MODELING AND STATIC MODAL ANALYSIS OF CI ENGINE TURBOCHARGER COMPRESSOR WITH VARIOUS MATERIALS USING FEM

[1]M.TECH STUDENT, DEPARTMENT OF MECHANICAL ENGINEERING, HELAPURI INSTITUTE OF TECHNOLOGY AND SCIENCE ELURU, ANDHRA PRADESH.
[2]ASSISTANT PROFESSOR, HEAD OF THE DEPARTMENT, DEPARTMENT OF MECHANICAL ENGINEERING, HELAPURI INSTITUTE OF TECHNOLOGY AND SCIENCE ELURU, ANDHRA PRADESH.
[1]SOMAYAJULA SHIVA SAI SARATH CHANDRA [2]Mr. K. SIVARAJU

ABSTRACT

Turbocharger is used throughout the automobile industry as they can intensify the output of an internal combustion engine without the need to increase its cylinder size. turbocharger to compress more air flowing into the engine's cylinder. When air is compressed the oxygen molecules are packed closer together. This increase in air means that more fuel can be added for the same size naturally aspirated engine.In order to increase the implementation of the conventional turbocharger compressor's to boost the pressure in the engine. The application of such a mechanical device enables automotive manufacture ring industries to adopt smaller displacement engines, commonly known as "engine downsizing". The aim of the project is modelling a turbo charger compressor wheel using in Catia v5 and Static and modal analysis using in Ansys software. Finally find out the Von-misses stresses, Total deformations, Shear stress, Strain in static analysis and in dynamic anlaysis using these materials INCOLOY 740, INCOLOY ALLOY 909, INCOLOY ALLOY A-286 find out the Frequncies at different total deformations I suggest the design modification to the Compressor to improve performance of the compressor.

Keywords - ANSYS, Catia, Ansys, Horse power, Turbocharger.

1 INTRODUCTION

1.1 TURBOCHARGER

A turbocharger consists of a compressor wheel and exhaust gas turbine wheel coupled together by a solid shaft and that is used to boost the intake air pressure of an internal combustion engine. The exhaust gas turbine extracts energy from the exhaust gas and uses it to drive the compressor and overcome friction. In most automotive-type applications, both the compressor and turbine wheel are of the radial flow type. Some applications, such as medium- and low- speed diesel engines, can use an axial flow turbine wheel instead of a radial flow turbine.

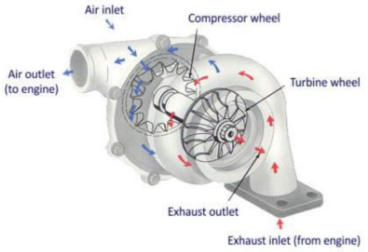


FIGURE 1 TURBOCHARGER CONSTRUCTION AND FLOW OF GASES

Center-Housing. The turbine-compressor common shaft is supported by a bearing system in the center housing (bearing housing) located between the compressor and turbine (Figure 2). The shaft wheel assembly (SWA) refers to the shaft with the compressor and turbine wheels attached, i.e., the rotating assembly. The center housing rotating assembly (CHRA) refers to SWA installed in the center-housing but without the compressor and turbine housings. The center housing is commonly cast from gray cast iron, but aluminum can also be used in some applications. Seals help keep oil from passing through to the compressor and turbine. Turbochargers for high exhaust gas temperature applications, such as spark ignition engines, can also incorporate cooling passages in the center housing.

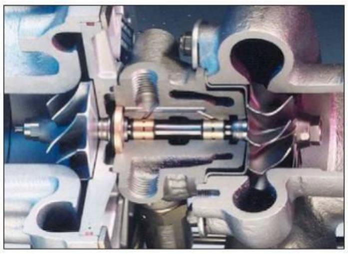


FIGURE 2 SECTIONAL VIEW OF TURBOCHARGER

1.2 COMPRESSOR WHEEL ANATOMY

(A).NOSE

This is the front most part of the compressor wheel, facing the incoming air. Its shape and design direct the air onto the wheel’s blades, helping to reduce turbulence and ensuring a smooth airflow.

(B).THE HUB

The hub is the central part of the component and connects to the turbo shaft. In effect, it is the anchor point for the blades and is essential for transferring rotational energy from the shaft to the blades.

(C).BLADE ROOT

The blade root attaches the base of each blade to the hub. To enable the compressor wheel to achieve high rotational speeds, blade roots are designed to withstand significant applied force and are crucial in ensuring consistent airflow and preventing blade damage.

(D).EXDUCER

The exducer is the point at which the compressed air exits the wheel on its way to the intercooler and intake manifold. In most cases it represents the longest diameter of the wheel and is essential for controlling the flow of pressurized air.

(E).SPLITTER BLADES

Splitter blades are smaller blades situated between the main blades of the compressor wheel. Their main role is to improve the wheel’s aerodynamic efficiency by reducing turbulence and enhancing air compression.

(F).BACK DISC

The back disc is the flat, circular portion of the component situated below the blades. It is important for wheel stability and provides a surface for the balancing cuts. A well-balanced compressor wheel is essential to minimize vibrations and ensure smooth operation.

(G).MAIN BLADES

The main blades are the primary components responsible for compressing incoming air. Their shape, angle and size are carefully engineered to maximize airflow and pressure increase. They play a central role in the overall efficiency of the component.

(H).INDUCER

The inducer is located just behind the nose and its role is to capture and accelerate incoming air. The design of the inducer is critical as it directly affects the wheel’s ability to draw in and compress air effectively.

(I).BALANCE CUTS

Balance cuts, also known as balance holes, are precision cuts made in the back disc and the nose. These cuts are strategically placed to prevent excessive vibration and bearing wear in the turbocharger, which can lead to premature failure.

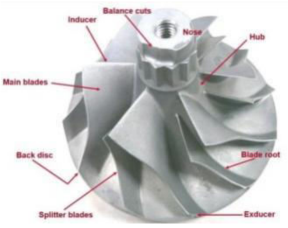


FIGURE 3 PARTS OF COMPRESSOR

1.3 TURBO CHARGER OPERATING PRINCIPLE:

In naturally aspirated piston engines, intake gases are drawn or "pushed" into the engine by atmospheric pressure filling the volumetric void caused by the downward stroke of the piston (which creates a low-pressure area), similar to drawing liquid using a syringe. The amount of air actually inspired, compared with the theoretical amount if the engine could maintain atmospheric pressure, is called volumetric efficiency. The objective of a turbocharger is to improve an engine's volumetric efficiency by increasing density of the intake gas (usually air) allowing more power per engine cycle.

The turbocharger's compressor draws in ambient air and compresses it before it enters into the intake manifold at increased pressure. This results in a greater mass of air entering the cylinders on each intake stroke. The power needed to spin the centrifugal compressor is derived from the kinetic energy of the engine's exhaust gases.

In automotive applications, 'boost' refers to the amount by which intake manifold pressure exceeds atmospheric pressure. This is representative of the extra air pressure that is achieved over what would be achieved without the forced induction. The level of boost may be shown on a pressure gauge, usually in bar, psi or possibly Kpa. The control of turbocharger boost has changed dramatically over the 100-plus years of their use. Modern turbochargers can use waste gates, blow-off valves and variable geometry, as discussed in later sections.

In petrol engine turbocharger applications, boost pressure is limited to keep the entire engine system, including the turbocharger, inside its thermal and mechanical design operating range. Over-boosting an engine frequently causes damage to the engine in a variety of ways including pre-ignition, overheating, and over-stressing the engine's internal hardware. For example, to avoid engine knocking (also known as detonation) and the related physical damage to the engine, the intake manifold pressure must not get too high, thus the pressure at the intake manifold of the engine must be controlled by some means. Opening the waste gate allows the excess energy destined for the turbine to bypass it and pass directly to the exhaust pipe, thus reducing boost pressure. The waste gate can be either controlled manually (frequently seen in aircraft) or by an actuator (in automotive applications, it is often controlled by the engine control unit).

2 LITERATURE REVIEW

D. Ramesh Kumar, B. Shanmugasundaram, P. Mohanraj et, al., [2017] in this work the author used different material for the turbine and compressor impeller and investigation has been done by ANSYS and CATIA software. The variation of stresses, strains, and deformation profile of the turbine and compressor impeller has been determined by using the ANSYS software. The authors are used different analysis, to investigate stresses, strains and displacements of the turbine used structural analysis, to investigate the frequency and deflection of the turbine and compressor impeller used modal analysis, to investigate total heat flux and direction heat flux used thermal analysis. The turbine and compressor impeller of a turbocharger will be recommend based on the better material results. They used different material for turbine and compressor, Inconel alloy N06230 and Incoloy alloy A-286 respectively, replace of existing material, Inconel alloy 740 and Incoloy alloy 909 respectively. They concluded that for turbine impeller the minimum von-mises stress, maximum frequency and maximum total heat fluxes is obtained for the Inconel alloy N06230, and for compressor impeller the minimum von-mises stress and maximum frequency is obtained for the Incoloy alloy A-286. So the Incoloy alloy A-286 and Inconel alloy N06230 is the best material for turbocharger impeller to get better efficiency and performance of it. [1]

Shujie Liu, Chi Liu, Yawei Hu, SIbo Gao, Yifan Wang, Hongchao Zhang et, al., [2016] studied about the fatigue life assessment of centrifugal compressor impeller has a critical issue in the industrial practise as well as automotive application. In this study, both centrifugal load and aerodynamic load have beern considered in the analysis of the impeller life using finite element analysis(FEA). The impeller working under an alternating cycle loads and a dynamic load caused by the centrifugal loads, aerodynamic loads, exciting loads, etc. All this loads are combined with impact loads from collision with particles in the medium, the impeller blade suffers multiple failure modes and this failure modes include abrasion, erosion, stress fatigue, and others. This research shown that the fatigue cracking and fractures of impeller blades are the main factors leading to almost fifty percent of the centrifugal compressor operational failure. There are two methods to ascertain the fatigue life of mechanical components. One is to conduct an experiment representing the actual working condition which give obviously accurate result but it is costly and complex process. The other method is the numerical method in which the simulation model and the fatigue parameters are combined to calculate the fatigue life with lower cost and high efficiency. The author concluded that compared to the working condition that set for the simulation, the real operational condition of the FV520B impeller blade is far more complex. And also conclude that there could be much more noise and uncertainties in the fatigue lab experiment that produced error in data, and hence a well designed experiment and data analysis procedure to reduce the error in lab experiment results are highly recommended. [2]

CH.Satyasai Manikanta, S.D.V.V.S.B.Reddy, A.Sirishabhadrakali et, al.,[2016] presents structural analysis of the turbocharger impeller by using different material under different static and dynamic condition to obtaining the stress values and strain values and deformation range. In this study the authors consider design for 30000 rpm of the impeller. The design has mainly focused to reduce the blade size according to the requirements and geometrical modeling is used when designing this impellers of turbocharger. The authors using four different material namely AISI 4063 STEEL, INCONEL 718, TECHNITIUM, TITANIUM 2646. Turbocharger impeller has to withstand high centrifugal loads and high pressures and temperatures when working, So these materials are selected in this paper for impeller depending on their properties. The design was made in CATIA (computer aided three dimensional interactive application) and analysis done in ANSYS workbench software. The author concluded after design and analysis of impeller that Titanium Ti 2646 gives better life for impeller because its having less stress and displacement values compared to Technatium. Its mass properties is half to the base material Inconel 718, So decreased mass and increased impeller life. [3]

M.F. Moreira et, al., [2016] studied about the aluminum compressor wheel used in the turbocharged diesel engine which are made with machined AA2618 T652 alloy and installed in light truck engines. The premature failure of the wheels happened after life between 40000 km and 300000 km, while the expected life was about 1000000 km. This particular wheel presents 14 blades, 7 full blades and 7 small blades. The goal of this study is to check whether the material of the faiure wheels was in accordance with standards, and to identify the fracture mechanisms involved in the premature failure of the wheels. The nine different impeller or compressor wheels were submitted to chemical analysis, microstructural characterization, X-ray diffraction, hardness testing and fractographic examinations. The conclusion of this study is that a fatigue process was trigged by intergranular corrosion on the upper surface of the AA 2618 T652 aluminum alloy compressor wheel. [4]

B.P.Terani, Dr. K.S.Badarinarayan, Prakasha.A.M et, al., [2015] stated that turbocharger are very essential to incorporate in diesel engine. Turbocharger will feed compressed air to engine which produce more power and torque than natural aspirated engine, this process to obtained more power from engine is called engine downsizing. This study is to analyses impellers structural, modal and thermal stability with various boundary conditions and blade parameters. In order to achieve boost the turbocharger needs power and this is provided by the exhaust gas which will spin the turbine impeller and with common shaft compressor wheel will compress air and feeds it in to same engine. Turbocharger spins speed up to 15000rpm (revolution per minute) that is about 30 times faster than car engine. Impeller wheel has to with stand high exhaust gas temperature and stress induced force and external pressure. The author studied about the difficulties in manufacturing and testing of turbocharger, for that the CAE is very useful to analyze. Also studied that various iterations of turbine impeller with varied blade thickness, varied blade number are made and they are compared with stock model. Author concluded that Structural analysis of impeller to find stress deformation and strain, modal analysis to find natural frequency and finally thermal analysis is carried out for effect of exhaust gases on impeller turbine. [5]

V.R.S.M. Kishore Ajjarapu1, K. V.P.P.Chandu, D.M.Mohanthy Babu et, al., [2015] In these work impeller was designed with three different materials. The investigation can be done by using CATIA and ANSYS software. The CATIA is used for modeling the impeller and analysis is done in ANSYS. ANSYS is dedicated finite element package used for determining the variation of stresses, strains and deformation across profile of the impeller. This work is about to investigate the effect of temperature, pressure and induced stresses on the impeller. There are several way to reduce the price of the turbochargers, easiest way is to keep the design as simple as possible and hence made to suggest the best material for an impeller of a turbocharger by comparing the results obtained for three different materials wrought aluminum alloy 2011, incoloy alloy 909, wrought aluminum copper alloy for compressor and inconel alloy 740, inconel alloy 783, wrought aluminum alloy 2219 for turbine impeller. Author get result that the compressor material is withstand up to the (482.61 HZ) with the minimum stress (32.981 MPA) for the compressor material incoloy alloy 909 and the turbine material is withstand up to the (773.58 HZ) with the minimum stress (171.01 MPA) for the turbine material inconel alloy 740. [6]

Alain Batailly, Mathias Legrand et, al., [2015] stated that the contribution addresses the vibratory analysis of unilateral contact induced structural interactions between a bladed impeller and is surrounding flexible casing. This study shows that the linear interaction condition, commonly considered for the safe design of impellers and casing in turbomachinery, may be advantageously combined with the presented numerical strategy in order to assess the actual importance of predicted critical speeds. This study involved the casing flexibility allows for broadening the scope of simulated interactions from rubbing phenomena to modal interaction and detecting critical angular speeds for each type of interaction. It is concluded that the linear interaction condition, which stands as an important guideline for the design of impeller and casings, may be advantageously complemented by the numerical strategy exposed. And also concluded that critical speed may be predicted for free vibration modes that are not geometrically compatible. [7]

Neelambika, Veerbhadrappa et, al., [2014] this work is about detailed CFD analysis was done to predict the flow pattern inside the impeller which is an active pump component. The optimum inlet and outlet vane angles are calculated for the existing impeller by using the empirical relations. In the first case, outlet angle is increased by 5˚.Improved efficiency by changing the outlet angle the efficiency of the impeller is improved to 59%. In the second case inlet angle is decreased by 10˚, and efficiency of the impeller in this case is 61%. From this analysis it is understood that the changes in the inlet vane angle did not changes the efficiency of the impeller as much as the changes in outlet angle. The existing impeller, the head and efficiency are found out to be 19.24 m and 55% respectively. The impeller 1, the percentage increase in the head and efficiency are 3.22% and 7.27% respectively. The impeller 2, the percentage increase in the head and efficiency are 10.29% and 10.91% respectively. The impeller 3, the percentage increase in the head and efficiency are 13.66% and 18.18% respectively. Based on the above, it is concluded that impeller 3 gives better performance than the impeller 1 and impeller 2. [8]

Shaikh Mohammad Rafi, N. Amara Nageswara Rao, et. Al.,[2014] this study is about structural analysis of turbocharger compressor wheel. In this research they work on different material and changing design of compressor wheel. Using Pro-E they design the compressor wheel and analysis is done by using FEA package. The main aim of this study is to increase the performance of the compressor wheel. They studied on three different materials steel, alloy706, and alloy718. After completion of the analysis they get the result that Inconel 706 alloy material is better than other two alloy, 718 alloy and steel. And changed model is also found safe because result of modified are nearly equal to the actual turbocharger wheel. From that they conclude that stress are minimized then the performance maximized. [9]

Seiichi Ibaraki, Tetsuya Matsuo, Keiichi Shiraishi, Koichiro Imakiire, et. al., [2013] studied about the optimization of the compressor performance for high pressure turbocharged diesel engines. The objective is to develop optimized compressors that realize a wider operating range, high efficiency and relatively robust performance with respect to changes in engine operating conditions in the high pressure region. At the same time, optimized compressors must maintain high performance and sufficient surge margin at low engine loads. The authors developed new compressor impeller having relatively large backward swept blades and examined its performance. As a result authors achieved a wider operating range at high loads and good characteristics at low loads. This compressor design has been applied in the Mitsubishi MET 42SH turbocharger for the Mitsubishi 18KU30B high power diesel engine. The author concluded that the performance of newly developed impeller is more than the conventional impeller, in pressure ratio, operating range and characteristics at low speeds. The shape of the suction surface of the blade leading edge was improved, such that the compressor efficiency was increased.[10]

B.Mohan, B.E.Kumar et, al., [2011] in this study the axial composite impeller has been developed using commercial tools pro-e. They have chosen the suitable material for this study, namely Kevlar-49, carbon and SGlass with a standard epoxy resin for the composite matrix. Static and dynamic behaviour of the component were analyzed using finite element analysis commercial tool ANSYS 14.5. They have analyzed the stress distribution and displacements on the composite impeller in static analysis. The stress concentration region was identified in this analysis. For transient analysis, they applied dynamic force at various operating speeds of the impeller and analyzed the deflections and stress concentration regions. [11]

Changhee Kim, Horim Lee, Jangsik Yang, Changmimn Son et, al., [2016] study about the series of aerothermo-mechanical analysis which were carried out to predict the running tip clearance and the effect of impeller deformation on the performance using the two different compressor. In operation, the impeller deformation due to the combination of centrifugal force, aerodynamic pressure and thermal load result in non uniform tip clearance profile. The results show that the maximum displacement occurs at the leading edge tip of the impeller blade but maximum stress takes place at the blade root of the impeller. A significant reduction of the tip clearance height has occurred at the leading edge and the trailing edge of the impeller. Due to the reduction of the tip clearance, the tip leakage flow has decreased by 19.4% and 16.2% in the blade type A and B, respectively. The polytropic efficiency of blade type A and B at operating condition has increased by 0.72% and 1.81%, respectively. Conclusion of this study is that the largest deformation occurred at the leading edge tip of the impeller and the maximum stress took place at the blade root. There is constant cold build tip clearance to the non uniform tip clearance due to the impeller deformation during operation and after that the largest tip clearance has occurred at the leading and tailing edges of the impeller. Thus, the impeller deformation changes the blade flow structure reliability. They also concluded that polytropic efficiency and pressure ratio also increase due to reduction in the tip clearance over entire range. [12]

Isaias Hernandez-Carrillo, Christopher J Wood, Hao Liu et, al.,[2017] studied about the advanced material for the impeller in microturbine, for that there are different materials are selected a composite polyether-etherketone with 30% glass fiber filling (PEEK-GF30), Acrylonitrile Butadiene Styrene (ABS):thermoplastic and aluminum A354 is used as reference material. .The work is divided in the five component namely, heat and mass balance, mean line turbine design, 3D blading, fluid structure interaction (FSI), and prototyping. The working fluid is R245, Impeller diameter of 49mm and rotational speed of 36000rpm considered. Three situations are evaluated, full load operation, rotor blocked and 27% over speed. As a result they get that in over speed PEEKGF30 is structurally 11% stronger than Aluminum whereas ABS is 40% weaker than Aluminum and both materials are sufficiently strong for the application. Author concluded that the thermoplastic materials cost effective alternative and also use at chemical resistance and lower inertia. Whereas the polymeric materials are more expensive than aluminum but the overall cost could be reduced by introducing leaner mass production process. With the coupled of CFD and FEA simulation it is confirmed that PEEK-GF30 and ABS are feasible substitutes for aluminum in ORC microturbine impellers to be used with low temperature resources. [13]

S. Mayakannan, V. Jeevabharathi, R. Mani, M.Muthuraj et, al., [2016] studied about the design of impeller of centrifugal pump to increase its power and efficiency. They uses the six blade turbine, comparing with old material of a turbine and investigate can be done by SOLIDWORKS and ANSYS work bench software. The modeling is done in SOLIDWORKS and analysis is done in ANSYS work bench. It is determine that the variation of heat flux and directional deformation across profile of the impeller in ANSYS. This study for an attempt is made to suggest the best material for an impeller of turbine for an impeller of a turbine by comparing the results obtained for two different materials inconel alloy 783, inconel alloy 740 for centrifugal is to made it. It is concluded from the analysis that heat flow rate of inconel alloy740(6.6*10-9) is greater than the inconel alloy783(1.18*10-9) and stainless steel 2324(1.3*10-9). The inconel alloy 783 will produced more deflection under tangential and axial load temperature. At last from analysis, Titanium alloy blade material provides the less heat losses as compared to other materials. But as a view of structural and thermal behaviour other material inconel alloy 783 and inconel alloy 740 is better than the Titanium alloy. [14]

Rachel Schwind and Shaaban Abdallah et, al., [2015] in this study analysis will focus on different impeller blading designs including splitter bladed impellers, tandem bladed impellers, and tandem bladed impellers with a casing blade. There are different advantages associated with each impeller design. Author get result that the tandem bladed impeller have a low efficiency and pressure ratio as compared with the backswept and splitter bladed design and also get that the operating range is increases with the tandem design due to lower surge margin. Surge occurs when there is a low flow rate at a relatively high pressure ratio causing flow reversal. Surge can lead to catastrophic failure. Light surge with smaller flow reversal areas not necessarily cause a failure of the system and the compressor may still operate, but the performance will suffer. While it may not completely catastrophic failure, it could result in engine misfires if not enough air is fed into the combustion chamber. Hence the surge margin can be harmful to the performance of both the turbocharger and the engine. The authors concluded that while the tandem impeller design shows an improvement in operating range, it also shows a decrease in overall efficiency. For the turbocharger application, a large operating range is extremely desirable so it may be worth sacrificing some efficiency to achieve. [15]

Santosh Shuklaa, ApurbaKumar, Royband KaushikKumar et, al., [2015] in this paper the authors highlight to minimize the stress developed and deformation. The 3D model of mixed flow pump impeller blade was developed using CATIA and with four different materials (Copper alloy, Bronze, Stainless steel, and Titanium alloy) analysis was done in ANSYS 11.0 with similar loading and support condition. The results obtained were compared. It was observed that Titanium alloy can be considered as the constructional material for the blades as it gave minimum deformation (at tip) and Stress (at base). [16]

3 OVER VIEW OF PROJECT

3.1 OBJECTIVES OF STUDY:

[1] To check strength of turbocharger Compressor creating the geomenty using catia software with and 6 blades and 5 blades after static analysis and Modal analysis using various material like INCOLOY 740, INCOLOY ALLOY 909, INCOLOY ALLOY A-286

[2] To Increase the strength of Compressor by using different materials

[3] To determine static analysis of INCOLOY 740, INCOLOY ALLOY 909, INCOLOY ALLOY A-286

[4] To determine the modal analysis and find out the Total deformation at different frequencies.

[5] Finally conclude the suitable design and material for Compressor

3.2. METHODOLOGY

Step 1: Collecting information and data related to turbocharger Compressor turbine

Step 2: A fully parametric model of the Compressor is created in catia software.

Step 3: Model obtained in Igs. analyzed using ANSYS 14.5(workbench), to obtain stresses , deformation, strain, Shear stress and modal analysis at different frequencies etc.

Step 4: Taking boundary conditions static and Modal

Step 5: Finally, we compare the results obtained from ANSYS and compared different geometry with different materials.

3.3 MATERIAL PROPERTIES:

S.NO	MATERIAL	Density (Kg/m^3)	Poisson's ratio µ	Youngs modulus Mpa	Ultimate Tensile strength (Mpa)
1	INCONEL 740	8190	0.29	200000	950
2	INCONEL 909	8140	0.28	220000	900
3	INCONEL A-286	7940	0.29	200000	930

3.4 TATA INDIGO ENGINE SPECIFICATIONS:

Engine volume =1405cc,

Bore diameter =0.075m,

Stroke length=0.0795m,

Max power =68HP @4500 rpm,

Max torque =127@2500rpm,

Fuel type=diesel No of gears =5

4 INTRODUCTION TO CATIA V5R20

4.1 INTRODUCTION TO CATIA V5R20:

Welcome to **CATIA (Computer Aided Three Dimensional Interactive Application)**. As a new user of this software package, you will join hands with thousands of users of this high-end CAD/CAM/CAE tool worldwide. If you are already familiar with the previous releases, you can upgrade your designing skills with the tremendous improvement in this latest release.

CATIA V5, developed by Dassault Systems, France, is a completely re-engineered, Next-generation family of CAD/CAM/CAE software solutions for Product Lifecycle Management.

Through its exceptionally easy-to-use and state-of-the-art user interface, CATIA V5 delivers innovative technologies for maximum productivity and creativity, from the inception concept to the final product. CATIA V5 reduces the learning curve, as it allows the flexibility of using feature-based and parametric designs.

4.2 DESIGN PROCEDURE IN CATIA:

Catia is a computer graphics system for modeling various mechanical designs and for performing related design and manufacturing operations. The system uses a 3D solid modeling system as the core, and applies the feature-based, parametric modeling method. In short, Catia Parametric is a feature-based, parametric solid modeling system with many extended design and manufacturing application.

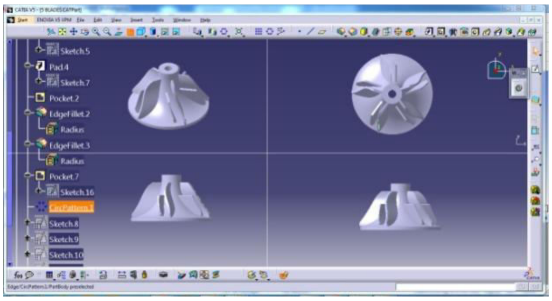


FIGURE 7 TURBOCHARGER COMPRESSOR 5 BLADES

CHAPTER 5 INTRODUCTION TO ANSYS

5.1 INTRODUCTION TO ANSYS:

ANSYS is a large-scale multipurpose finite element program developed and maintained by ANSYS Inc. to analyze a wide spectrum of problems encountered in engineering mechanics**.**

5.2 PROGRAM ORGANIZATION:

The ANSYS program is organized into two basic levels:

- Begin level
- Processor (or Routine) level

The Begin level acts as a gateway into and out of the ANSYS program. It is also used for certain global program controls such as changing the job name, clearing (zeroing out) the database, and copying binary files. When you first enter the program, you are at the Begin level. At the Processor level, several processors are available.

Each processor is a set of functions that perform a specific analysis task. For example, the general pre-processor (PREP7) is where you build the model, the solution processor (SOLUTION) is where you apply loads and obtain the solution, and the general postprocessor (POST1) is where you evaluate the results of a solution.

An additional postprocessor, POST26, enables you to evaluate solution results at specific points in the model as a function of time.

5.3 ANALYSIS PROCEDURE IN ANSYS:

Designed component in CATIA V5 workbench after imported into ANSYS workbench now select the steady state thermal ANALYSIS.

1. ENGINEEERING MATERIALS (MATERIAL PROPERTIES).

2. CREATE OR IMPORT GEOMENTRY.

3. MODEL (APPLY MESHING).

4. SET UP (BOUNDARY CONDITIONS).

5. SOLUTION.

6. RESULT.

5.4 STATIC STRUCTURAL ANALYSIS

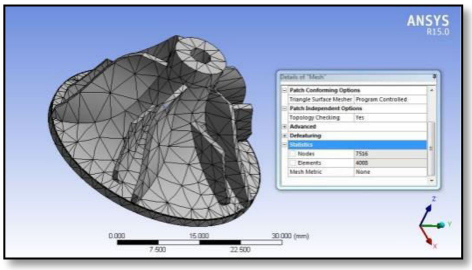
The static structural analysis calculates the stresses, displacements, strains, and forces in structures caused by a load that does not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that the loads and the structure’s response are assumed to change slowly with respect to time. A static structural load can be performed using the ANSYS WORKBENCH solver. The types of loading that can be applied in a static analysis include:

5.5 MODAL ANALYSIS

Modal analysis is a technique used to study the dynamic characteristics of a structure or system. It involves determining the natural frequencies, mode shapes, and damping ratios of the structure's vibration modes. Here's a breakdown of modal analysis

5.6 BLADES MESH AND BOUNDARY CONDITIONS:

MESH:



Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Patch Independent Options	
Topology Checking	Yes
Advanced	
Defeaturing	
Statistics	
Nodes	7516
Elements	4008
Mesh Metric	None

FIGURE 4 MESH OF 5 BLADES NODES: 7516, ELEMENTS:4008

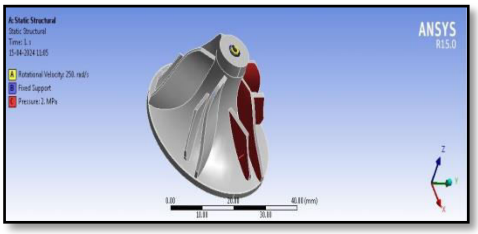


FIGURE 5 MESH OF 5 BLADES NODES: 7516, ELEMENTS:4008

6 RESULTS AND DISCUSSIONS

Design and analysis is done using with various designs 5 blades and 6 blades with different materials . Here find out the stresses, total deformations, strain, shear stresses obtained by analyzing the turbocharger compressor by using different materials Inconel 909, Inconel 740 , Inconel alloy A 286 material as shown in below figures.

6.1 BLADES COMPRESSOR:

6.1.1 INCONEL MATERIAL:

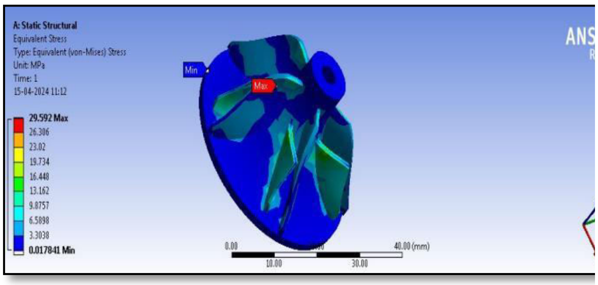


FIGURE 5 VON-MISSES STRESS OF INCONEL MATERIAL

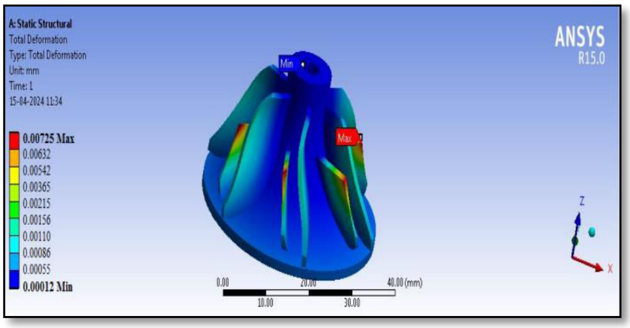


FIGURE 6 TOTAL DEFORMATION OF INCONEL MATERIAL

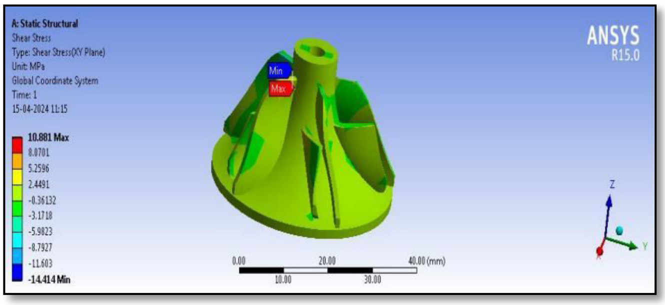


FIGURE 7 SHEAR STRESS OF INCONEL MATERIAL

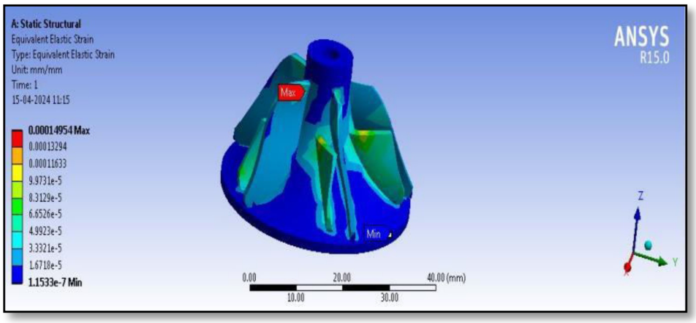


FIGURE 8 STRAIN OF INCONEL MATERIAL

6.1.2 INCONEL ALLOY 909 MATERIAL:

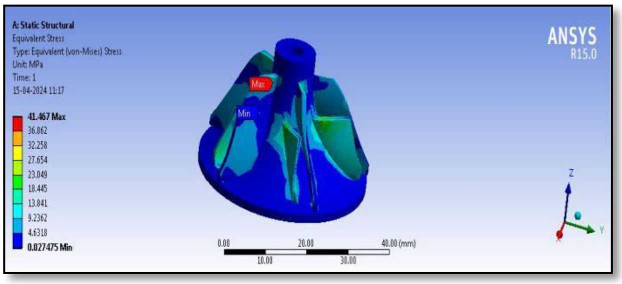


FIGURE 9 VON-MISSES STRESS OF INCONEL ALLOY 909 MATERIAL

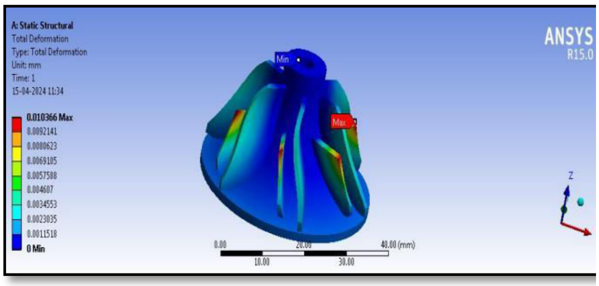


FIGURE 10 TOTAL DEFORMATION OF INCONEL ALLOY 909 MATERIAL

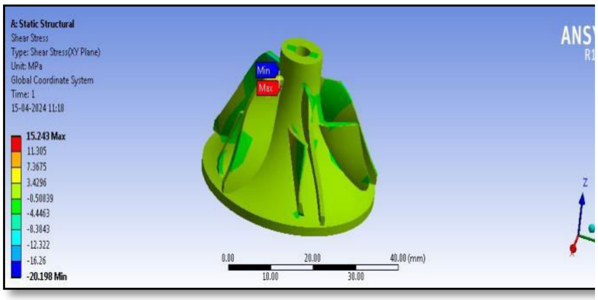


FIGURE 11 SHEAR STRESS OF INCONEL ALLOY 909 MATERIAL

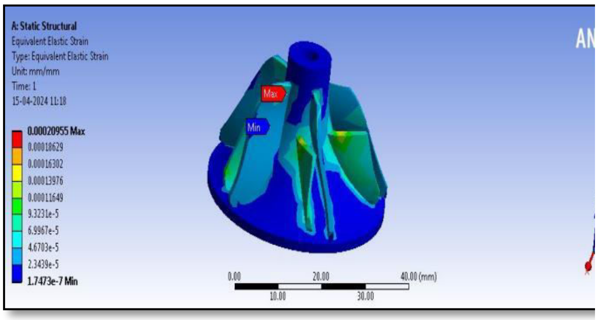


FIGURE 12 STRAIN OF INCONEL ALLOY 909 MATERIAL

6.1.3 IN CONEL ALLOY A 286 MATERIAL:

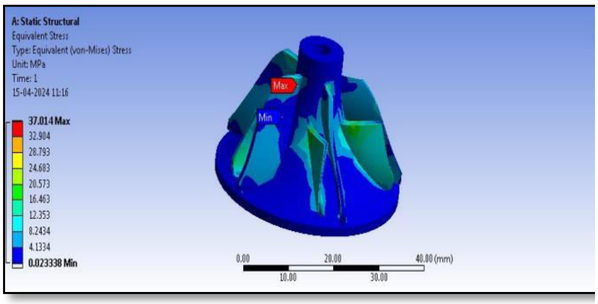


FIGURE 13 VON-MISSES STRESS OF INCONEL ALLOY A 286 MATERIAL

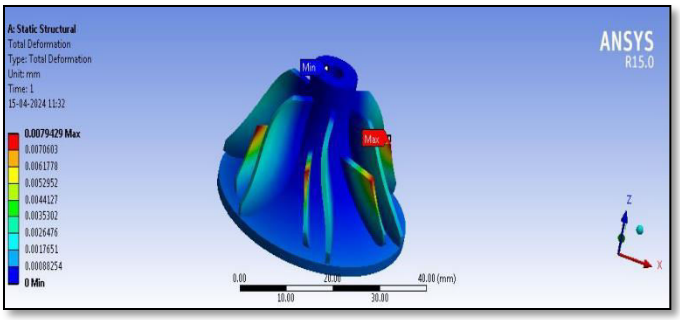


FIGURE 14 TOTAL DEFORMATION OF INCONEL ALLOY A 286 MATERIAL

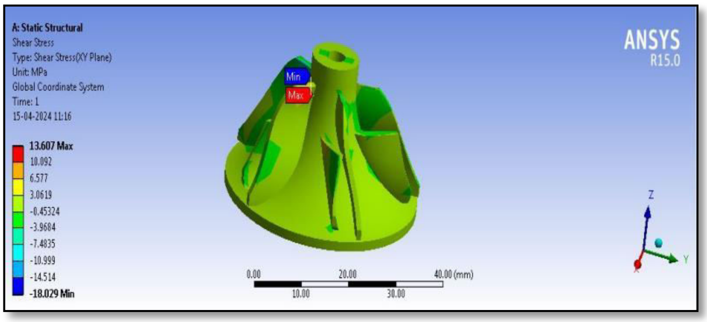


FIGURE 15 SHEAR STRESS OF INCONEL ALLOY A 286 MATERIAL

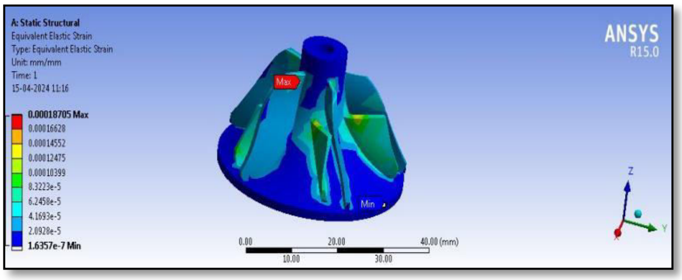
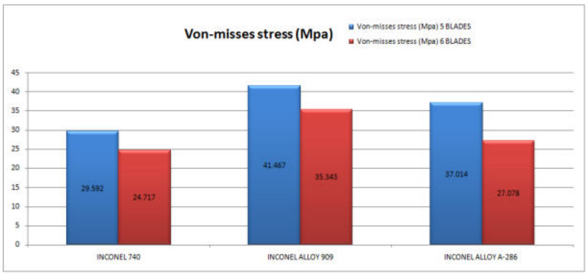


FIGURE 16 STRAIN OF INCONEL ALLOY A 286 MATERIAL

6.2 GRAPHS:

6.2.1 VON-MISSES STRESS GRAPH:

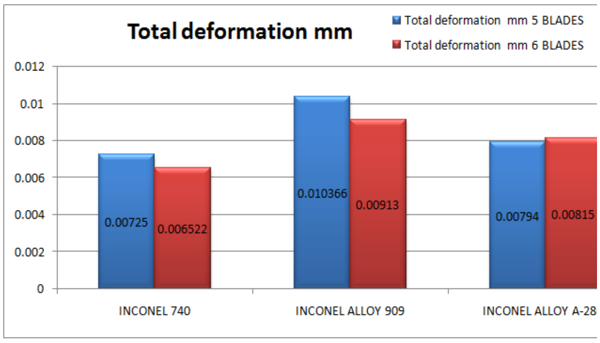
The below graph shows that with Variation of stresses two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286 Finally least von-mises stress is Inconel 740 material 6 Blades design have 24.717 Mpa.



GRAPH: 1 VON-MISSES STRESS GRAPH

6.2.2 TOTAL DEFORMATION GRAPH:

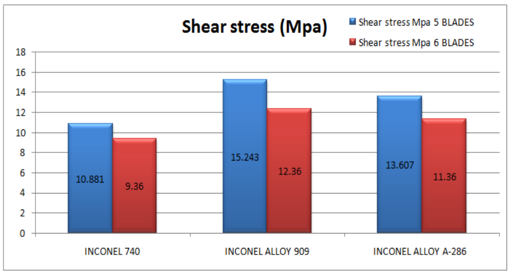
The below graph shows that with Variation of Total deformation two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286. Finally least Total deformation is Inconel 740 material 6 Blades design have 0.0065mm



GRAPH:2 TOTAL DEFORMATION GRAPH

6.2.3 SHEAR STRESS GRAPH:

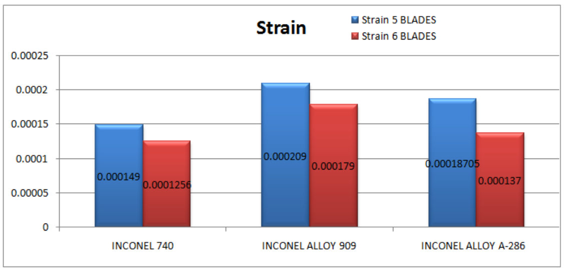
The below graph shows that with Variation of Shear stress two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286. Finally least Shear stress is Inconel 740 material 6 Blades design have 9.36 Mpa



GRAPH:3 SHEAR STRESS GRAPH

6.2.4 STRAIN GRAPH:

The below graph shows that with Variation of Strain two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286. Finally least Strain is Inconel 740 material 6 Blades design have 0.000125.



GRAPH:4 STRAIN GRAPH

6.3 MODAL ANALYSIS:

Modal analysis of turbocharger compressor point of view 5 blades at first mode Frequency 45.63Hz at deformation is 1.563mm and 70.31 Hz at 2.957mm and 106.44Hz at 5.44mm another design 6 Blades Frequency 50.63 Hz at Total deformation is 1.311 and 80.45 Hz at 2.645mm and mode 3 113.92 Hz at 4.631 mm

6.4 BLADES INCONEL 740 MATERIAL:

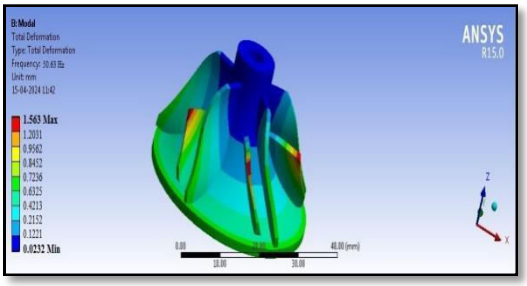


FIGURE 17 MODE 1 OF INCONEL 740 MATERIAL

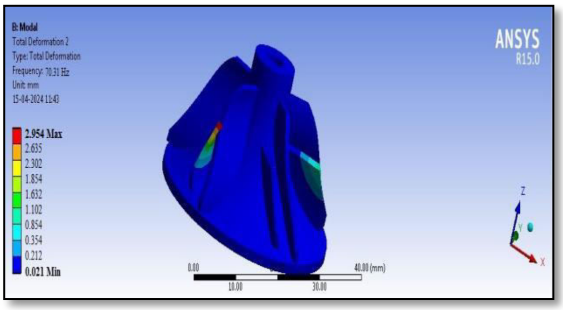


FIGURE 18 MODE 2 OF INCONEL 740 MATERIAL

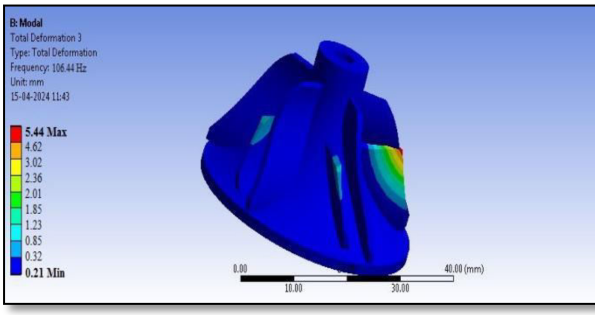


FIGURE 19 MODE 3 OF INCONEL 740 MATERIAL

7 CONCLUSION

In this project the turbo charger compressor wheel is designed in catia software. The analysis is done on ANSYS workbench. In this analysis was done by changing the geometry of the compressor blades 5 and 6 and changing the materials of the compressor wheels are Inconel 740 and Inconel 909, Inconel Alloy A-286.In this project other materials are considered which have more strength and stability. From the above observations I conclude that out of Six blades with inconel 740 have best material.

1. The below graph shows that with Variation of Total deformation two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286. Finally least Total deformation is Inconel 740 material 6 Blades design have 0.0065mm
2. The Variation of stresses two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286 Finally least von-mises stress is Inconel 740 material 6 Blades design have 24.717 Mpa.
3. The Variation of Shear stress two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286. Finally least Shear stress is Inconel 740 material 6 Blades design have 9.36 Mpa
4. The Variation of Strain two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286. Finally least Strain is Inconel 740 material 6 Blades design have 0.000125.
5. Modal analysis of turbocharger compressor point of view 5 blades at first mode Frequency 45.63Hz at deformation is 1.563mm and 70.31 Hz at 2.957mm and 106.44Hz at 5.44mm another design 6 Blades Frequency 50.63 Hz at Total deformation is 1.311 and 80.45 Hz at 2.645mm and mode 3 113.92 Hz at 4.631 mm

REFERENCES

1. D. Ramesh Kumar, B. Shanmugasundaram, P. Mohanraj, “Design and Analysis of Turbocharger Impeller in Diesel Engine”, International Jouranal of Advanced Mechanical and Mechanics Engineering, 2017.

2. Shujie Liu, Chi Liu, Yawei Hu, SIbo Gao, Yifan Wang, Hongchao Zhang, “Fatigue life assessment of centrifugal compressor impeller based on FEA”, ELSEVIER, 2016.

3. CH.Satyasai Manikanta, S.D.V.V.S.B.Reddy, A.Sirishabhadrakali, “Design & Analysis of Turbocharger Impeller” International Journal & Magazine of Engineering, Technology, Management and Research, 2016.

4. M.F. Moreira, “Failure analysis in aluminum turbocharger wheels”, ELSEVIER, 2016.

5. B.P.Terani, Dr. K.S.Badarinarayan, Prakasha.A., “Stability Analysis of Turbocharger Impeller: A Review” International Research Journal of Engineering and Technology (IRJET), 2015.

6. V.R.S.M. Kishore Ajjarapu1, K. V.P.P.Chandu, D.M.Mohanthy Babu, “Design and Analysis of the Impeller of a Turbocharger for a Diesel Engine” International Journal of Advanced Engineering Research and Studies, 2015.

7. Alain Batailly, Mathias Legrand, “Unilateral contact induced blade/casing vibratory interactions in impeller: Analysis for flexible casing with friction and abradable coating”, ELSEVIER, 2015.

8. Neelambika, Veerbhadrappa, “CFD Analysis of mixed flow Impeller”, International Journal of Engineering Research & Technology, 2014.

9. Shaikh Mohammad Rafi, N. Amara Nageswara Rao, “Structure Analysis of a Turbocharger

Compressor Wheel using FEA", Int. Journal of Engineering Research and Applications, 2014.

10. Seiichi Ibaraki, Tetsuya Matsuo, Keiichi Shiraishi, Koichiro Imakiire, "Design optimization of Turbocharger Compressor for High pressure Turbocharged Diesel engine" Conseil International DES Machines A combustion, 2013.

11. B.Mohan, B.E. Kumar, "Structural Analysis on Impeller of an Axial Flow Compressor using FEM", International Journal of Engineering Research & Technology, 2011.

12. Changhee Kim, Horim Lee, Jangsik Yang, Changmimn Son, "Study on the Performance of a Centrifugal Compressor Considering Running Tip Clearance", ELSEVIER 2016.

13. Isaias Hernandez-Carrillo, Christopher J Wood, Hao Liu, "Advanced materials for the impeller in an ORC radial microturbine", ELSEVIER, 2017.

14. S. Mayakannan, V. Jeevabharathi, R. Mani, M.Muthuraj, "Design and analysis of Impeller for Centrifugal Pump", IJARIIE, 2016.

15. Rachel Schwind and Shaaban Abdallah, "A Look at Compressor Impeller Technologies for Turbochargers Focusing on Surge Mitigation", Global J Techno Optim, 2015.

16. Santosh Shuklaa, ApurbaKumar, Royband KaushikKumar, "Material Selection for blades of mixed flow Pump Impeller using ANSYS", ELSEVIER, 2015.

17. Chou, N. K.; Wang, S. S.; Chu, S. H.; Chen, Y. S.; Lin, Y. H.; Chang, C. J.; Shyu, J. J.; Jan, G. J. "Physiologic analysis of cardiac cycle in an implantable impeller centrifugal left ventricular assist device". Artificial Organs, 2001.SS