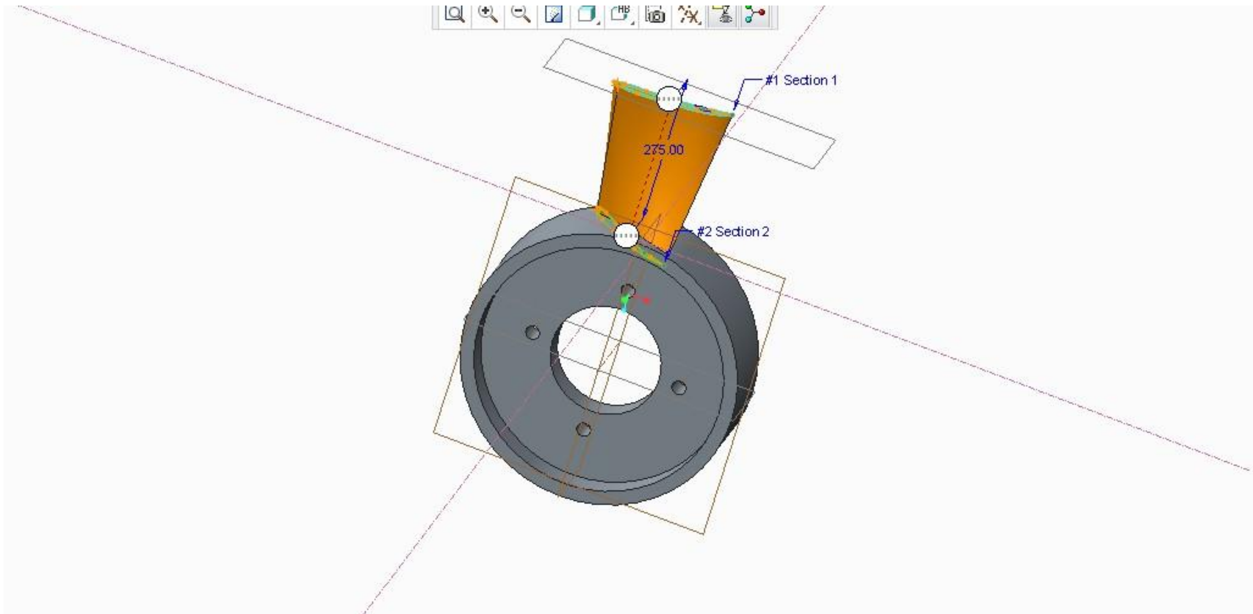

25.00
200.00
137.50
25.00
25.00
137.50
137.50
R 1
137.50
R 1

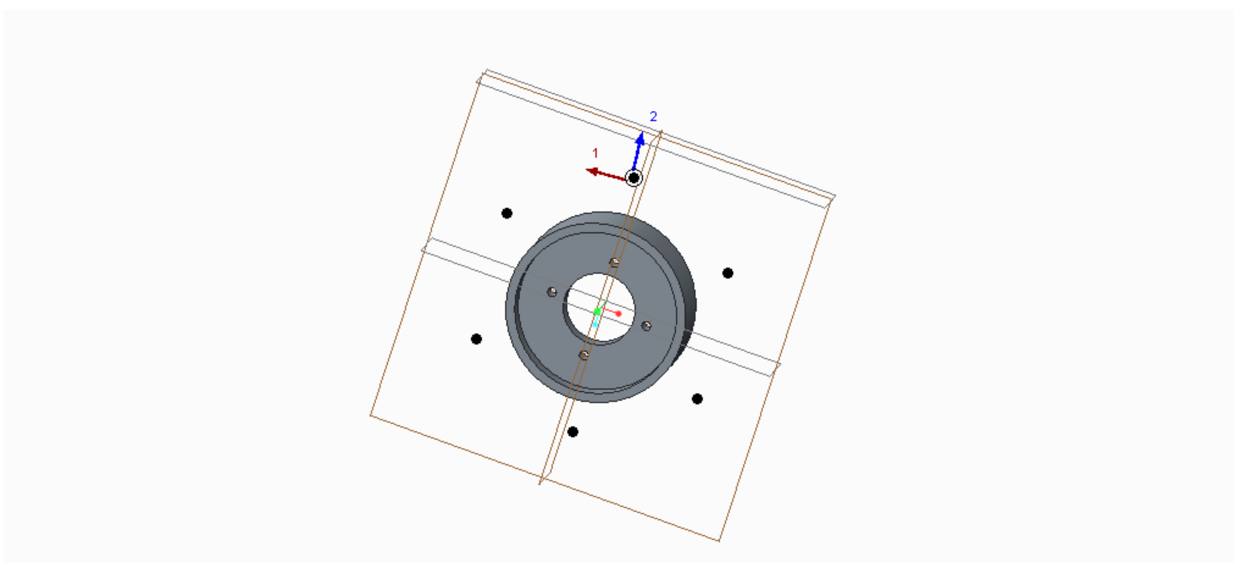

180.71
R 1
R 1

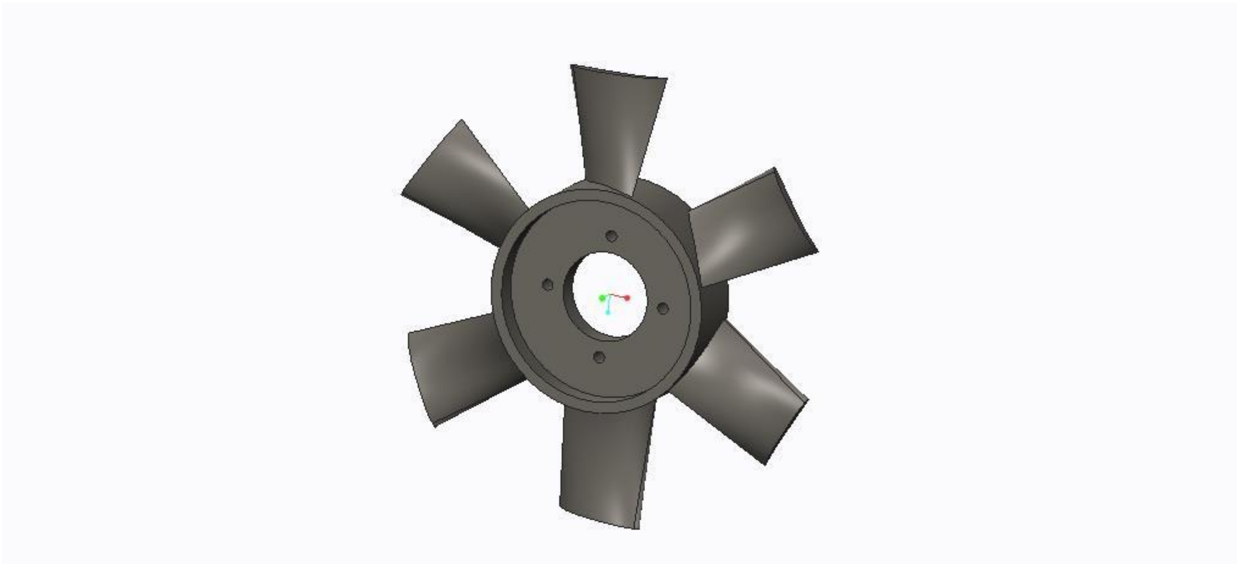


125.00
35.00
20.00
75.00




#1 Section 1
275.00
#2 Section 2


2
1



Final model

CHAPTER 3
MATERIAL SELECTION

3.1 Al-4032

Aluminium/Aluminum alloys are known for strong corrosion resistance. These alloys are sensitive to high temperatures ranging between 200 and 250°C (392 and 482°F), and tend to lose some of its strength. However, the strength of Aluminium/Aluminum alloys

can be enhanced at subzero temperatures, making them ideal low-temperature alloys. Aluminium/Aluminum 4032 alloy is a wrought alloy type. The following datasheet will provide more details about Aluminium/Aluminum 4032 alloy.

3.2 Chemical Composition

The following table shows the chemical composition of Aluminium/Aluminum 4032 alloy.

Element	**Content (%)**
Aluminum, Al	85
Silicon, Si	12.20
Magnesium, Mg	1.0
Copper , Cu	0.90
Nickel, Ni	0.9

3.3 Fabrication and Heat Treatment

3.3.1 Machinability

Machinability of Aluminium/Aluminum 4032 alloy is rated as fair to good. Machining should be performed using lubricating oils.

3.3.2 Forming

Aluminium/Aluminum 4032 alloy is a forging alloy and can be formed using hot die forging.

3.3.3 Welding

Aluminium/Aluminum 4032 alloy is weldable and the recommended method is inert-gas arc welding method. The gas welding method is not suitable.

3.3.4 Heat Treatment

Solution heat treatment of Aluminium/Aluminum 4032 alloy is performed at 510°C (950°F) for 1 to 12 hours based on the thickness of the section.

3.3.5 Forging

As Aluminium/Aluminum 4032 alloy is a forging alloy, hot die forging can be easily performed in the range of 510 to 371°C (950 to 700°F).

3.3.6 Cold Working

Aluminium/Aluminum 4032 alloy cannot be cold worked.

3.3.7 Annealing

Annealing of Aluminium/Aluminum 4032 alloy can be performed at 413°C (775°F) for a certain amount of time to ensure thorough heating, and then the alloy has to be cooled in a controlled manner at rate of 10°C (50°F) per hour to 204°C (400°F). Finally it is air cooled.

3.3.8 Aging

Aluminium/Aluminum 4032 alloy can be aged (T6 temper) by solution heating at 510°C (950°F), cold water quenching, heating at 171°C (340°F) for 10 hours and finally air cooling.

3.4 Applications

Aluminium/Aluminum 4032 alloy is widely used in the manufacture of pistons.

3.4.1 Az91d

Magnesium alloys are some of lightest structural materials around. Magnesium AZ91D cast alloy is a high-purity alloy that has excellent corrosion resistance, excellent castablilty and good strength. It is the most commonly used magnesium die casting alloy.

3.5 Chemical Composition

The chemical composition of magnesium AZ91D cast alloy is outlined in the following table.

Element	Content (%)
Aluminum, Al	8.3-9.7
Manganese, Mn	0.15-0.50
Zinc, Zn	0.35-1
Silicon, Si	0.1
Copper, Cu	0.03
Iron, Fe	0.005
Nickel, Ni	0.002
Others, each max	0.02
Magnesium, Mg	Remainder

3.6 Physical Properties

The physical properties of magnesium AZ91D cast alloy are tabulated below.

3.7 Applications

Magnesium AZ91D cast alloy is used in several components. Some of them are listed below:

- Covers
- Housings
- Handheld tools
- Sporting goods
- Computer parts
- Mobile and telephones
- Household equipment
- Automobile components.

CHAPTER 4

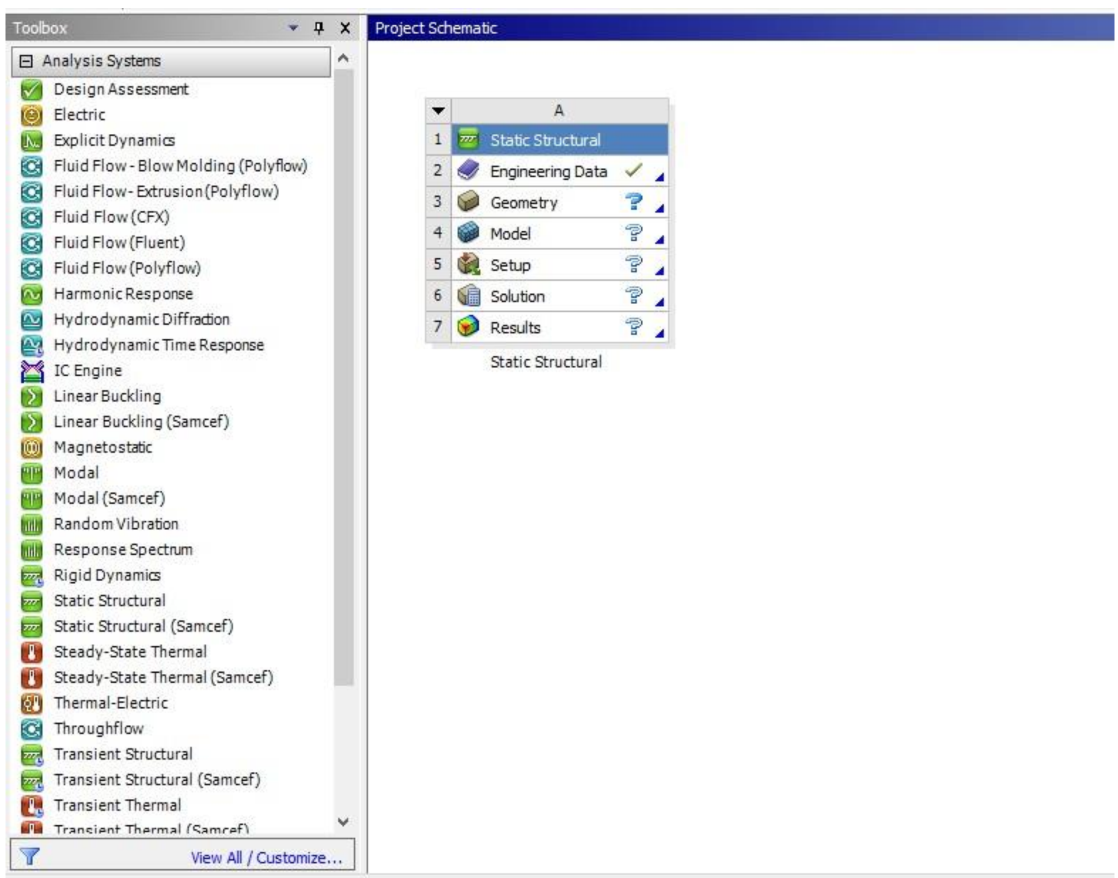
ANSYS PROCESS

IMPORTING THE COMPONEENT FROM CAD (SOLID-WORKS) TOOL TO CAE TOOL (ANSYS):

4.1 STRUCTURAL ANALYSIS:-

4.1.1 Click on Ansys workbench

Static structural



3. Engineering data→right click→ enter values

FOR

Cast iron

Young's modulus: - 1.25*10^11 Pa

Poison ratio: 0.25

Density: 7100 Kg/m^3

Yield strength: 240Mpa

Az91d

Young's modulus: - 45*10^9 Pa

Poison ratio: 0.33

Density: 1870 Kg/m^3

Yield strength: 250Mpa

Al-4032

Young's modulus: - 73*10^9 Pa

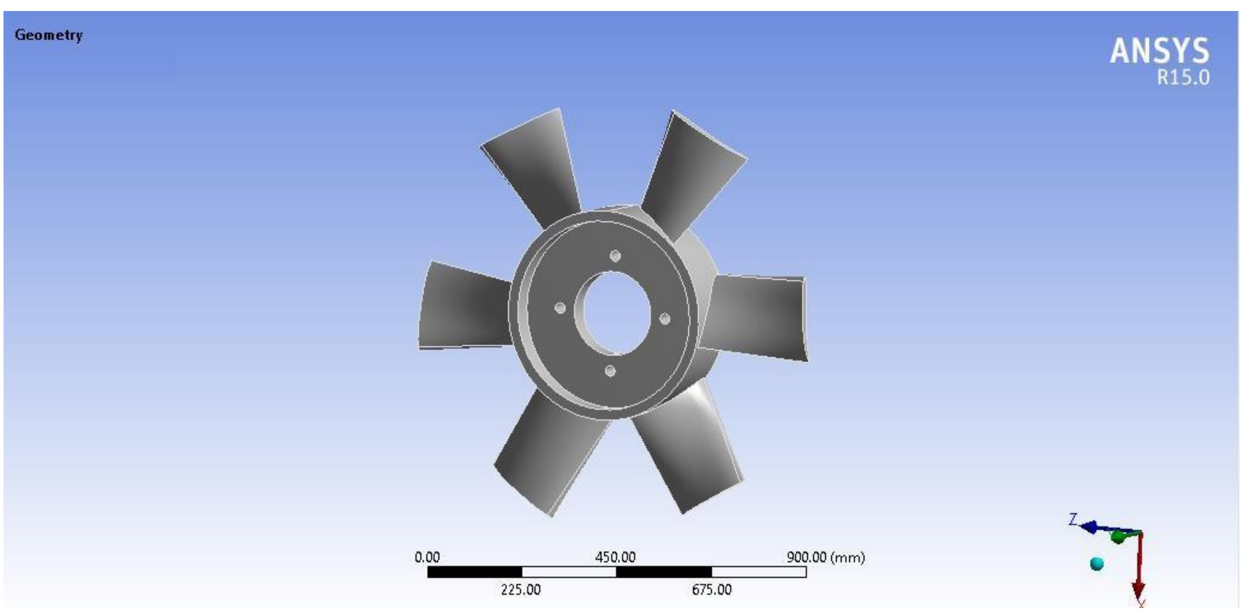
Poison ratio: 0.33

Density: 2600 Kg/m^3

Yield strength: 320Mpa

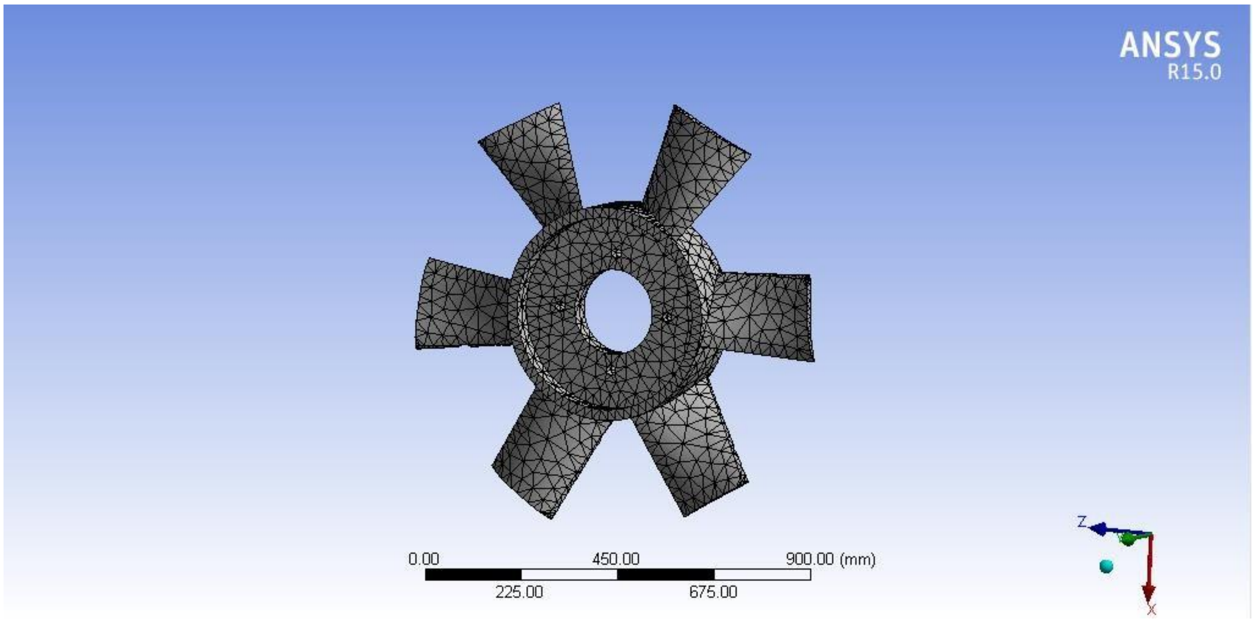
Geometry→ right click→ import geometry→ import iges format model

After importing model just click on geometry option then we will get selection of material. From engineering data here we already applied the above mentioned materials.



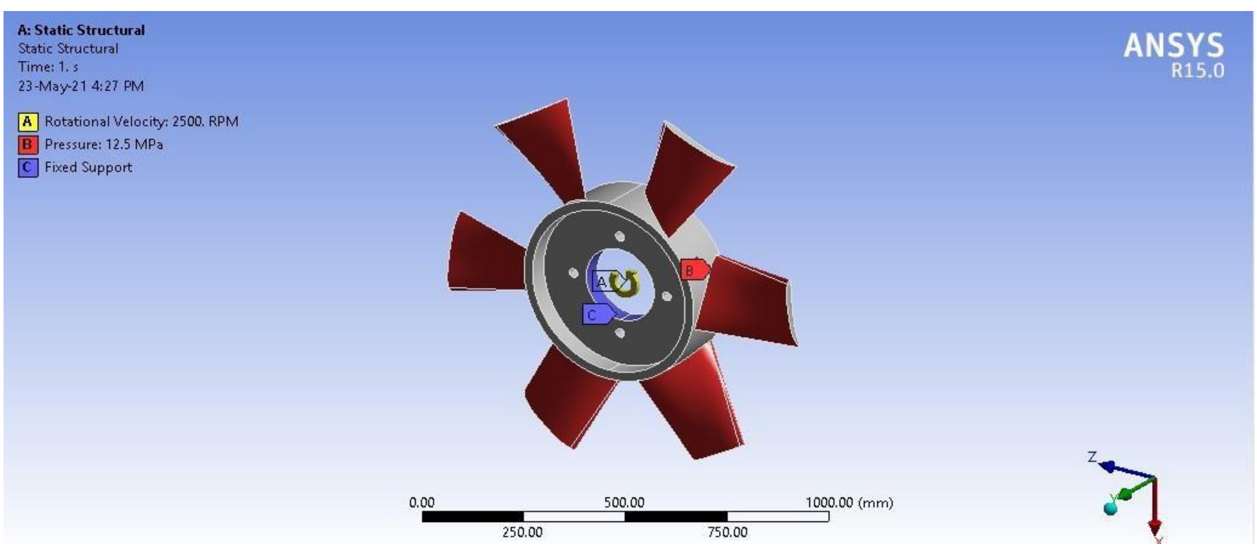
After completion of material selection here we have to create meshing for each object meshing means it is converting single part into no of parts. And this mesh will transfer applied loads for overall object. After completion meshing only we can solve our object. Without mesh we cannot solve our problem. And here we are using tetra meshing and the model shown in below.

Meshing



Boundary conditions

After completion of meshing now we have to apply boundary conditions



Fixed support → select center hole

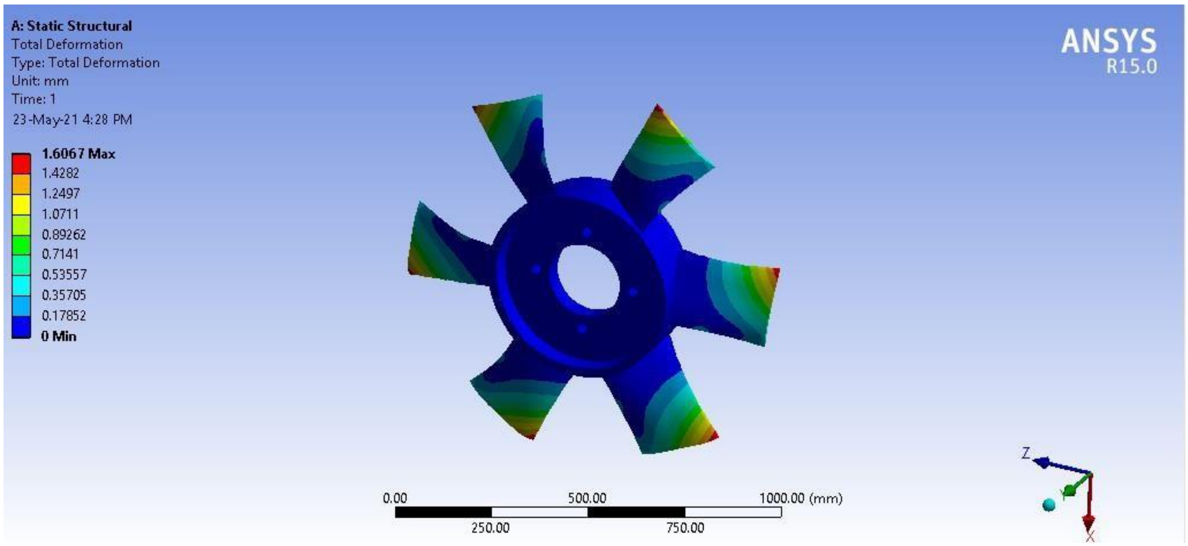
Pressure→ 12.5Mpa on wings

Rotational velocity→ 2500Rpm

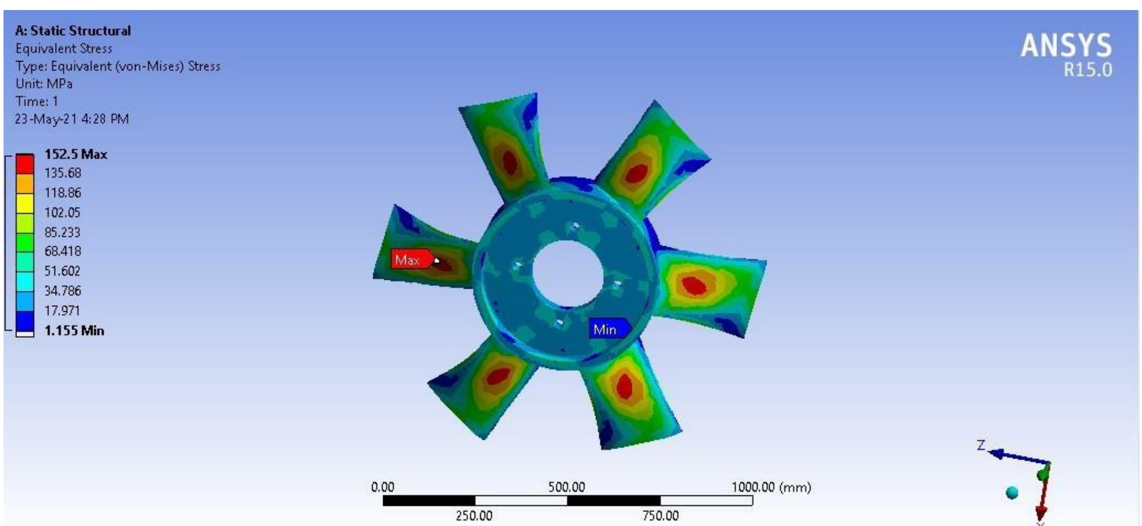
Solve→ solution →deformation→stress→ok

CAST IRON

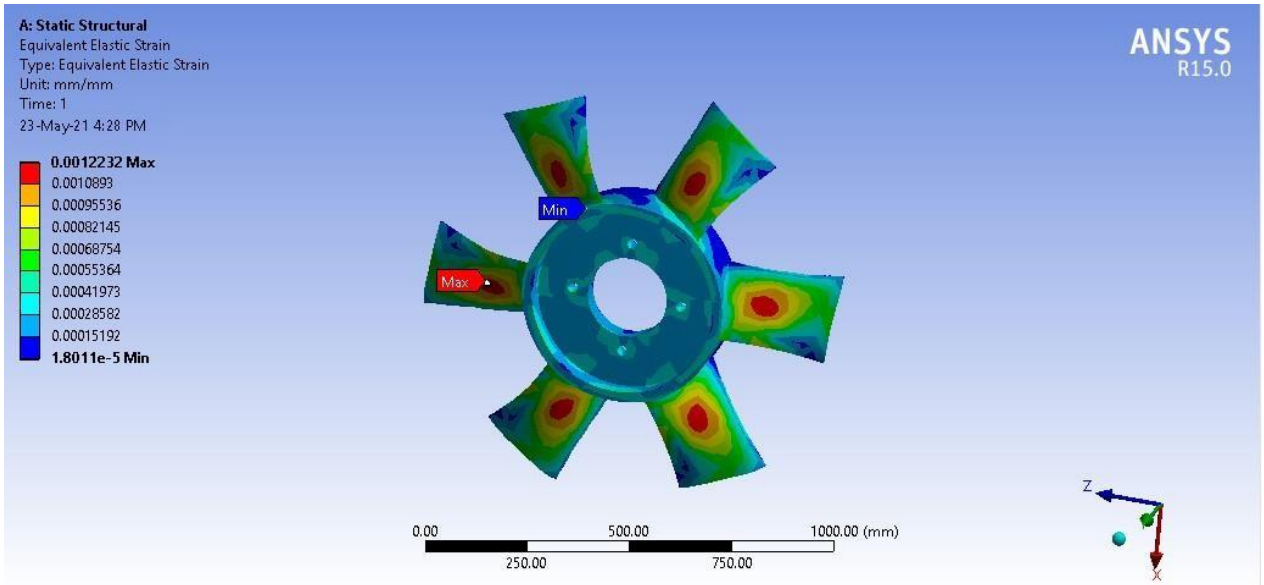
DEFORMATION



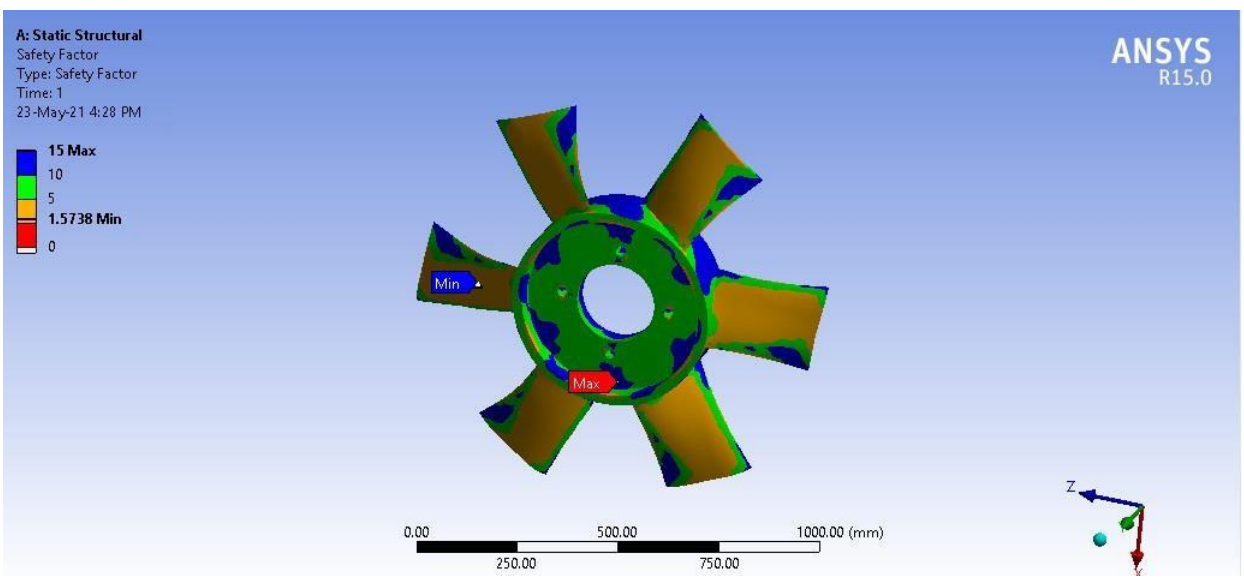
STRESS



STARIN

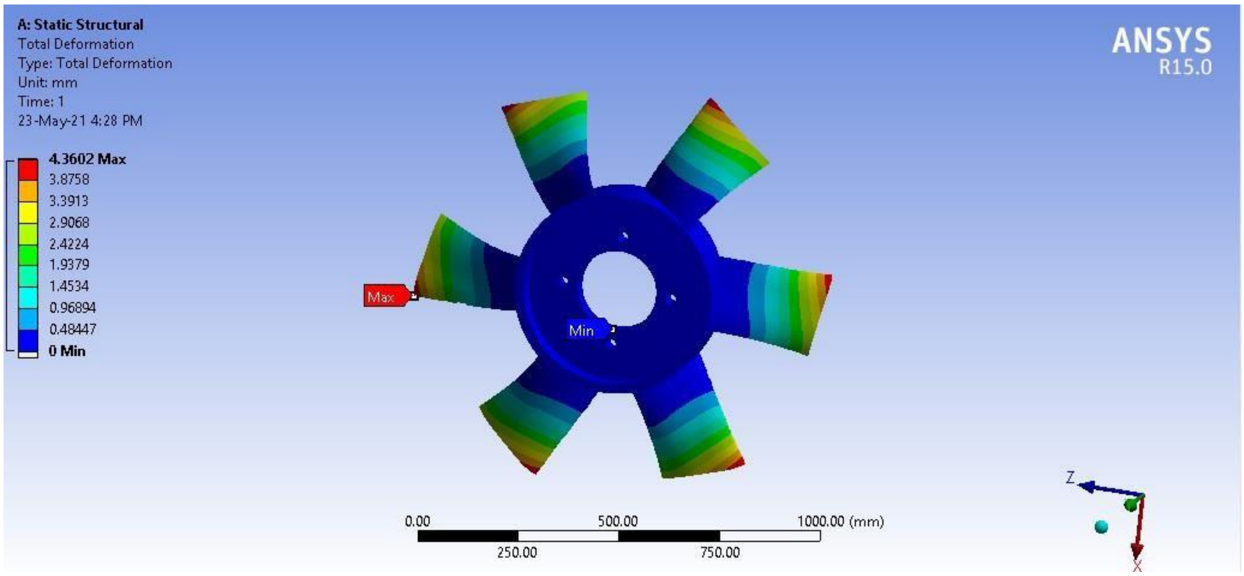


SAFETY FACTOR

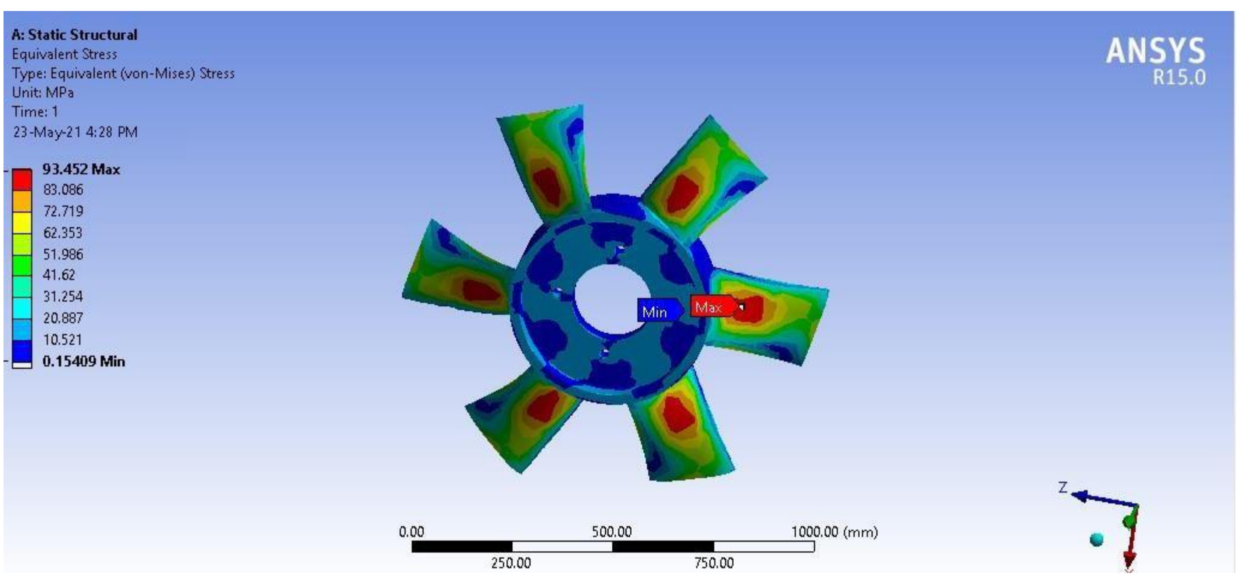


AZ91D

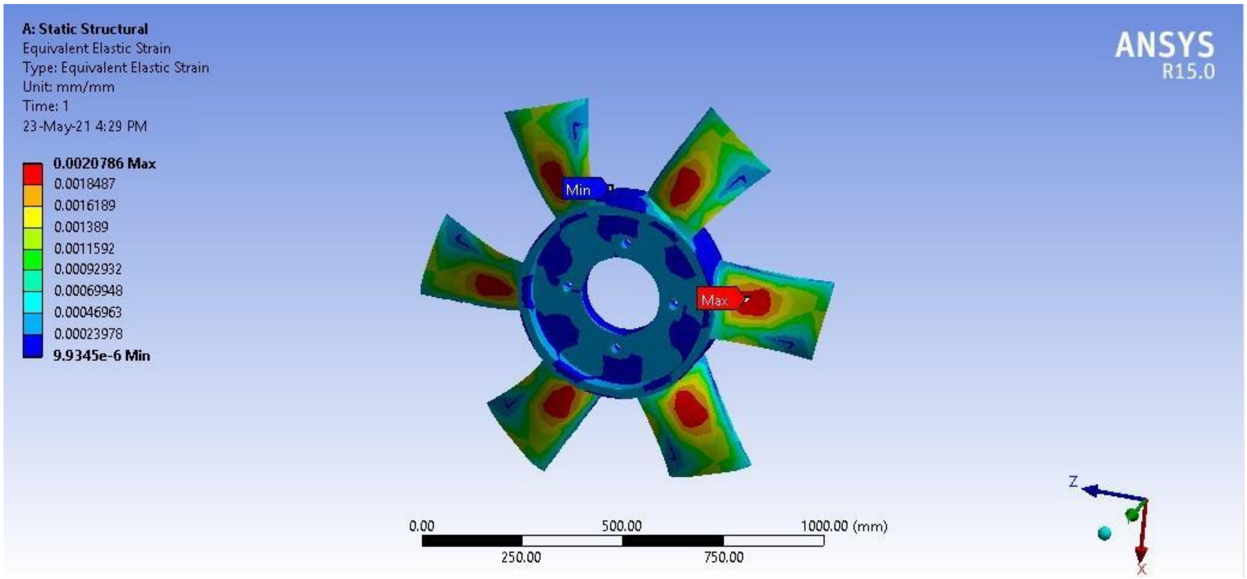
DEFORMATION



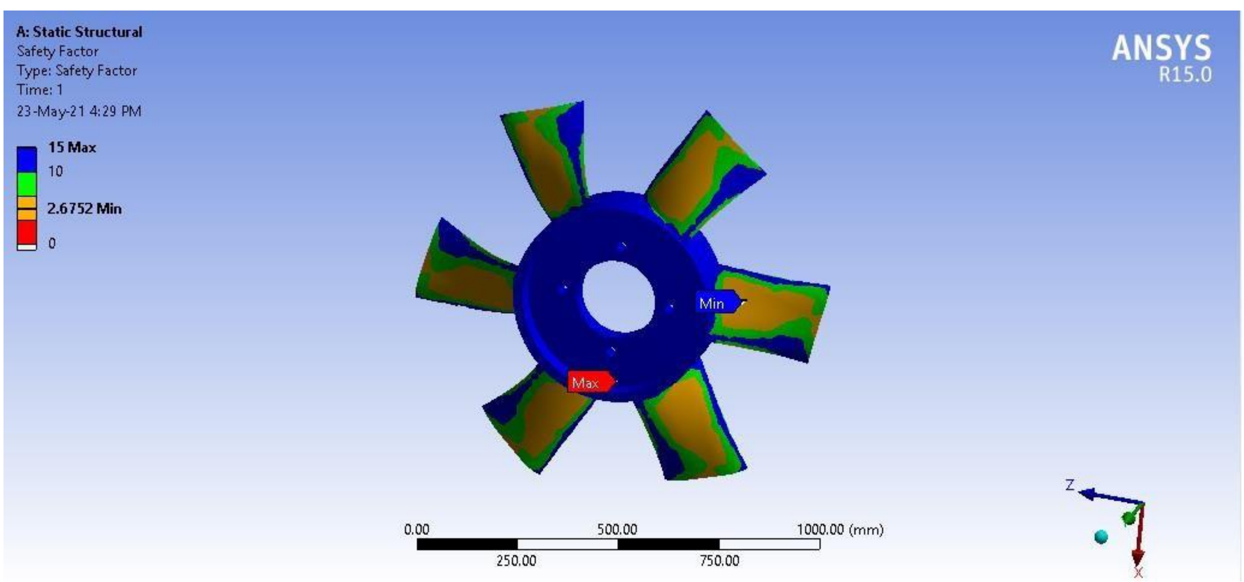
STRESS



STRAIN

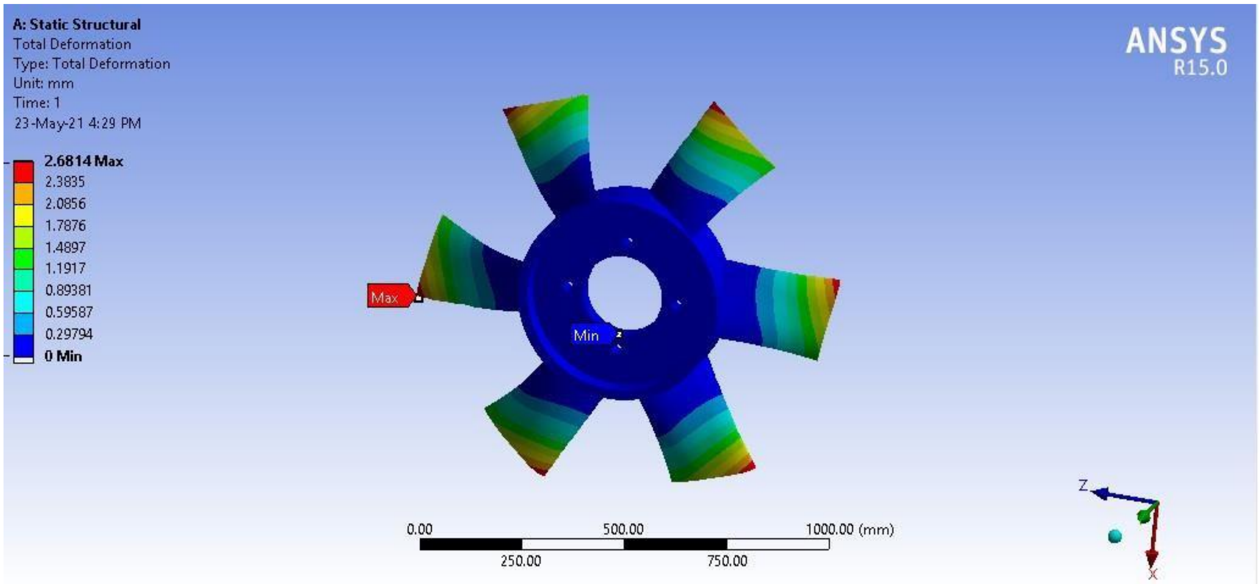


SAFETY FACTOR

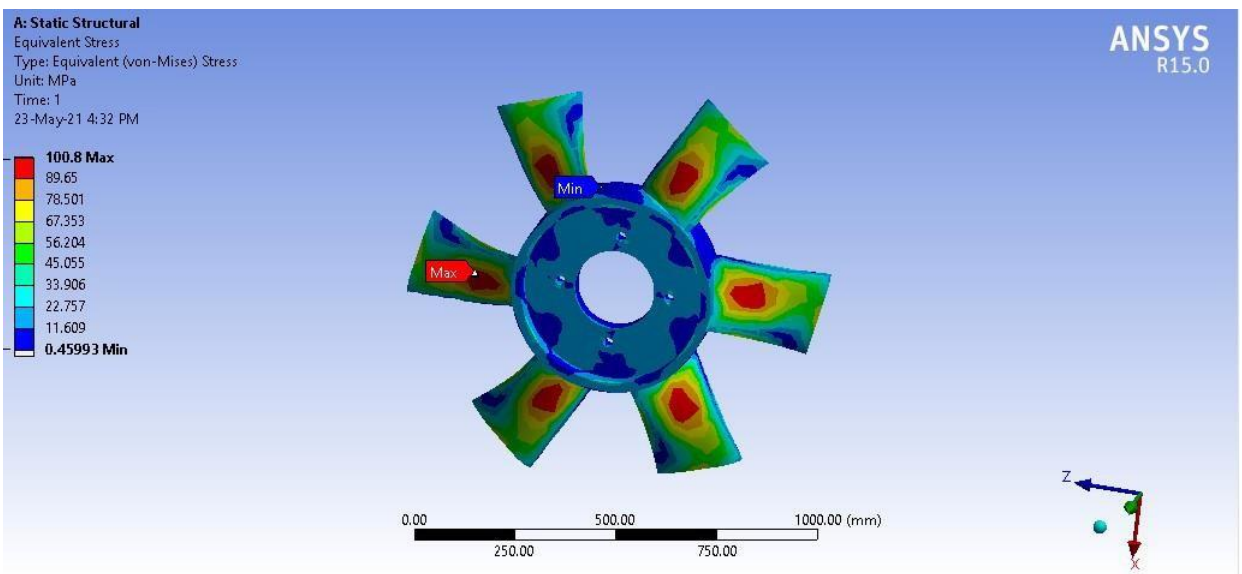


AL-4032

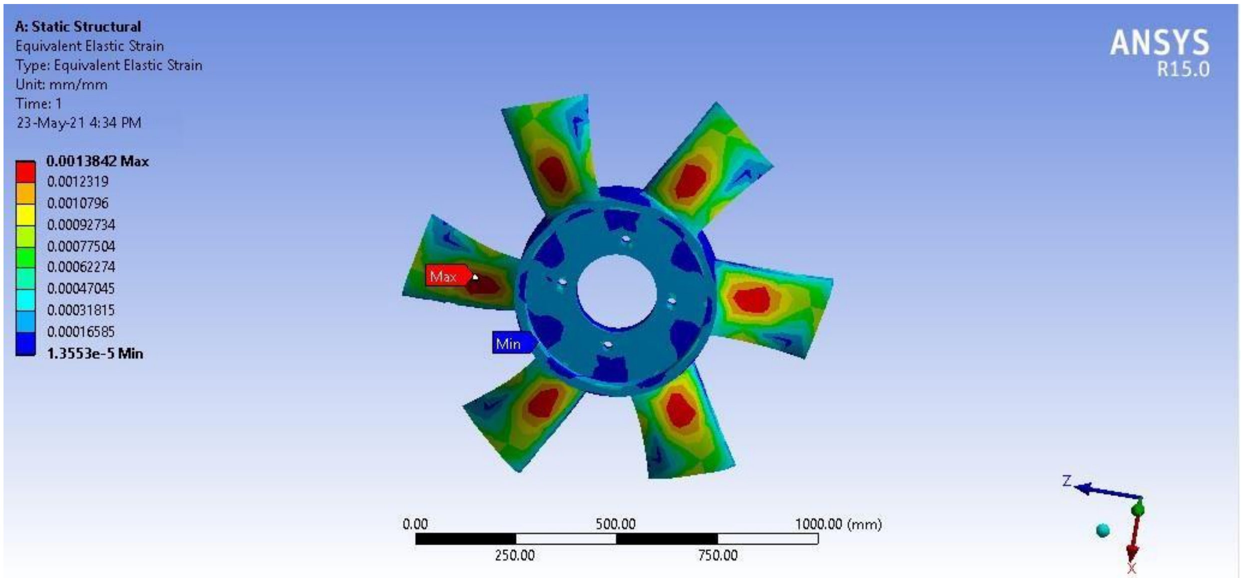
DEFORMATION



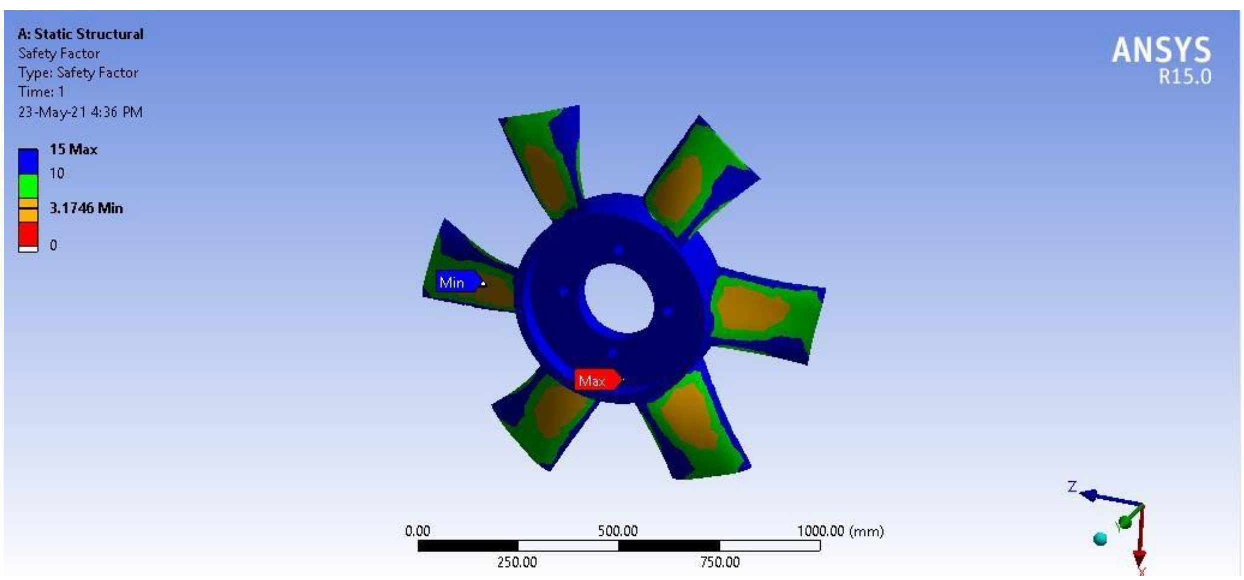
STRESS



STRAIN



SAFETY FACTOR

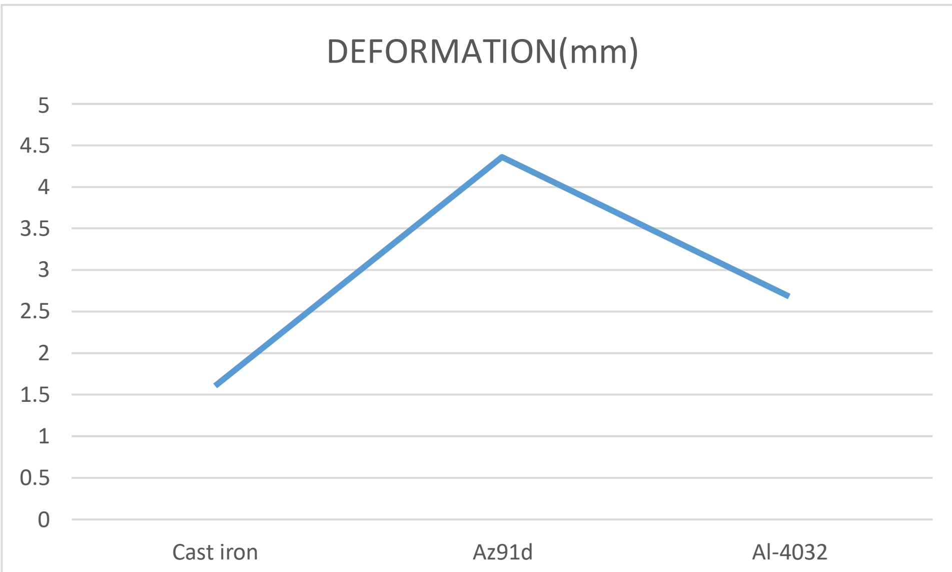


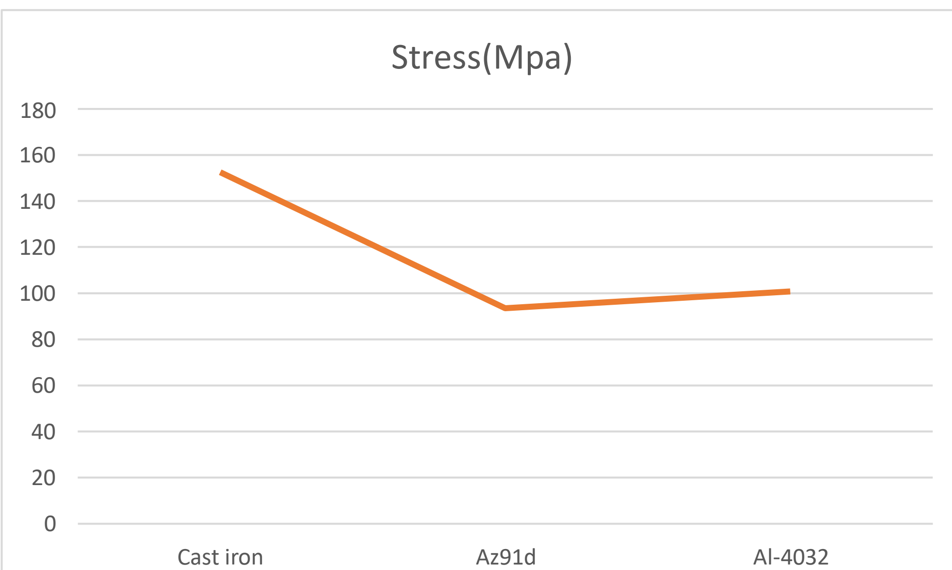
TABLES

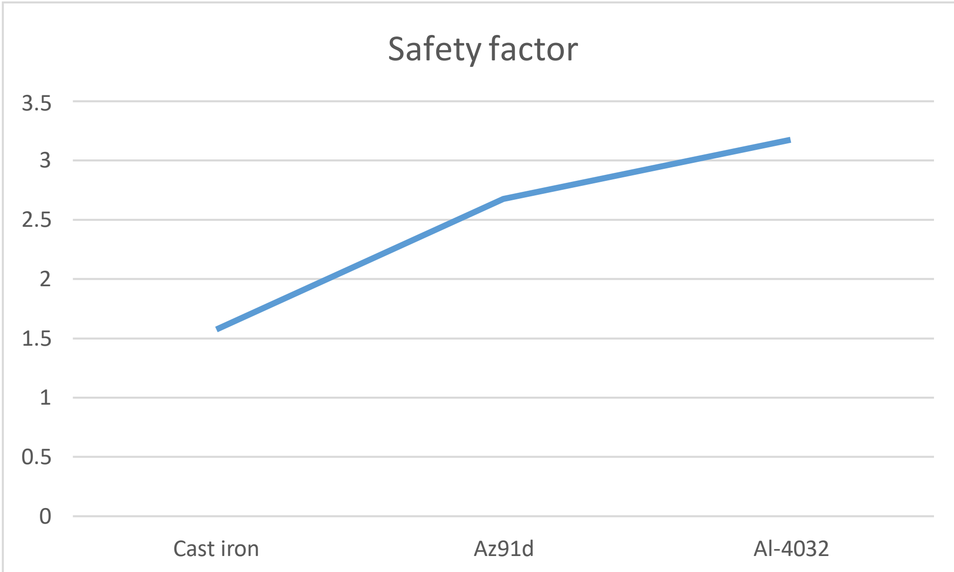
	DEFORMATION(mm)	Stress(Mpa)	Safety factor	Strain
Castiron	1.6067	152.5	1.5738	0.0012232
Az91d	4.3602	93.452	2.67552	0.0020786
Al-	2.6814	100.8	3.	0.00

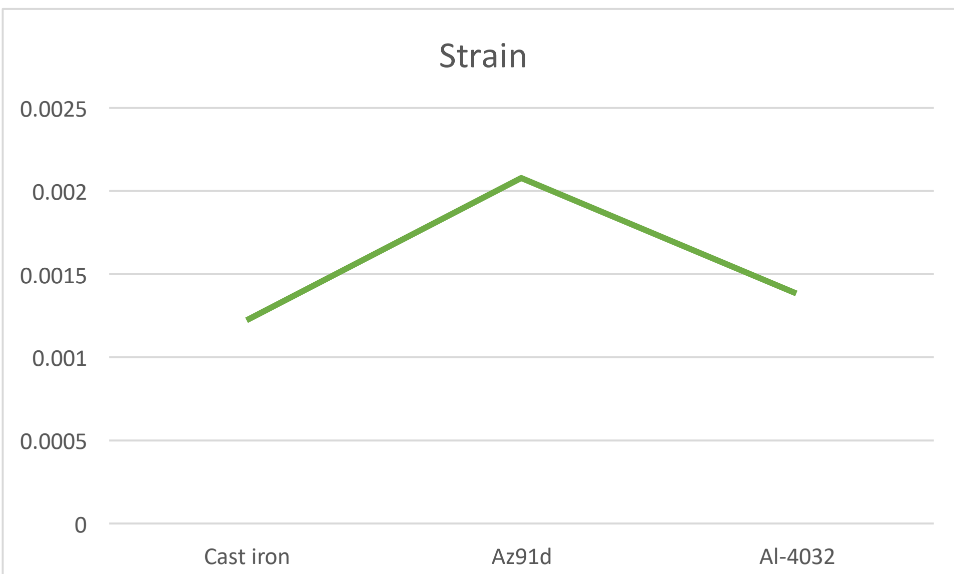
4 **0** **3** **2**			1 7 4 6	13 84 2

Graphs






Safety factor
3.5
3
2.5
2
1.5
1
0.5
0
Cast iron
Az91d
Al-4032


Strain
0.0025
0.002
0.0015
0.001
0.0005
0
Cast iron
Az91d
Al-4032

CHAPTER 5
MODEL ANALYSIS

5.1 Natural frequency

A sound wave is created as a result of a vibrating object. The vibrating object is the source of the disturbance that moves through the medium. The vibrating object that creates the disturbance could be the vocal cords of a person, the vibrating string and soundboard of a guitar or violin, the vibrating tines of a tuning fork, or the vibrating diaphragm of a radio speaker. Any object that vibrates will create a sound. The sound could be musical or it could be noisy; but regardless of its quality, the sound wave is created by a vibrating object.

Nearly all objects, when hit or struck or plucked or strummed or somehow disturbed, will vibrate. If you drop a meter stick or pencil on the floor, it will begin to vibrate. If you pluck a guitar string, it will begin to vibrate. If you blow over the top of a pop bottle, the air inside will vibrate. When each of these objects vibrates, they tend to vibrate at a particular frequency or a set of frequencies. The frequency or frequencies at which an object tends to vibrate with when hit, struck, plucked, strummed or somehow disturbed is known as the **natural frequency** of the object. If the amplitudes of the vibrations are large enough and if natural frequency is within the human frequency range, then the vibrating object will produce sound waves that are audible. All objects have a natural frequency or set of frequencies at which they vibrate. The quality or **timbre** of the sound produced by a vibrating object is dependent upon the natural frequencies of the sound waves produced by the objects. Some objects tend to vibrate at a single frequency and they are often said to produce a pure tone. A flute tends to vibrate at a single frequency, producing a very pure tone. Other objects vibrate and produce more complex waves with a set of frequencies that have a whole number mathematical relationship between them; these are said to produce a rich sound. A tuba tends to vibrate at a set of frequencies that are mathematically related by whole number ratios; it produces a rich tone. Still other objects will vibrate at a set of multiple frequencies that have no simple mathematical relationship between them. These objects are not musical at all and the sounds that they create could be described as noise. When a meter stick or pencil is dropped on the floor, it vibrates with a number of frequencies, producing a complex sound wave that is clunky and noisy.

The natural frequency is the frequency at which a system oscillates when it is disturbed. If you pluck a guitar string in the middle it vibrates back and forth. If you pluck the same string 10 times in a row and measure the frequency of vibration you find that it is always the same. When plucked, the string vibrates at its natural frequency. The pendulum also had a natural frequency. The natural frequency is important for many reasons:

1 All things in the universe have a natural frequency, and many things have more than one

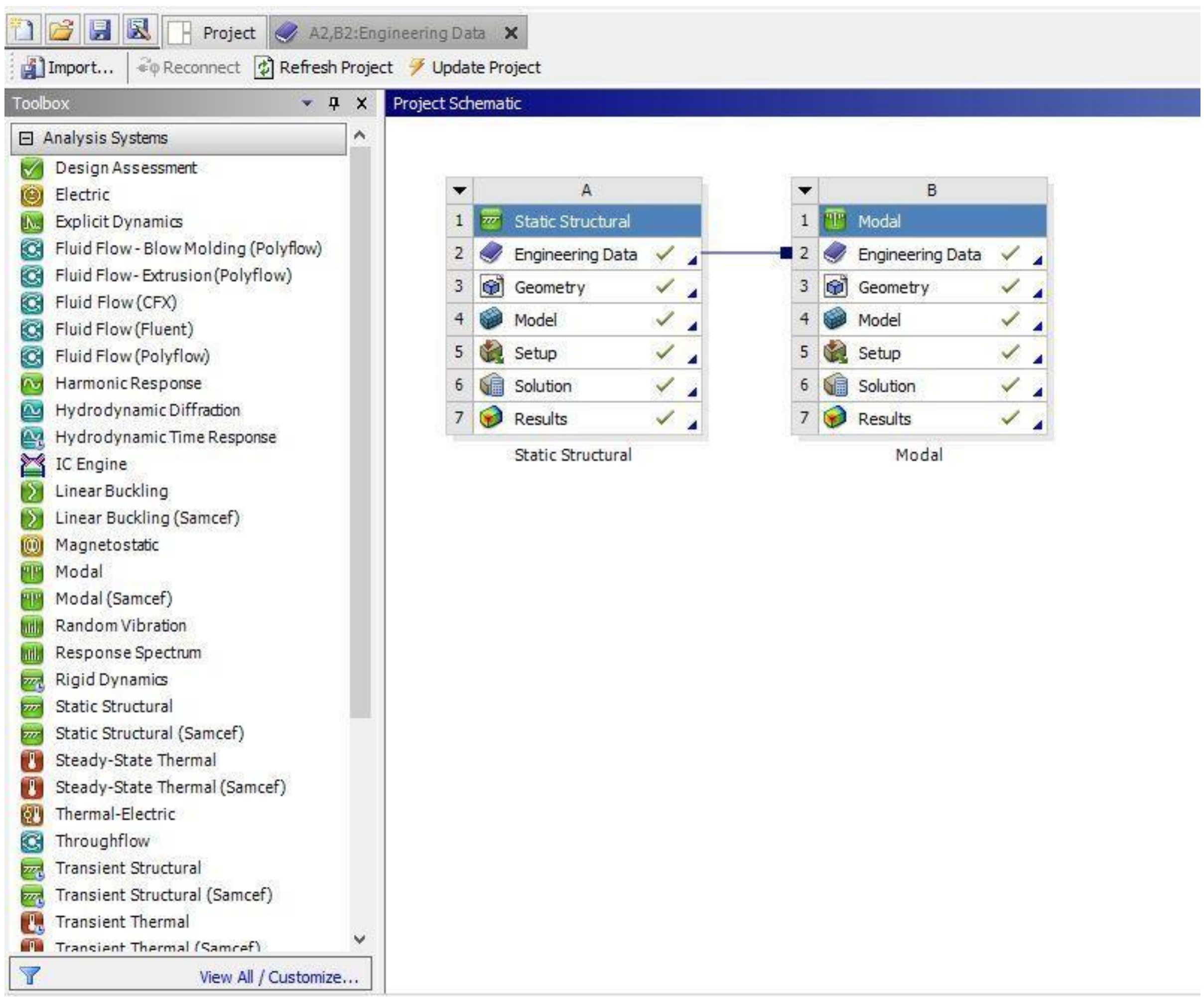
. 2 If you know an object's natural frequency, you know how it will vibrate.

3 If you know how an object vibrates, you know what kinds of waves it will create.

4 If you want to make specific kinds of waves, you need to create objects with natural frequencies that match the waves you want.

All bodies have natural frequencies because all bodies have mass and stiffness's. And mechanical vibration is essentially a play between inertial and elastic forces.

5.2 Modal analysis (Dynamic Analysis)



Import geometry→Assign material properties

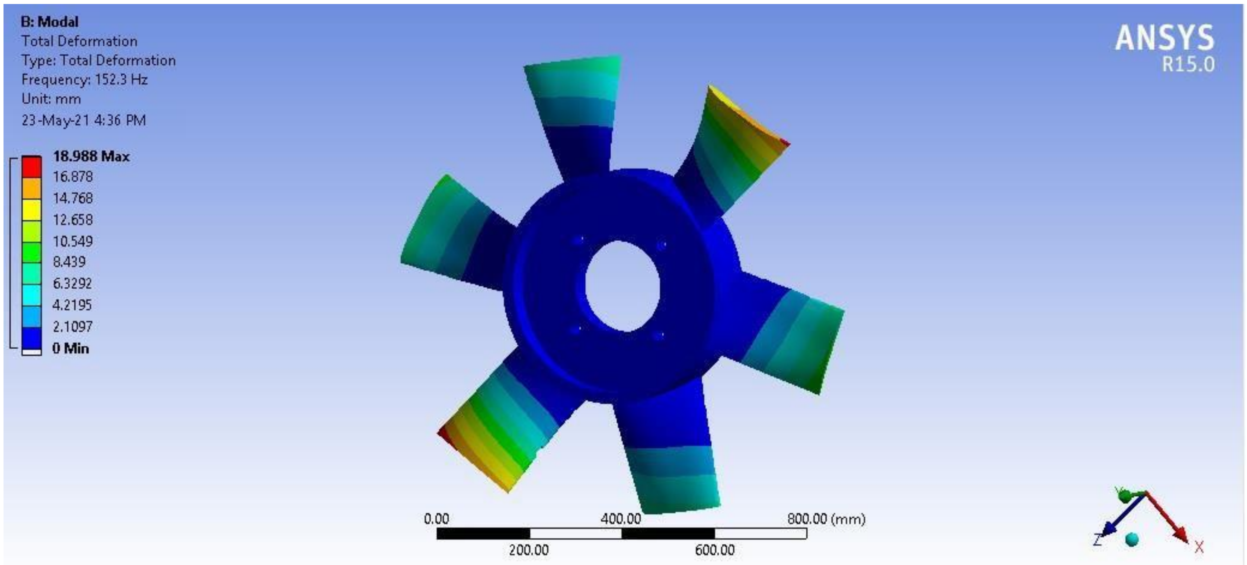
Static structural→fixed support→select holes

Analysis settings→no of modes→6

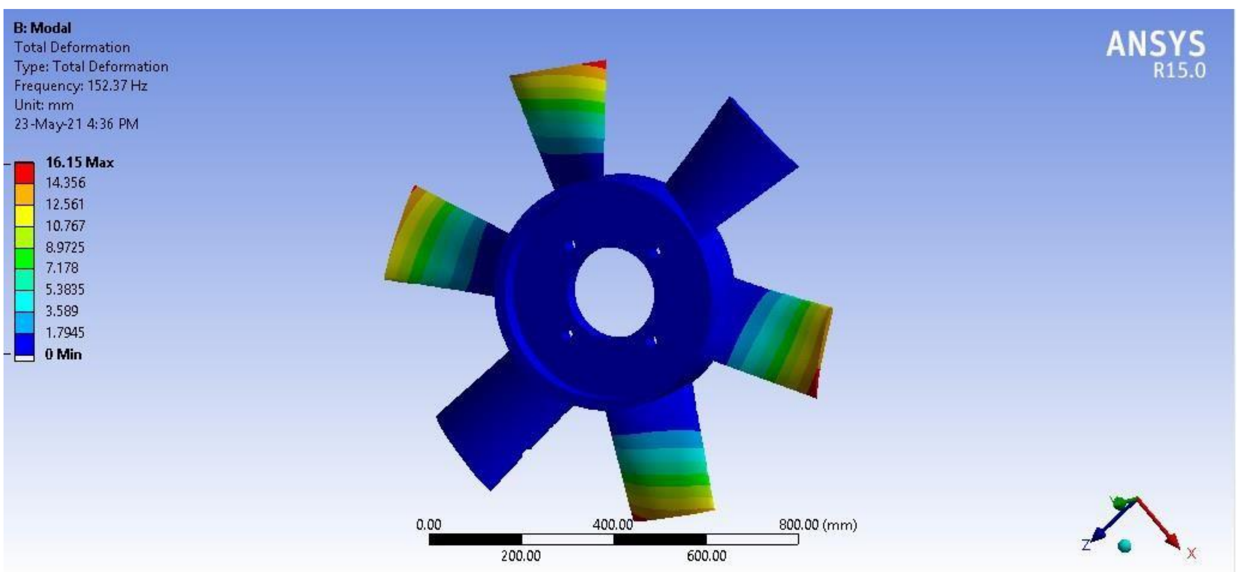
Solution →deformation

CAST IRON

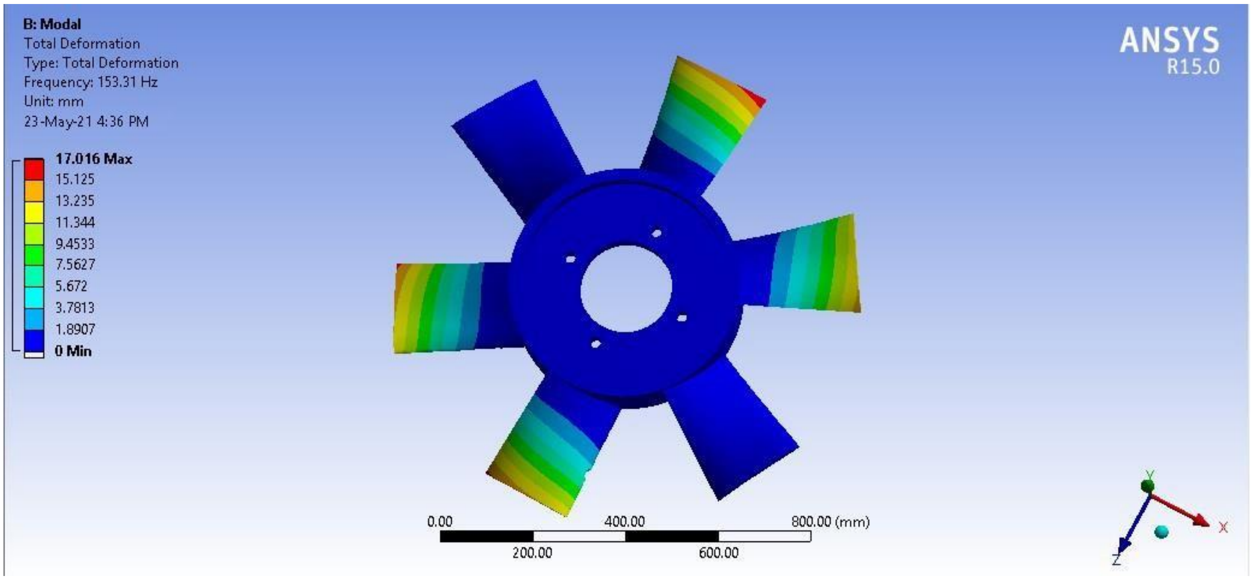
MODE 1



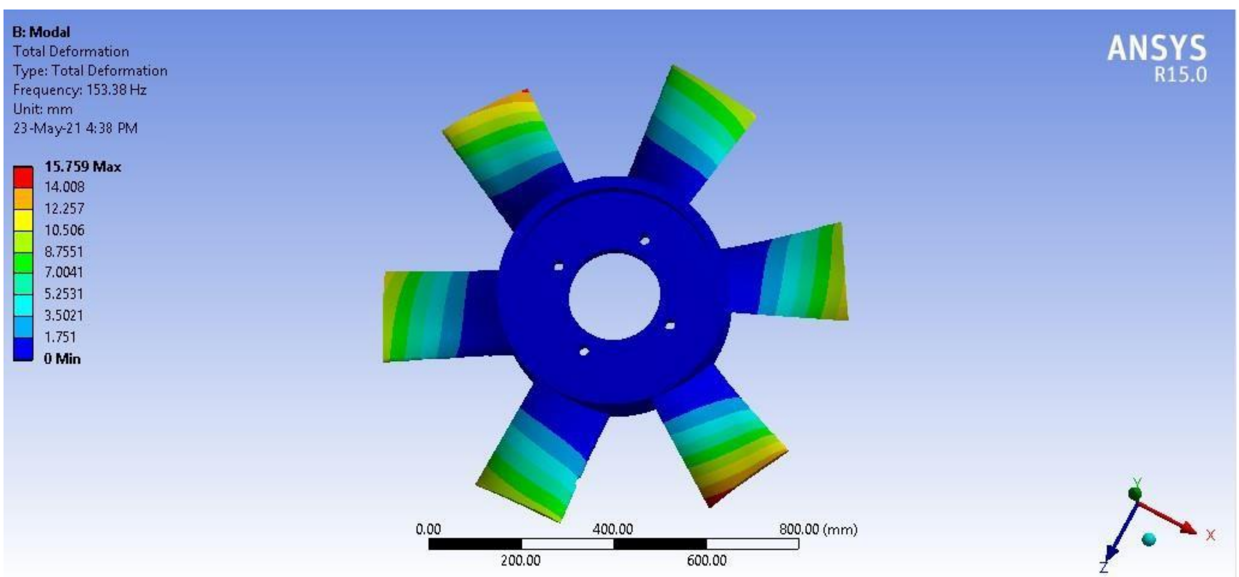
MODE 2



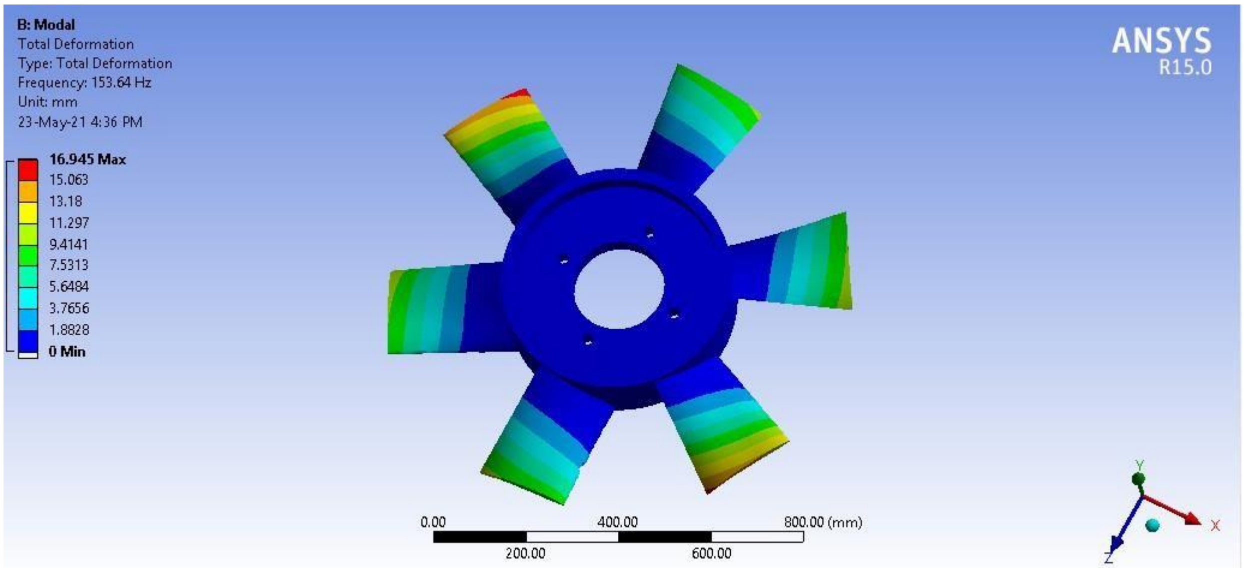
MODE 3


B: Modal
Total Deformation
Type: Total Deformation
Frequency: 153.31 Hz
Unit: mm
23-May-21 4:36 PM
17.016 Max
15.125
13.235
11.344
9.4533
7.5627
5.672
3.7813
1.8907
0 Min
ANSYS
R15.0
0.00
400.00
800.00 (mm)
200.00
600.00
Y
X
Z

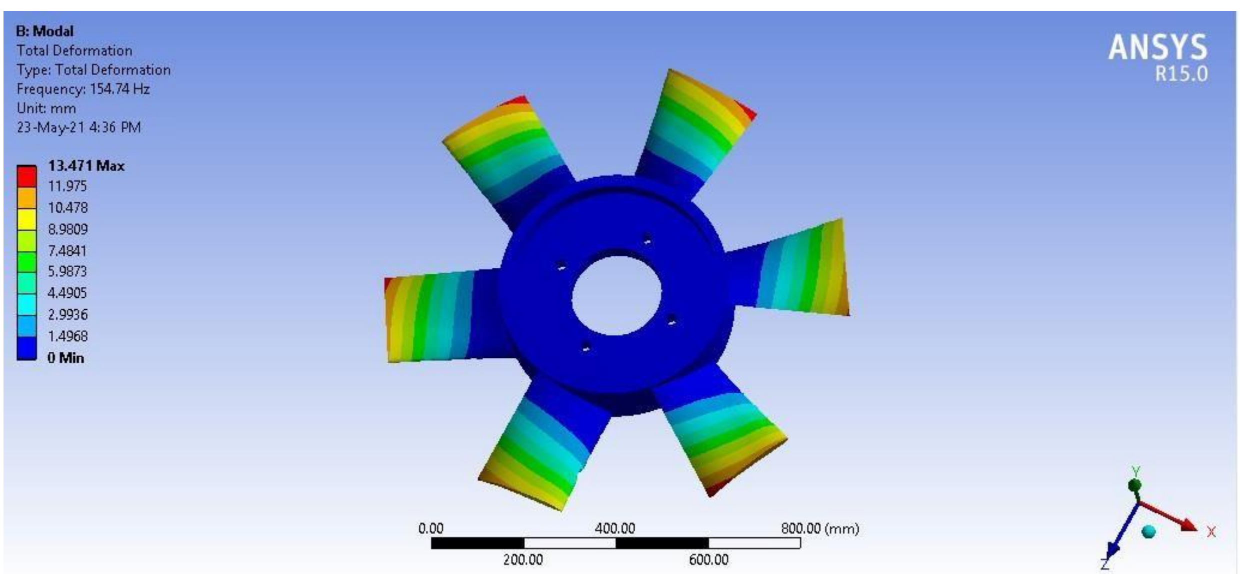
MODE 4


B: Modal
Total Deformation
Type: Total Deformation
Frequency: 153.38 Hz
Unit: mm
23-May-21 4:38 PM
15.759 Max
14.008
12.257
10.506
8.7551
7.0041
5.2531
3.5021
1.751
0 Min
ANSYS
R15.0
0.00
400.00
800.00 (mm)
200.00
600.00
Y
X
Z

MODE 5

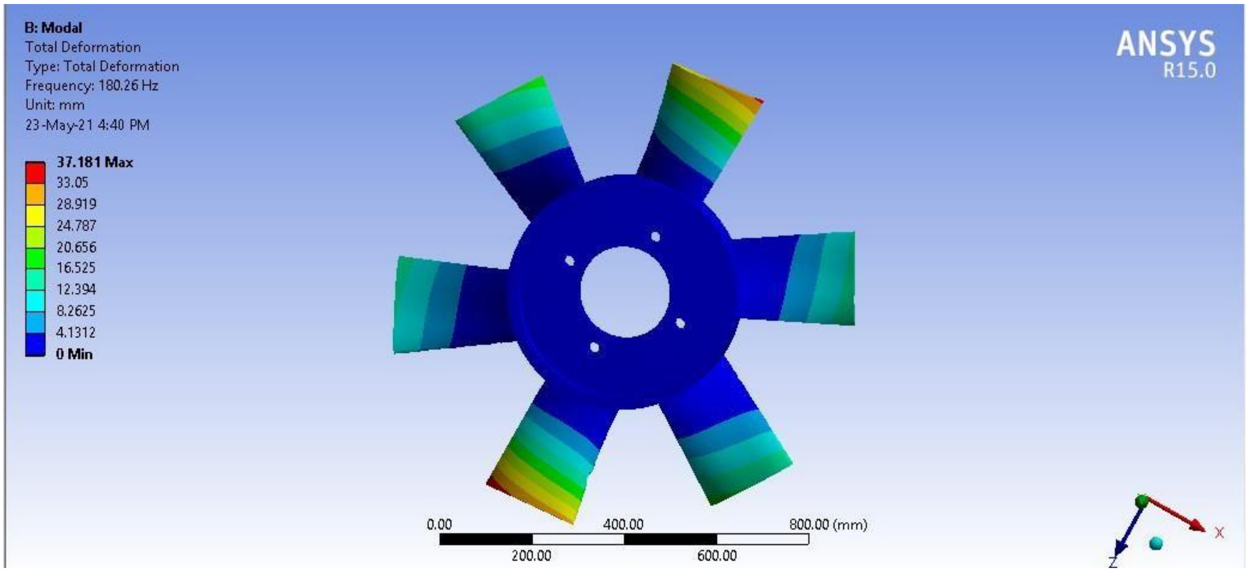

B: Modal
Total Deformation
Type: Total Deformation
Frequency: 153.64 Hz
Unit: mm
23-May-21 4:36 PM
16.945 Max
15.063
13.18
11.297
9.4141
7.5313
5.6484
3.7656
1.8828
0 Min
ANSYS
R15.0
0.00
400.00
800.00 (mm)
200.00
600.00
Y
X
Z

MODE 6

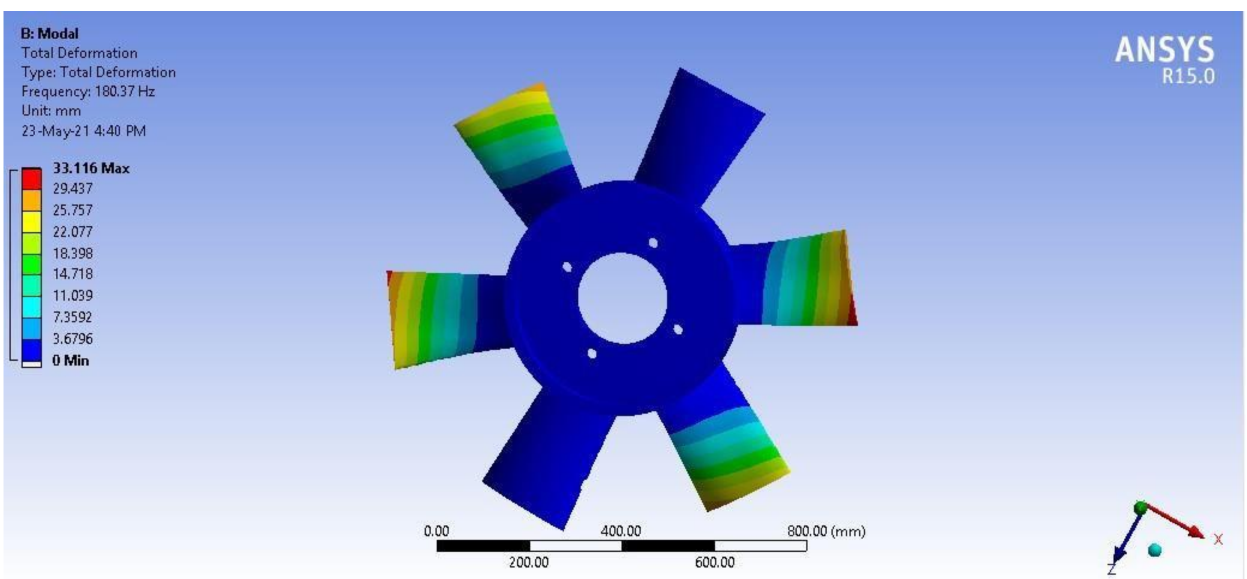

B: Modal
Total Deformation
Type: Total Deformation
Frequency: 154.74 Hz
Unit: mm
23-May-21 4:36 PM
13.471 Max
11.975
10.478
8.9809
7.4841
5.9873
4.4905
2.9936
1.4968
0 Min
ANSYS
R15.0
0.00
400.00
800.00 (mm)
200.00
600.00
Y
X
Z

AZ91D

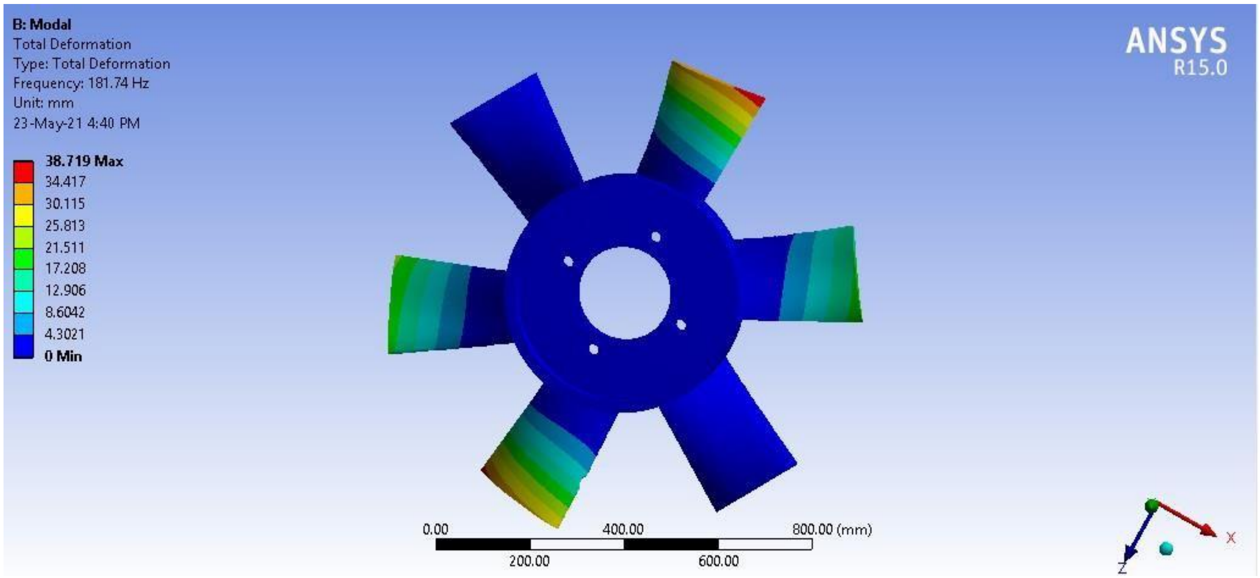
MODE 1



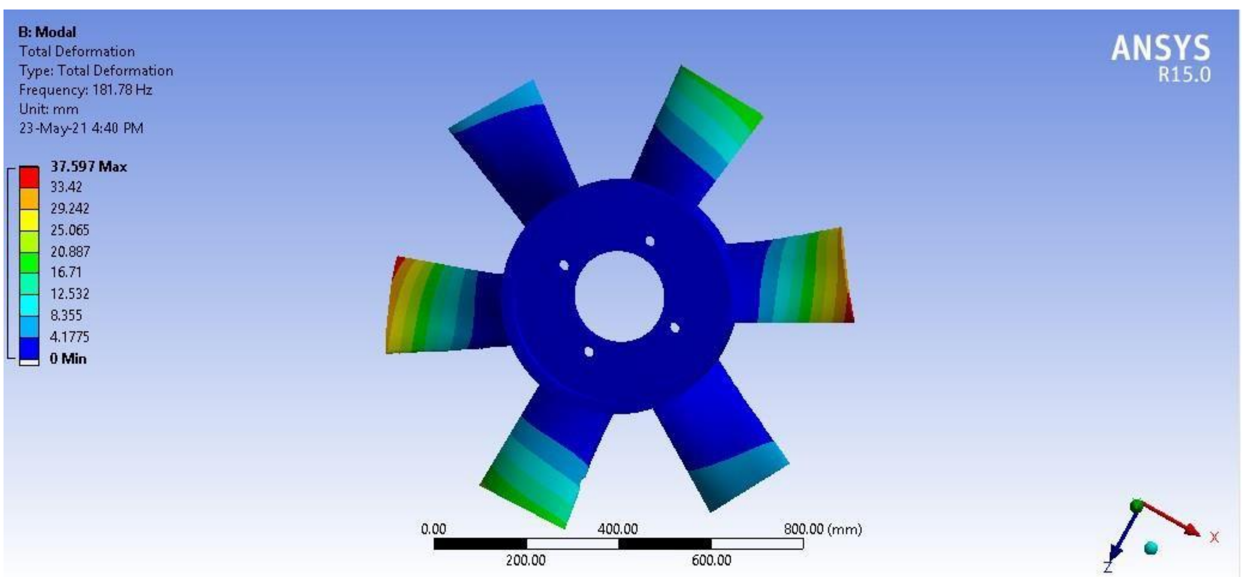
MODE 2



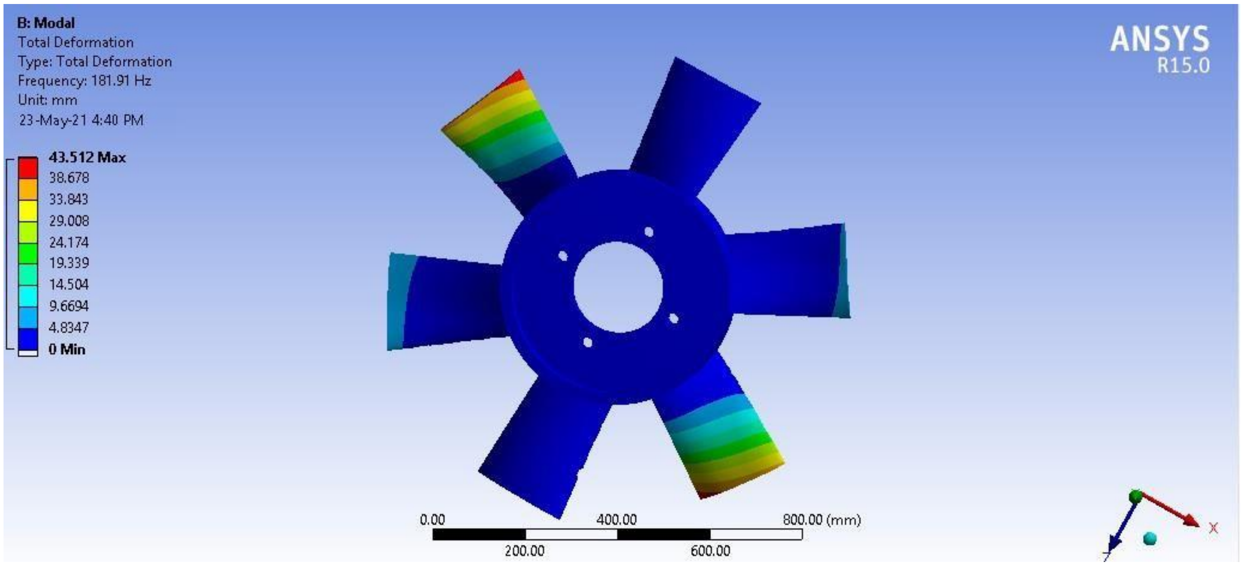
MODE3


B: Modal
Total Deformation
Type: Total Deformation
Frequency: 181.74 Hz
Unit: mm
23-May-21 4:40 PM
38.719 Max
34.417
30.115
25.813
21.511
17.208
12.906
8.6042
4.3021
0 Min
ANSYS
R15.0
0.00
400.00
800.00 (mm)
200.00
600.00
X
Z

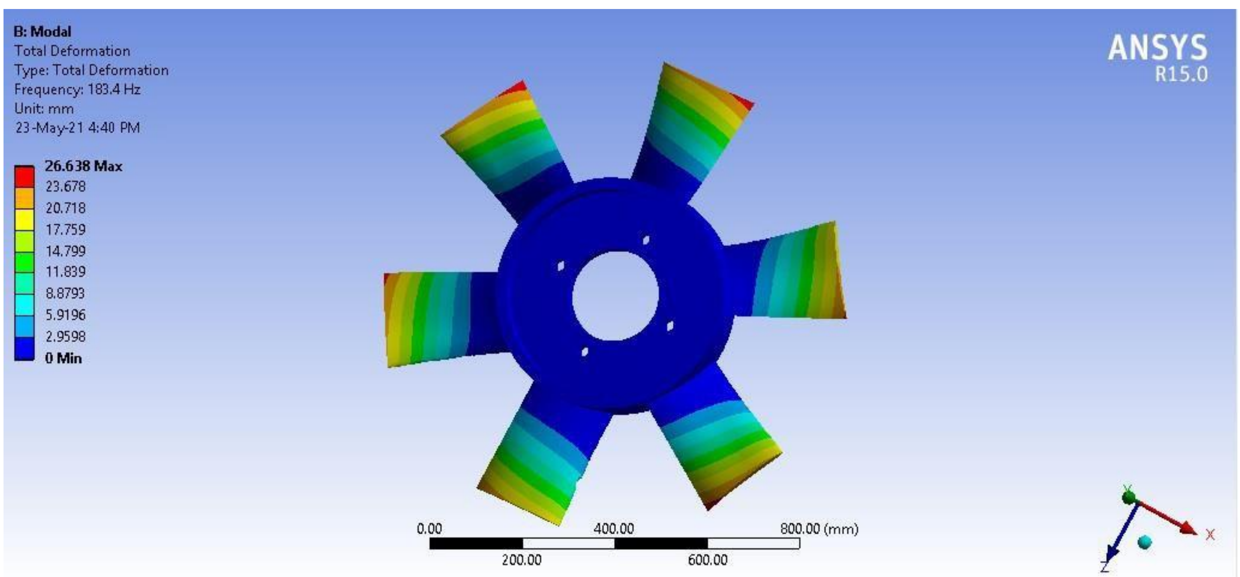
MODE4


B: Modal
Total Deformation
Type: Total Deformation
Frequency: 181.78 Hz
Unit: mm
23-May-21 4:40 PM
37.597 Max
33.42
29.242
25.065
20.887
16.71
12.532
8.355
4.1775
0 Min
ANSYS
R15.0
0.00
400.00
800.00 (mm)
200.00
600.00
X
Z

MODE5

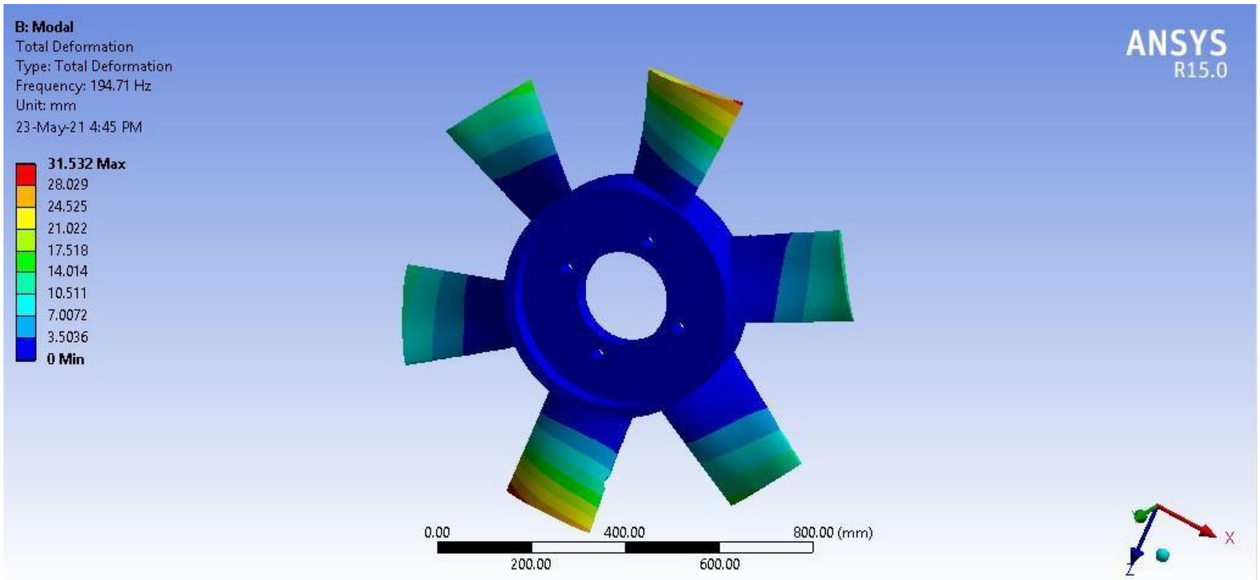

B: Modal
Total Deformation
Type: Total Deformation
Frequency: 181.91 Hz
Unit: mm
23-May-21 4:40 PM
43.512 Max
38.678
33.843
29.008
24.174
19.339
14.504
9.6694
4.8347
0 Min
ANSYS
R15.0
0.00
400.00
800.00 (mm)
200.00
600.00

MODE6

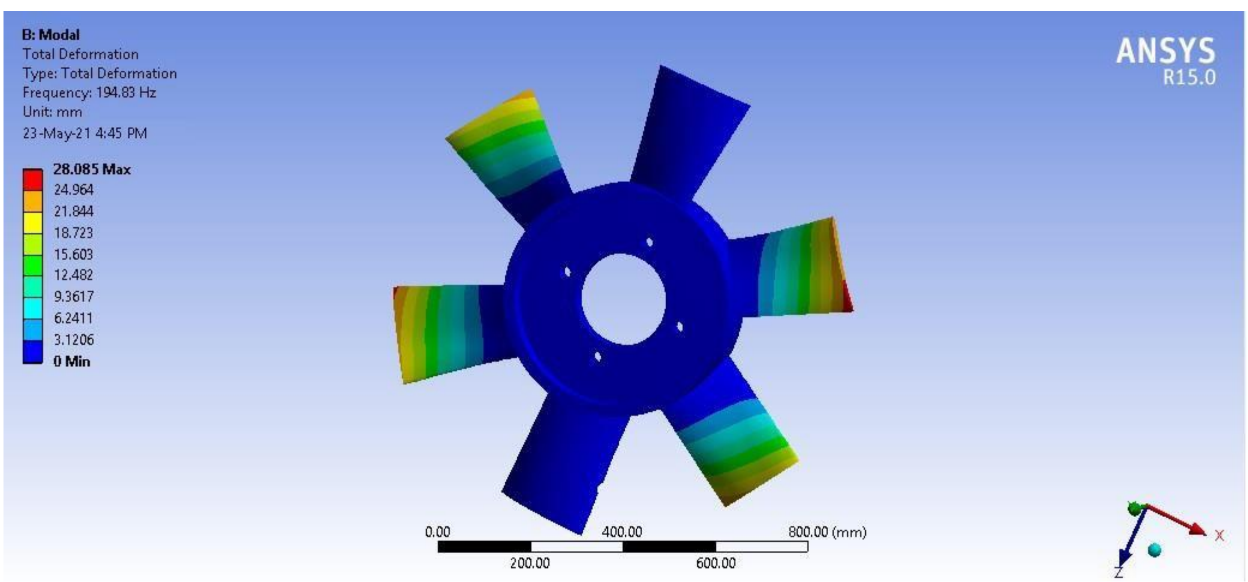

B: Modal
Total Deformation
Type: Total Deformation
Frequency: 183.4 Hz
Unit: mm
23-May-21 4:40 PM
26.638 Max
23.678
20.718
17.759
14.799
11.839
8.8793
5.9196
2.9598
0 Min
ANSYS
R15.0
0.00
400.00
800.00 (mm)
200.00
600.00

AL-4032

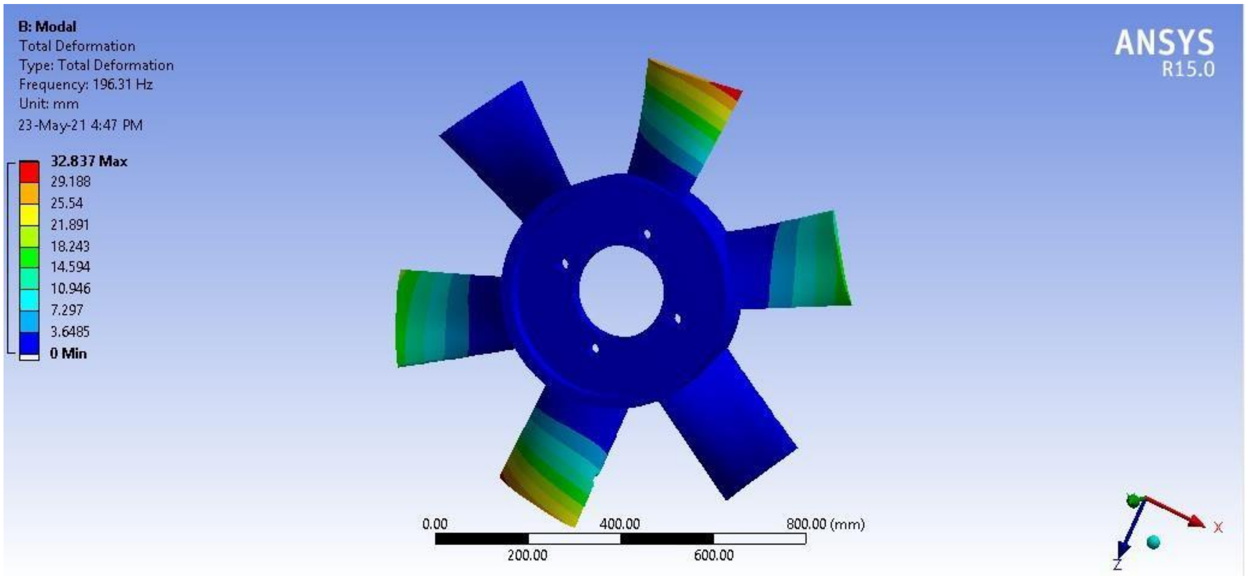
MODE1



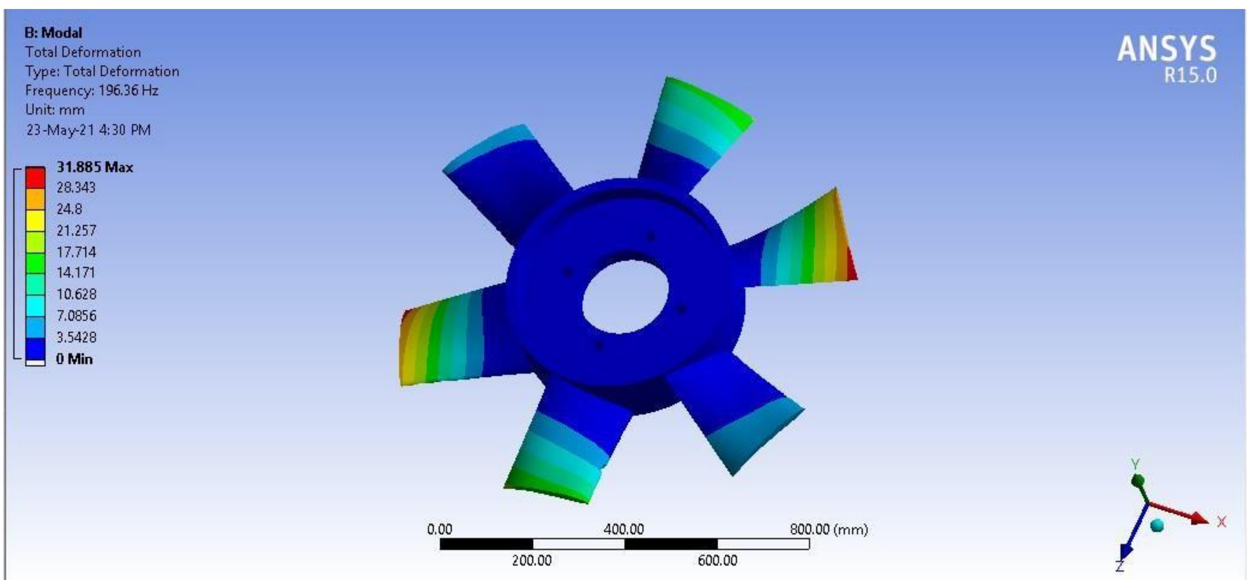
MODE2



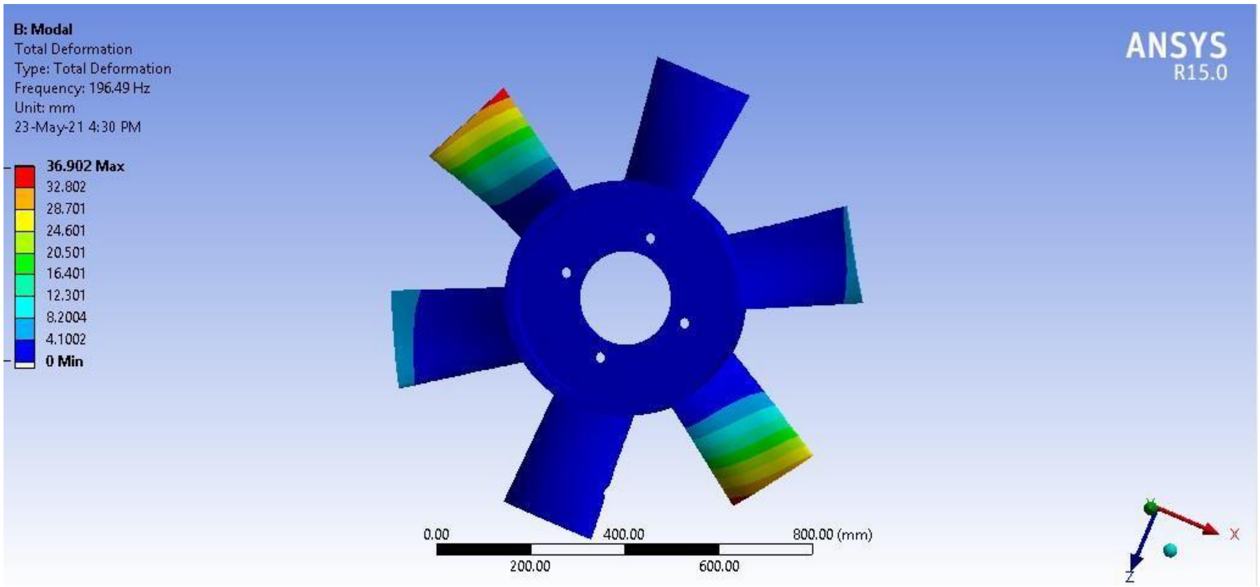
MODE3


B: Modal
Total Deformation
Type: Total Deformation
Frequency: 196.31 Hz
Unit: mm
23-May-21 4:47 PM
32.837 Max
29.188
25.54
21.891
18.243
14.594
10.946
7.297
3.6485
0 Min
ANSYS
R15.0
0.00
400.00
800.00 (mm)
200.00
600.00

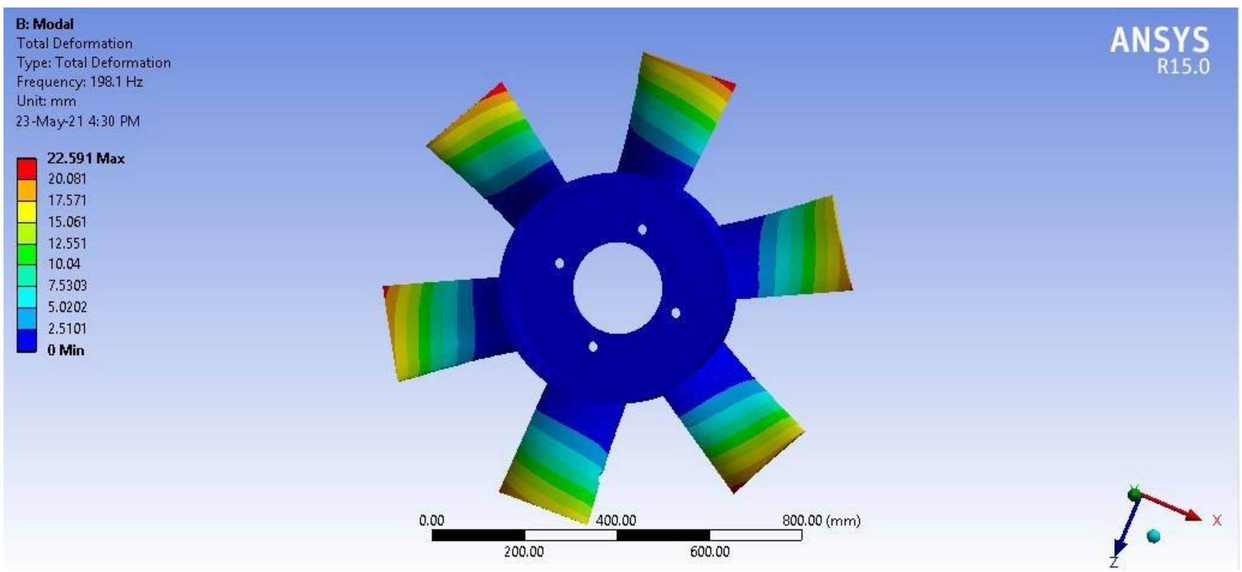
MODE4


B: Modal
Total Deformation
Type: Total Deformation
Frequency: 196.36 Hz
Unit: mm
23-May-21 4:30 PM
31.885 Max
28.343
24.8
21.257
17.714
14.171
10.628
7.0856
3.5428
0 Min
ANSYS
R15.0
0.00
400.00
800.00 (mm)
200.00
600.00

MODE5


B: Modal
Total Deformation
Type: Total Deformation
Frequency: 196.49 Hz
Unit: mm
23-May-21 4:30 PM
36.902 Max
32.802
28.701
24.601
20.501
16.401
12.301
8.2004
4.1002
0 Min
ANSYS
R15.0
0.00
400.00
800.00 (mm)
200.00
600.00
X
Z

MODE6


B: Modal
Total Deformation
Type: Total Deformation
Frequency: 198.1 Hz
Unit: mm
23-May-21 4:30 PM
22.591 Max
20.081
17.571
15.061
12.551
10.04
7.5303
5.0202
2.5101
0 Min
ANSYS
R15.0
0.00
400.00
800.00 (mm)
200.00
600.00
X
Z

Table

	Cast iron	**Az91d**	**Al-4032**
Mode1(Hz)	152.3	180.26	194.71
Mode2(Hz)	152.37	180.37	194.83
Mode3(Hz)	153.31	181.74	196.31
Mode4(Hz)	153.38	181.78	196.36
Mode5(Hz)	153.64	181.91	196.49
Mode6(Hz)	154.74	183.4	198.1

CHAPTER 6
CONCLUSION

In this project engine cooling fan model was developed by using cad tool solid works and analyzed with cae tool Ansys workbench in this process to calculate the strength of the model here pressure applied on model with rotational velocity values. And calculating the results like deformations stress and strain and safety facto values and also natural frequency results

Our model with existing material cast iron and it used in real time due to cheap and easy to cast, so that here new materials are az91d and al-4032t6 these two materials are also very good at casting and also these materials having less density values so that weight can be reduces

From the results model can with stand 12.5Mpa pressure at 2500RPM rotational velocity these two are the applied boundary conditions on the fan. Here cast iron got 152.5Mpa stress where az91d (93.452Mpa) and al-4032(100.8Mpa) stress values compare to all results az91d is having less stress values and high factor of safety values, but al-4032t6 is having factor of safety value more than other materials and also it having good natural frequency results than other materials, by these cases we can use both materials and finally among all al-4032 is strongest of any other and less in weight

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