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DESIGN AND OPTIMIZATION OF TURBINE FOR TURBO JET ENGINE USING CFD

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ABSTRACT

The purpose of this project is to optimize the turbine in a gas turbine engine. By altering the number of blades in the turbine to utilize the energy from combustion. Turbine blades are divided into three categories. In each category, the number of turbine blades is increased. In first design, the number of blades in turbine is increased by 5, then total no of blade in the turbine is 74. In second design, the number of blades in turbine is increased by 10 then total no of blade in the turbine is 79. In third design, the number of blades in turbine is increased by 15 then total no of blade in the turbine is 84. The three dimensional model of this all three turbine blade is designed in CATIA V5. The structural analysis of the turbine blades is carried out in Ansys. The forces acting on the turbine is analyzed by using CFD. The computational fluid analysis over a turbine blade is carried out with respect to the multiple flow velocity.

Keywords: Jet Engine, Velocity, Turbine and Rotor

1. INTRODUCTION

Useful work or propulsive thrust can be obtained from a gas-turbine engine. It may drive a generator, pump, or propeller or, in the case of a pure jet aircraft engine, develop thrust by accelerating the turbine exhaust flow through a nozzle. Large amounts of power can be produced by such an engine that, for the same output, is much smaller and lighter than a reciprocating internal-combustion engine. Reciprocating engines depend on the up-and-down motion of a piston, which must then be converted to rotary motion by a crankshaft arrangement, whereas a gas turbine delivers rotary shaft power directly. Although conceptually the gas-turbine engine is a simple device, the components for an efficient unit must be carefully designed and manufactured from costly materials because of the high temperatures and stresses encountered during operation. Thus, gas-turbine engine installations are usually limited to large units where they become cost-effective.

2. LITERATURE SURVEY

DESIGN AND ANALYSIS OF GAS TURBINE BLADE V Nagabhushana Rao, et al. 2018

The current study used Inconel 718 and Titanium T-6 as turbine blade materials. The influence of temperature and induced stresses on the turbine blade has been studied. A thermal analysis was performed to determine the direction of temperature flow caused by thermal loading. The turbine blade's tensions, shear stresses, and displacements developed due to the coupling effect of heat, and centrifugal loads were investigated structurally. The findings of two materials are compared to indicate the optimal material for a turbine blade (Inconel 718 and titanium T6). Based on the plots and results, Inconel718 is the best material since it is cheaper and has better qualities at higher temperatures than TitaniumT6. Finally, the conclusion can be done on the basis of the cost and the availability of the materials. It is also seen Inconel 718 have good material properties at higher temperature has compare to that of the titanium T6.

Proper way of cooling should be adopted such that hot corrosion and creep strain distribution on the trailing edge will get minimized on turbine blade (Inconel 718).

DESIGN AND ANALYSIS OF STEAM TURBINE ROTOR M. Chandra Eschar Reddy et al. 2015.

In this paper steam turbine rotor is analyzed by using finite elements. In the complex systems, many of the engineering problems, it is difficult to solve the problem by closed form or exact solution method. Then we have to go for some numerical/approximate method for solving the problem. There are lot of numerical/approximate methods available. Finite element technique is a numerical method used for many engineering applications very widely. We have analyzed the rotors acted by different mechanical & thermo-mechanical loads, and analyzed to find out the Behaviour of the rotors. In the analysis results it is seen that the solid rotor is better than the hollow rotor. In the analysis result it is seen that the solid rotor is better than the hollow rotor in both ease of manufacturing & failure criteria. Till now we have covered steady state thermal analysis of the rotors more analysis could be done by applying transient conditions, as after sometime the temperature distribution changes.

DESIGN AND ANALYSIS OF TURBINE BLADE Alugala sravan, et al. 2021

Turbine blade is the individual component which makes up the turbine section of a gas turbine. The blades are responsible for extracting energy from the high temperature, high pressure gas produced by the combustor. The turbine blades are often the limiting component of gas turbines. To survive in this difficult environment, turbine blades often use exotic materials like super alloys and many different methods of cooling, such as internal air channels, boundary layer cooling, and thermal barrier coatings. By observing the thermal results, thermal flux is more for Nickel alloy than titanium alloy. So using Nickel alloy is better than Titanium alloy. But the main disadvantage is its weight. By comparing the results for all the models, thermal flux is increasing by increasing number of holes, so heat transfer rate is increased. So we can conclude that by using Nickel alloy with 6 holes is better.

DESIGN AND FINITE ELEMENT ANALYSIS OF TURBINE BLADE Male Koteswara Rao, et al. 2015

This project explains designing and analysis of Gas turbine blade, Catia V5 R18 software is used to design the blade with the help of 2D and 3D commands and the analysis of blade is done in ANSYS 14.5 software by meshing the blade and applying the boundary conditions. This project uses Ansys software to analyze the complex turbine blade geometries and apply boundary conditions to examine structural performance of the blade for Stainless steel, Nimonic Alloy 80 and Haste Alloy X. Finally selecting the most appropriate material among the three from the report created after analysis. From this the results are stated and reported. The best material has been suggested for turbine blade by analysis on different materials. Maximum elongations and temperatures are observed at the tip portion of the blade and minimum elongation and temperature variations at the root of the blade are observed. Maximum stresses and strains are found at the root of the turbine blade and upper surface. From the above results, Mnemonic Alloy X has been selected for the performance analysis because of its low stresses and deformation.

DESIGN AND ANALYSIS OF STEAM TURBINE BLADES Mingy Zhu, et al. 2019

With the wide application of turbomachinery and the continuous advancement of design technology, steam turbine blade design technology has become an important research field. The level of design is one of the most important factors restricting the performance of steam turbines, which is related to the working efficiency of the steam turbine. This paper systematically introduces the structure of steam turbine blades, analyzes the factors affecting blade operation and design principles, and compares the design of traditional toothed blade root blades with the optimization design of steam turbine blades after improved parameters. Finally, finally, the future design of steam turbine blade is prospected. The application of titanium alloy can greatly reduce the weight of the whole machine, improve the thermoelectric conversion efficiency of the unit, and adapt to the higher temperature, pressure, efficiency of the steam turbine. The trend of long-life development is much costlier for power plants than for one-time inputs. Therefore, titanium alloy blades will have broad application prospects on steam turbines.

3. METHODOLOGY

In its most common sense, methodology is the study of research methods. However, the term can also refer to the methods themselves or to the philosophical discussion of associated background assumptions. A method is a structured procedure for bringing about a certain goal, like acquiring knowledge or verifying knowledge claims. This normally involves various steps, like choosing a sample, collecting data from this sample, and interpreting the data. The study of methods concerns a detailed description and analysis of these processes. It includes evaluative aspects by comparing different methods. This way, it is assessed what advantages and disadvantages they have and for what research goals they may be used. These descriptions and evaluations depend on philosophical background assumptions. Examples are how to conceptualize the studied phenomena and what constitutes evidence for or against them. When understood in the widest sense, methodology also includes the discussion of these more abstract issues. Methodologies are traditionally divided into quantitative and qualitative research. Quantitative research is the main methodology of the natural sciences. It uses precise numerical measurements. Its goal is usually to find universal laws used to make predictions about future events. The dominant methodology in the natural sciences is called the scientific method. It includes steps like observation and the formulation of a hypothesis. Further steps are to test the hypothesis using an experiment, to compare the measurements to the expected results, and to publish the findings. Qualitative research is more characteristic of the social sciences and gives less prominence to exact numerical measurements. It aims more at an in-depth understanding of the meaning of the studied phenomena and less at universal and predictive laws. Common methods found in the social sciences are surveys, interviews, focus groups, and the nominal group technique. They differ from each other concerning their sample size, the types of questions asked, and the general setting. In recent decades, many social scientists have started using mixed- methods research, which combines quantitative and qualitative methodologies.

In this regard, methodology comes after formulating a research question and helps the researchers decide what methods to use in the process. Different methodologies provide different approaches to how methods are evaluated and explained and may thus make different suggestions on what method to use in a particular case. In my design and analysis of the turbine involve the following methodology

Define the parameters for the optimization.
Calculate the dimensions of blade profile.
Increasing the numbers of turbine blade.
Design of three dimensional model of the turbine blade in CATIA V5.
Material selection for turbine blade.
Stress analysis of the turbine blade is carried out in ANSYS.
CFD analysis of the turbine blade is carried out in FLUENT.
Conclusion based on the result from the analysis.

4. FLOW CHART

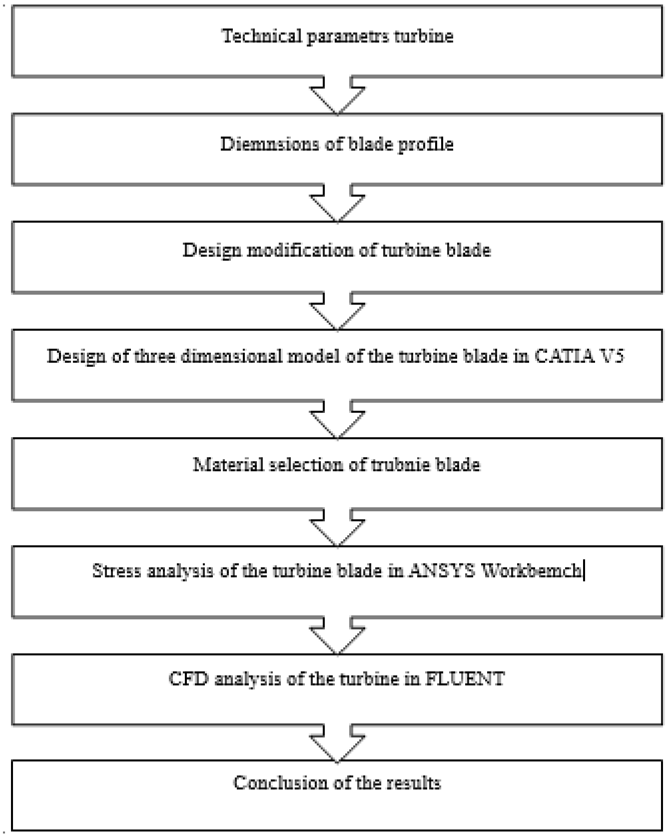


Fig :1 flow chart.

5. THREE DIMENSIONAL MODEL OF THE TURBINE BLADE

This tool is used to create 2D technical drawings of parts and assemblies, including dimensions, tolerances, and annotations.

Part Design: This tool allows users to create 3D models of individual parts using a variety of features such as extrusion, revolve, sweep, and loft.

Sheet Metal Design: This tool is used to create 3D models of sheet metal parts and assemblies, including features such as bends, flanges, and cut outs.

Assembly Design: This tool allows users to create complex assemblies by combining multiple parts together and defining their relationships and constraints.

Generative Shape Design: This tool is used to create complex 3D shapes and surfaces using advanced modeling techniques such as wireframe, surface, and volume modeling.

Kinematics: This tool is used to simulate the motion of assemblies and mechanisms, allowing engineers to test and optimize their designs before manufacturing.

Digital Mock-up: This tool is used to create virtual prototypes of products, allowing engineers to visualize and test their functionality and performance.

Part Design Module - Part design environment is used to create 3D models from the basic 2D sketches created in sketcher environment.

PAD command - Extruding a profile or a surface in one or two directions.

POCKET command - Removes material from a design body.

SHAFT command - You can create shafts from sketches including several closed profiles.

RIB command - To define a rib, you need a center curve, a planar profile and possibly a reference element or a pulling direction

SLOT command - The slot has swept a profile along a center curve to remove material.

Assembly Module - Assembly environment is used to provide mating to two or more part models to from complete assembly. Entire design structure will be created in product environment in Top - down approach whereas in bottom - up parts will be created separately and will be mated using mating or constraint tools.

Drafting Module - Drafting is a process of generating 2D machine drawing for the

5.1 TOTAL NO OF BLADES IN THIS DESIGN OF TURBINE IS 74.

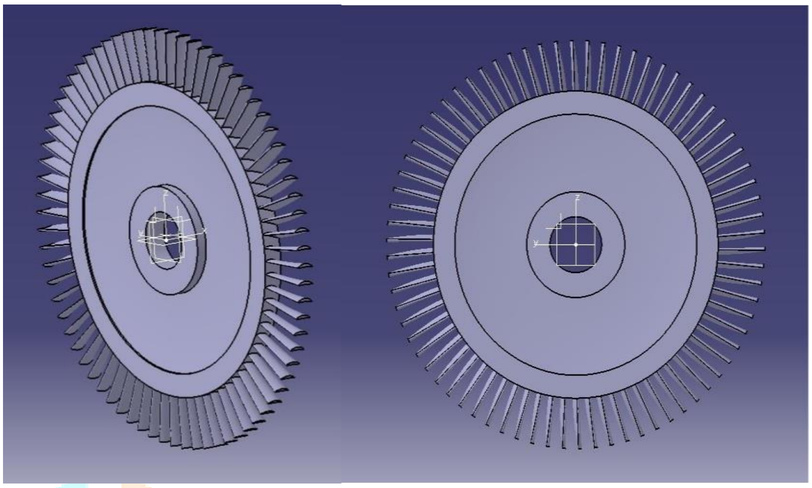


Fig :2 Turbine design with 74 blade

5.2 TOTAL NO OF BLADES IN THIS DESIGN OF TURBINE IS 79.

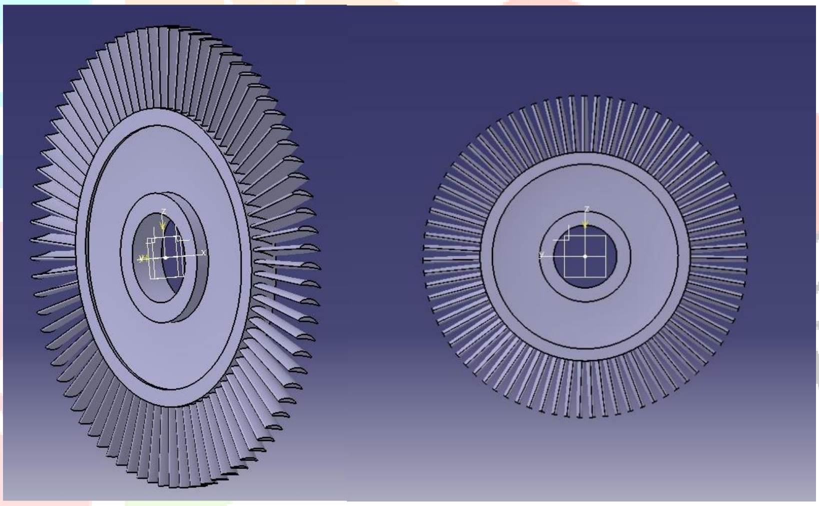


Fig :3 Turbine design with 79 blade

5.3.3TOTAL NO OF BLADES IN THIS DESIGN OF TURBINE IS 84.

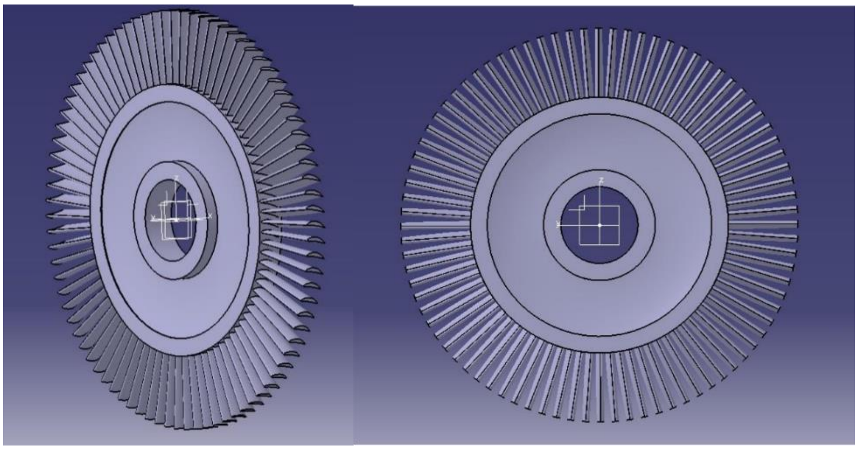


Fig 4 Turbine design with 84 blade

6. MATERIAL SELECTION OF TURBINE BLADE

S no	Properties	Inconel 718	Titanium t6	Nickel alloy
1	Young's modulus (Mpa)	2.00E+05	1.06E+05	2.00E+05
2	Density kg/m3	8193.3	4420	8900
3	Poisson's ratio	0.31	0.3	0.31
4	Tensile yield strength (Mpa)	1069	530	1240
5	Max operating temperature °C	982	980	1150

Fig: 5 Turbine material comparison

From the material listed above depend on the characteristics, the nickel alloy provides best material characteristics for turbine blade.

7. MESHING OF TURBINE BLADE

The goal of meshing in ANSYS Workbench is to provide robust, easy to use meshing tools that will simplify the mesh generation process. These tools have the benefit of being highly automated along with having a moderate to high degree of user control. The first option the panel allows you to set is your Physics Preference. This corresponds to the Physics Preference value in the Details View of the Mesh folder.

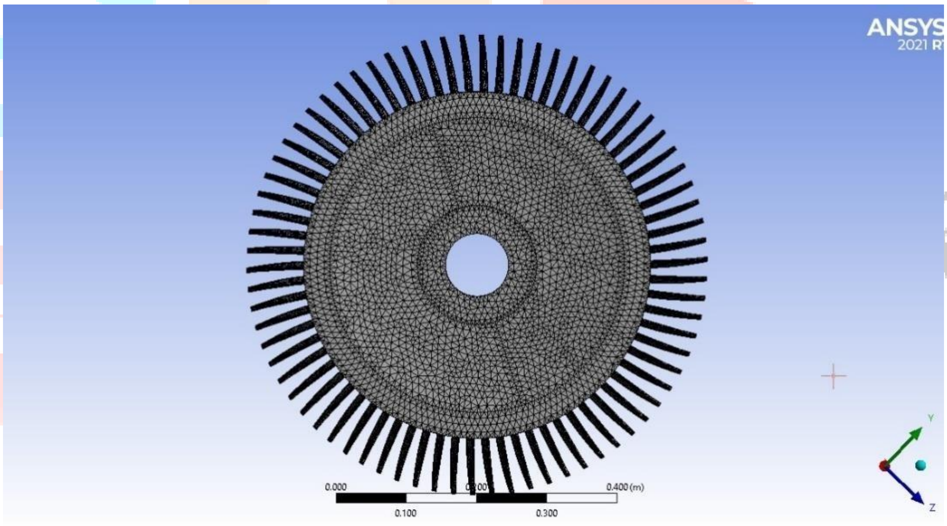


Fig 6: Meshing of Turbine design with 74 blade

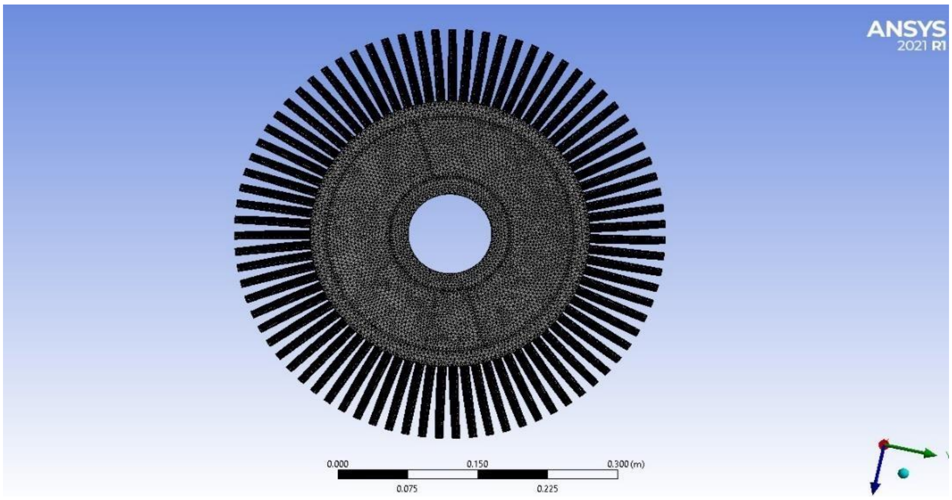


Fig 7 Meshing of Turbine design with 79 blade

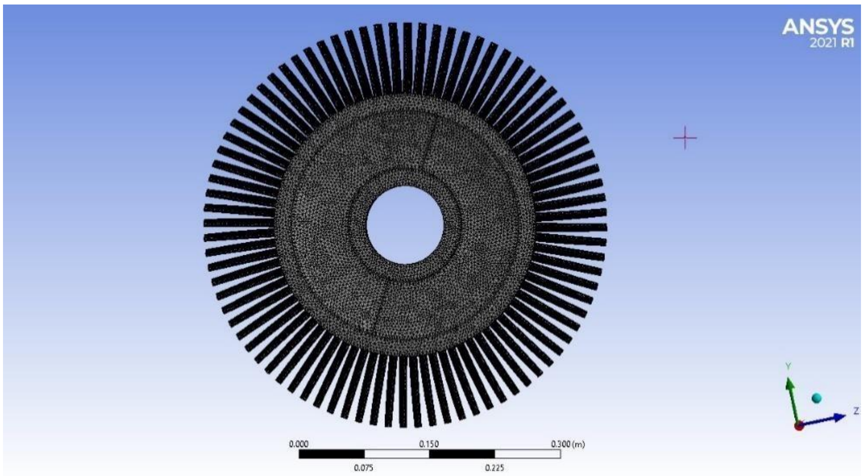


Fig 8: Meshing of Turbine design with 84 blade

8. RESULT ANALYSIS OF TURBINE BLADE

A structural analysis of the three designs of the turbine blade is carried out in ANASYS. The total deformation, equivalent von misses stress and equivalent elastic strain solutions are analysedfor 74 blade, 79 blade and 84 blade integrated turbines. The discussion of the results from turbines are listed below.

8.1 THE 74 BLADE INTEGRATED TURBINE DESIGN

In this turbine, there are 74 blades are integrated. The analysis of the turbine is carried out around 10800 rpm. The result of total deformation, equivalent von misses stress and equivalent elastic strain from the analysis is listed below.

TOTAL DEFORMATION

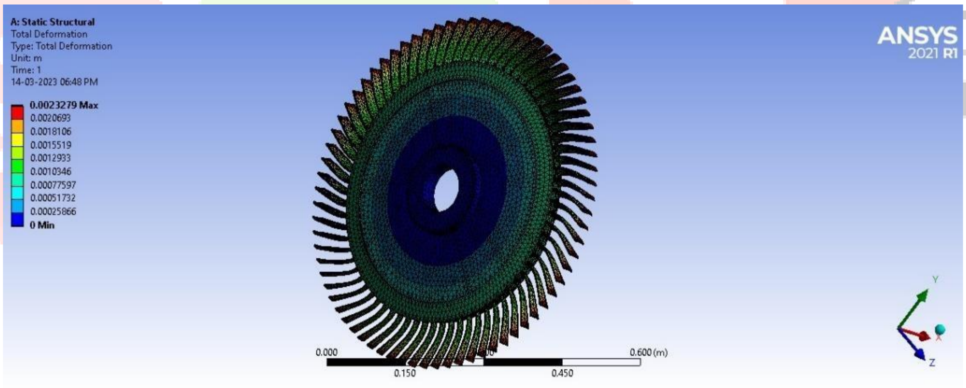


Fig 9: Total deformation of 74 blade turbine design

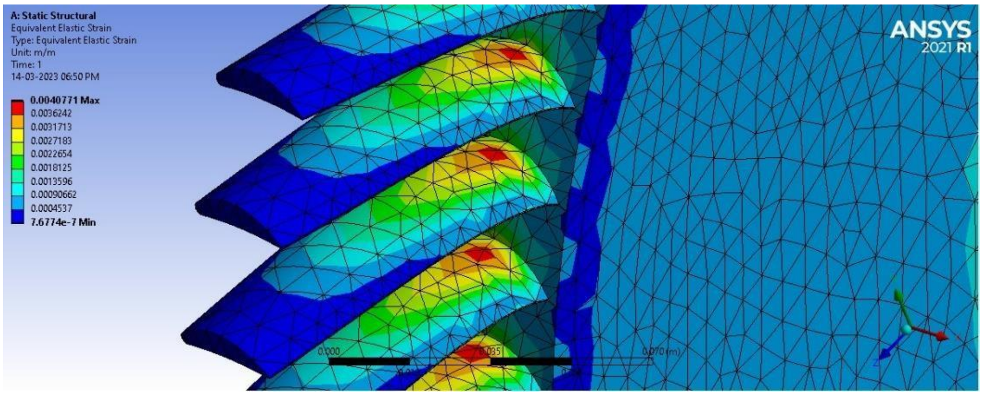


Fig 10: Equivalent elastic strain of 74 blade turbine design

STRAIN

EQUIVALENT VON MISES STRESS

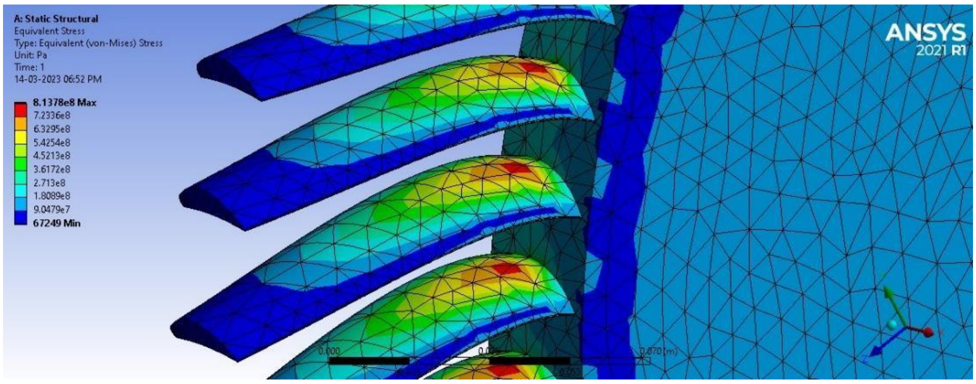


Fig 11: Equivalent von miss stress of 74 blade turbine design

8.2 RESULT COMPARISON OF TURBINE BLADES

TOTAL DEFORMATION (m)			
S.No	**Blade types**	**Max**	**Min**
1	74 blade	0.002	0.00025
2	79 blade	0.00015	0.000019
3	84 blade	0.00016	0.00028
EQUIVALENT ELASTIC STRAIN			
1	74 blade	0.0036	0.00045
2	79 blade	0.0023	0.00028
3	84 blade	0.0022	0.00028
EQUIVALENT VON MISES STRESS (pa)			
1	74 blade	7.23×108	9.04×107
2	79 blade	4.60×108	5.76×107
3	84 blade	4.59×108	5.74×107

Fig 12 :.Result comparison of turbine blade9. COMPUTATIONAL FLUID DYNAMIC ANALYSIS OF TURBIEN BLADE

9.1 COMPUTATIONAL FLUID DYNAMICS INTRODUCTION

In this focuses on computational fluid dynamics (CFD). Computational fluid dynamics is a science that, with the help of digital computers, produces quantitative predictions of fluid-flow phenomena based on the conservation laws (conservation of mass, momentum, and energy) governing fluid motion. CFD has increased in importance and in accuracy; however, its predictions are never completely exact. Because many potential sources of error may be involved, one has to be very careful when interpreting the results produced by CFD techniques. The most common sources of error are mentioned in the chapter. The key to various numerical methods is to convert the partial different equations that govern a physical phenomenon into a system of algebraic equations. Different techniques are available for this conversion. CFD is merely a tool for analyzing fluid-flow problems. If it is used correctly, it can provide useful information cheaply and quickly. This chapter presents the basics of the finite-difference and finite-element methods and their applications in CFD. There are other kinds of numerical methods, for example, the spectral method and the spectral element method, which are often used in CFD. They share the common approach that discretizes the Naiver-Stokes equations into a system of algebraic equations.

9.2 ANSYS FLUENT

Any's Fluent, the industry gold-standard in computational fluid dynamics (CFD), frees up time for engineers to innovate and improve product results. With software that has been thoroughly tested across a wide variety of applications, you can have confidence in your simulation performance. You can develop advanced physics models and analyze a variety of fluids phenomena with Ansys Fluent, all in a customizable and intuitive environment. Ansys Fluent expands the capabilities of CFD analysis. A fluid simulation platform with quick pre-processing and solve times that will help you be the first to market. Ansys Fluent's industry-leading features allow for endless creativity without sacrificing accuracy.

PRESSURE DISTRIBUTION AT 80 m/s

The pressure distribution over the turbine blade at angle 22 degree, 10 degrees and 0-degree angle of attach is being analyzed in fluent. Pressure distribution of turbine blade at 22 degree (root) angle of attack at 80 m/s is shown below.

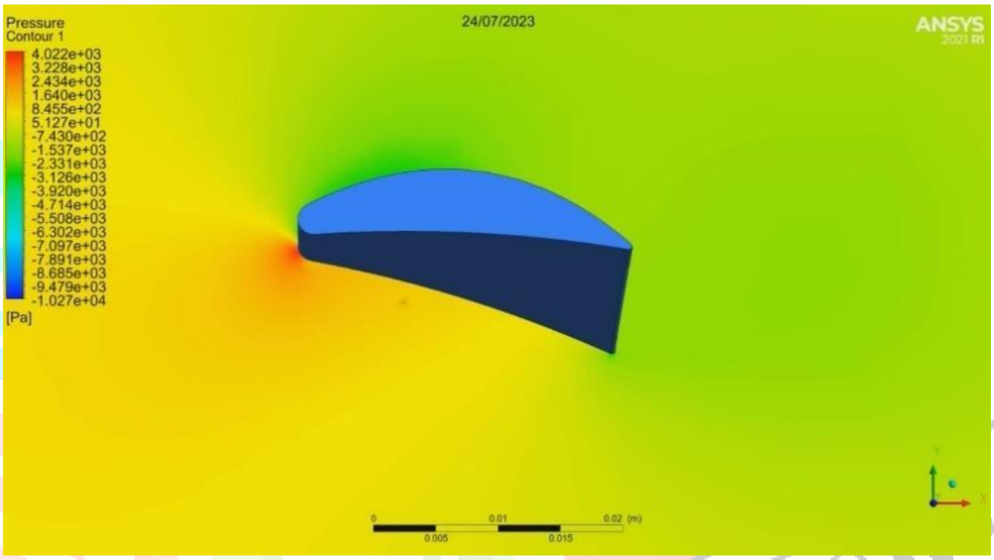


Fig 13: Pressure distribution of blade at 22-degree angle of attack at 80 m/s.

Pressure distribution of turbine blade at 10 degree (mid) angle of attack at 80 m/s is shown below.

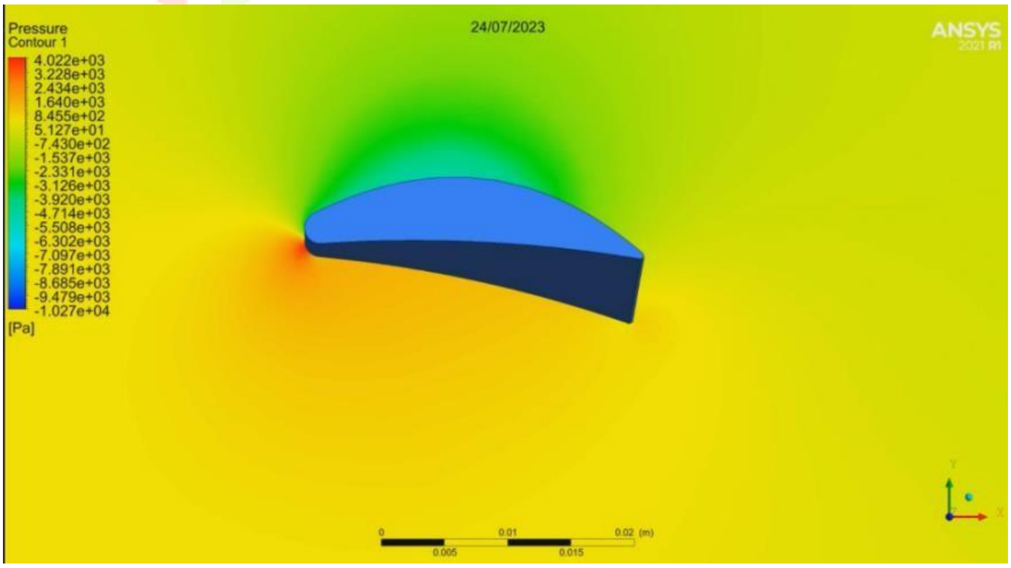


Fig 14: Pressure distribution of blade at 10-degree angle of attack at 80 m/s.

Pressure distribution of turbine blade at 0 degree (tip) angle of attack at 80 m/s is shown below.

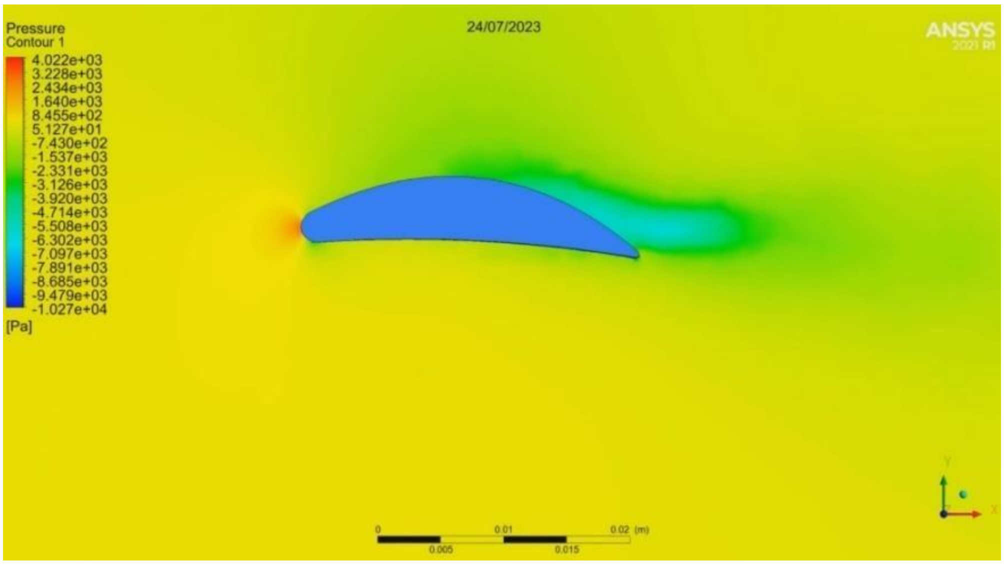


Fig 15: Pressure distribution of blade at 0-degree angle of attack at 80 m/s.

VELOCITY DISTRIBUTION AT 80 m/s

The velocity distribution over the turbine blade at angle 22 degree, 10 degrees and 0-degree angle of attach is being analyzed in fluent. Velocity distribution of turbine blade at 22 degree (root) angle of attack at 80 m/s is shown below.

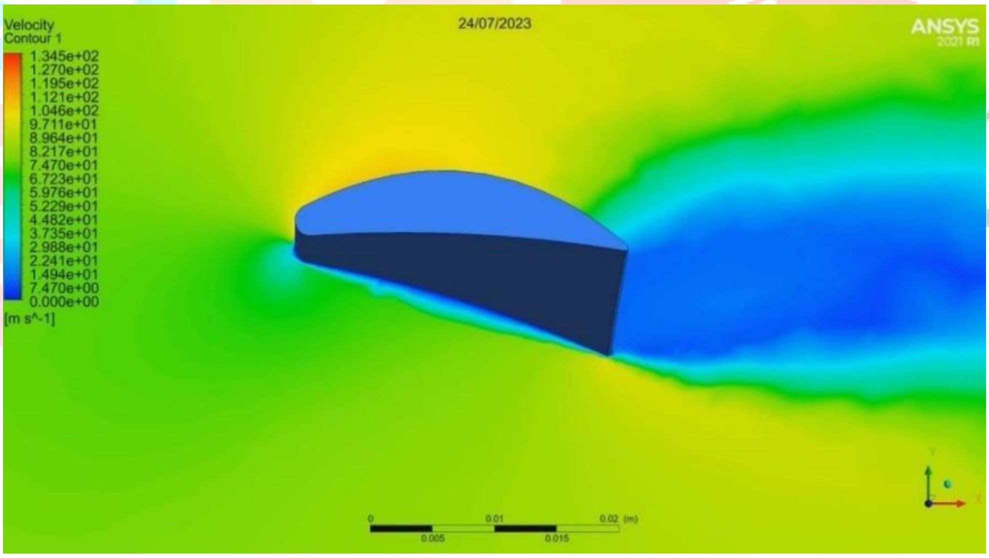


Fig 16: velocity distribution of blade at 22-degree angle of attack at 80 m/s.

Velocity distribution of turbine blade at 10 degree (mid) angle of attack at 80 m/s is shown below.

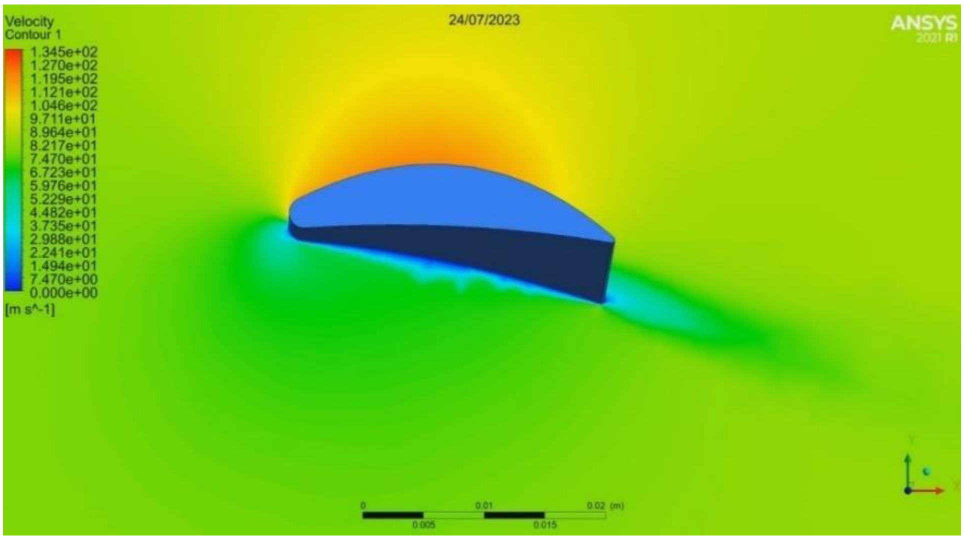


Fig 17: velocity distribution of blade at 10-degree angle of attack at 80 m/s.

Velocity distribution of turbine blade at 0 degree (tip) angle of attack at 80 m/s is shown below.

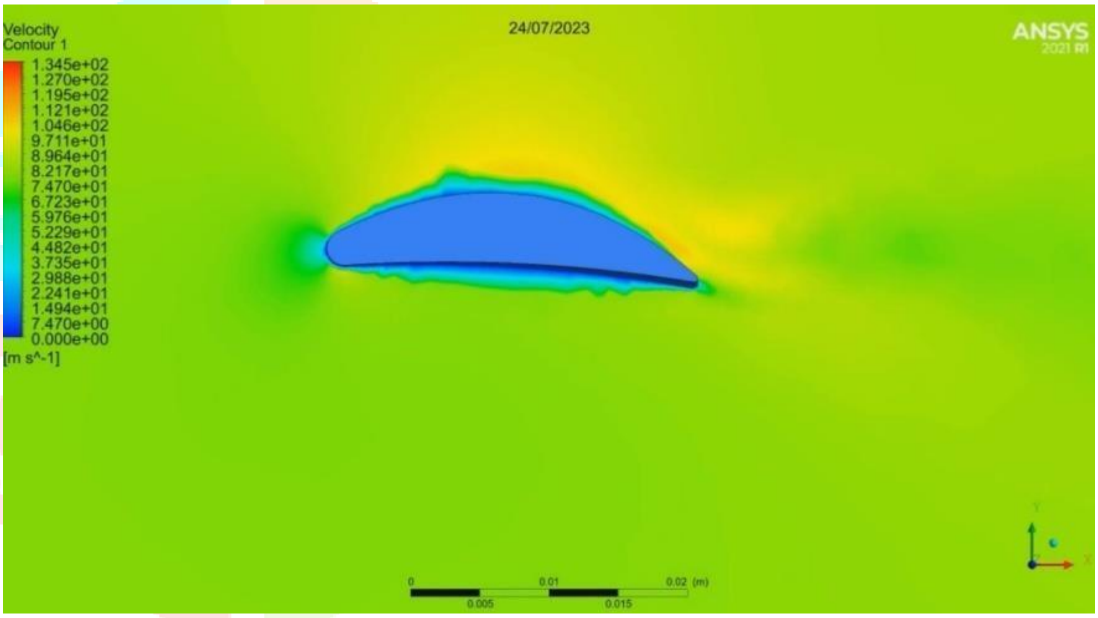


Fig 18: velocity distribution of blade at 0-degree angle of attack at 80 m/s.

TURBULENCE AT 80 m/s

The Turbulence over the turbine blade at angle 22 degree, 10 degrees and 0-degree angle of attach at 80 m/s is analyzed in fluent. The turbulence of turbine blade at 22-degree angle of attack is only shown because 10 and 0-degree angle of almost are similar which doesn't create much turbulence. Turbulence of turbine blade at 22 degree (root) angle of attack at 80 m/s is shown below.

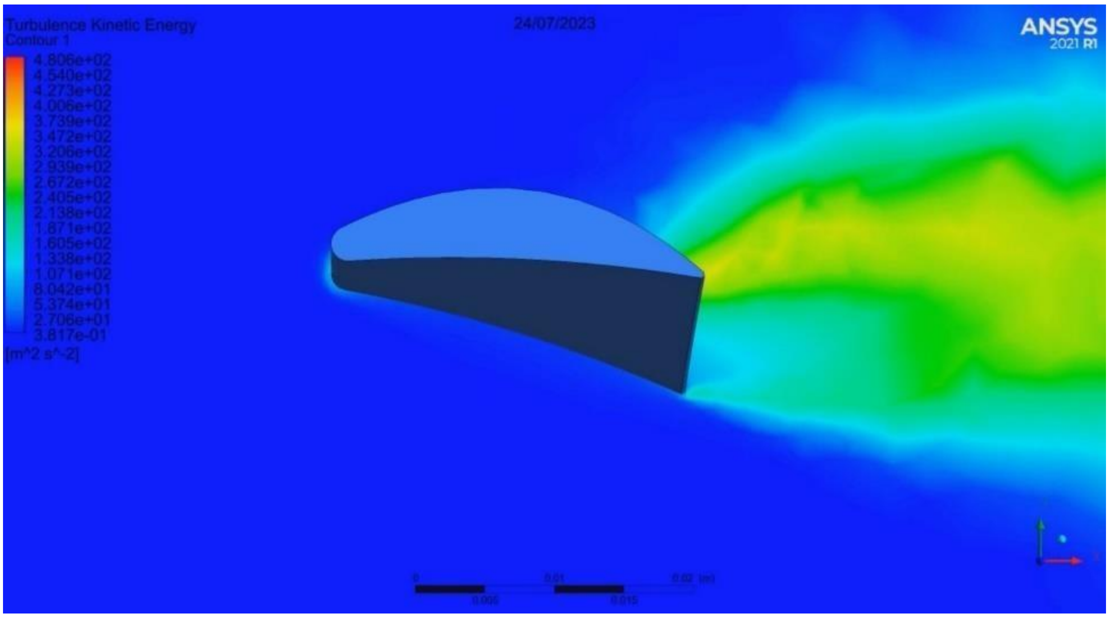
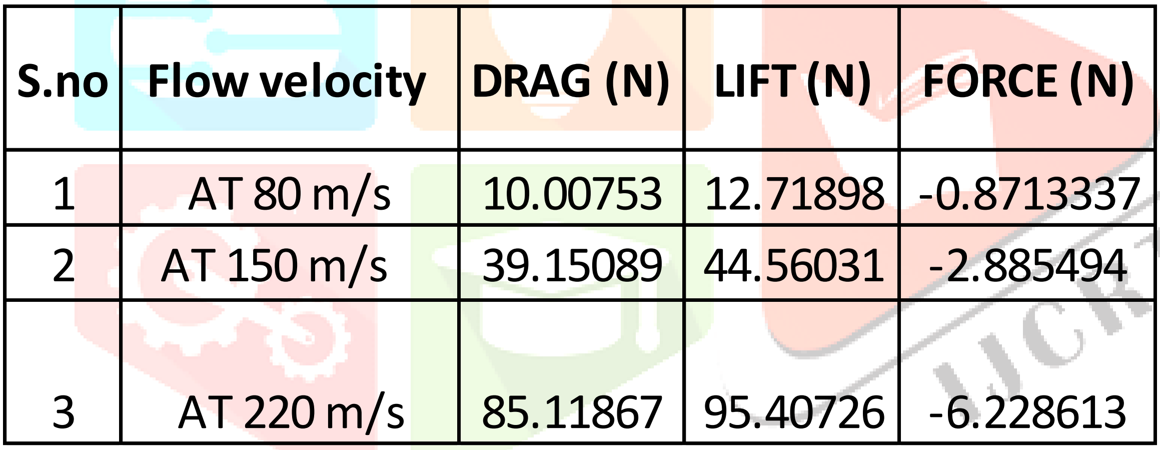


Fig 19: Turbulence of blade at 22-degree angle of attack at 80 m/s.

10. CFD RESULT COMPARISON

From the CFD analysis result, drag, lift and force at velocity 80, 150 and 220 m/s are compared in the below table



S.no	Flow velocity	DRAG (N)	LIFT (N)	FORCE (N)
1	AT 80 m/s	10.00753	12.71898	-0.8713337
2	AT 150 m/s	39.15089	44.56031	-2.885494
3	AT 220 m/s	85.11867	95.40726	-6.228613

Fig 20: Result comparison of CFD

11. CONCLUSION

In this project, the optimization of the turbine is done by increasing the number of blade and split in to three configurations. From the comparison of the material for turbine blade, nickel alloy provides the good technical parameters. All three types of turbines are designed in CATIA V5 and structural analysis is carried out. In the structural analysis, total deformation, equivalent elastic strain and equivalent von mises stress solutions of 74 blades, 79 blade and 84 blade turbines are compared. Based on the result discussion, the 79 blade turbine configuration results in a more effective optimization. Based on the result comparison from various flow velocitiesIn the computational fluid analysis. The lift is greater than the drag which helps the turbine to rotate higher rpm effectively. The turbulence in turbine blade at high angle of attack is higher than the lower angle of attack, which helps the flow leave the tip of the blade smoothly. So thus turbojet engine is optimized by varied technical specification of turbine.

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