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Modeling and Cfd Analysis of Three Different Naca 2412, Naca 4412, and Naca 8412 Series Gas Turbine BLADES

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Abstract- A turbine blade is the individual component which makes up the turbine section of a gas turbine or steam 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 that can be categorized as internal and external cooling, and thermal barrier coatings. Blade fatigue is a major source of failure in steam turbines and gas turbines. Fatigue is caused by the stress induced by vibration and resonance within the operating range of machinery. In this thesis 3 NACA series (NACA 2412, NACA 4412, and NACA 8412) blades are to be designed by using cad tool-solid works and thermal and CFD are analyzed with the help of CAE tool- Ansys workbench in both static and flow boundary conditions for materials steel, and Ti-15mo to be analyzed, and results like deformation, stress, safety factor, velocity and pressure distribution and coefficient of lift and coefficient of drag on each model are to be calculated. According to previous base and research papers it is clear that most of the companies were using gas turbine blades with NACA four series blades only, but due to company protocol and rules regulations we are not aware of which Naca series blade is optimum for real time boundary conditions. Finally optimum NACA blade series and best material among three are concluded with required graphs and tables and limitations

Keywords-Turbine, NACA, Blade

Introduction

A gas turbine's individual turbine component is known as a turbine blade. Together, these components form the turbine part of the gas turbine. It is the job of the blades to extract energy from the high temperature and high pressure gas that is produced by the combustor. In gas turbines, the turbine blades are typically the component that is the limiting factor. In order to survive in such a harsh environment, turbine blades often make use of unusual materials such as super-alloys and a wide variety of additional methods of cooling, including internal air channels, boundary layer cooling, and thermal barrier coatings. Failure in steam turbines and gas turbines is often caused by blade fatigue as the major factor. The strain brought on by vibration and resonance that occur within the functioning range of equipment is a primary contributor to fatigue. Friction dampers are used so that blades are not subjected to the large dynamic loads that are present.

The blades of wind turbines and water turbines are designed to perform in a variety of different circumstances, the majority of which involve lower temperatures and rotational rates. A single turbine section of a gas turbine engine is formed from a disc or hub that comprises several turbine blades. This component is known as the generator. This turbine part is connected to a compressor section by a shaft (or "spool"), and the compressor section may either be axial or centrifugal, depending on the application. The compressor stages of the engine are responsible for the compression of air, which raises both the pressure and the temperature. The combustor, which is located between the compressor stages and the turbine stages, is where the fuel is burned, which ultimately results in a significant increase in temperature. After that, the very hot and pressurised exhaust gases go through each step of the turbine. The compressor stages along the spool receive the kinetic energy that is sent along from the turbine stages after they have absorbed the energy from the flow and lowered both the pressure and temperature of the air. This method operates in a manner that is quite similar to that of an axial compressor, just in reverse.

Although there is a large variety of different ways in which the turbine stages of an internal combustion engine may be arranged, high-bypass-ratio engines typically have the most of these stages. The amount

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of stages that a turbine has may have a sizeable influence on the arrangement of the turbine blades that are implemented for each stage of the turbine. In the design of many different types of gas turbine engines, there is a high-pressure spool as well as a low-pressure spool. A twin-spool design refers to this particular arrangement of components. Other kinds of gas turbines consist of three spools: a high-pressure spool, a low-pressure spool, and an intermediate-pressure spool in the centre. Each of these spools is designed to operate at a different pressure. The high-pressure turbine is exposed to air that is hotter and at a greater pressure than the low-pressure turbine, which is exposed to air that is cooler and at a lower pressure than the air that is exposed to by the high-pressure turbine. Even though the fundamentals of aerodynamics and thermodynamics do not change, the turbine blades for high-pressure and low-pressure turbines are designed to be very different from one another in terms of the materials used and the cooling methods that they employ. This is due to the fact that the conditions for high-pressure and low-pressure turbines are very different from one another. As a consequence of the difficult working conditions inside the turbines, the blades of the gas and steam turbines are exposed to high temperatures, high stresses, and perhaps powerful vibrations. This is because the circumstances within the turbines are so harsh. In order to convert the linear motion of high-temperature and high-pressure steam flowing down a pressure gradient into a rotational motion, power plants need steam turbine blades as one of its fundamental components. These blades spin the turbine shaft in order to accomplish this transformation.

Implementation

Steel

Young's modulus: - 2.0*10^11 Pa

Poison ratio: 0.29

Density: 7850 Kg/m^3

Yield strength: 250Mpa

Thermal conductivity: 60.5 w/m-k

Ti-15mo

Young's modulus: - 1.*10^11 Pa

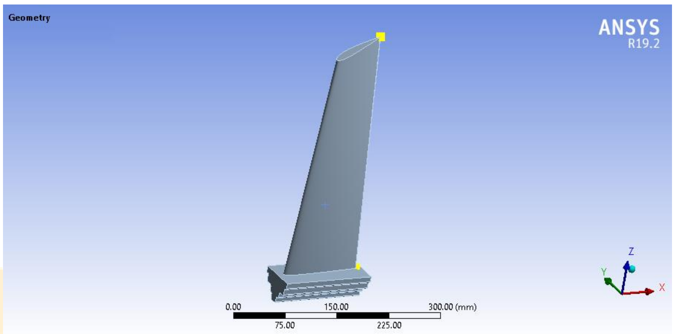
Poison ratio: 0.33

Density: 7913 Kg/m^3

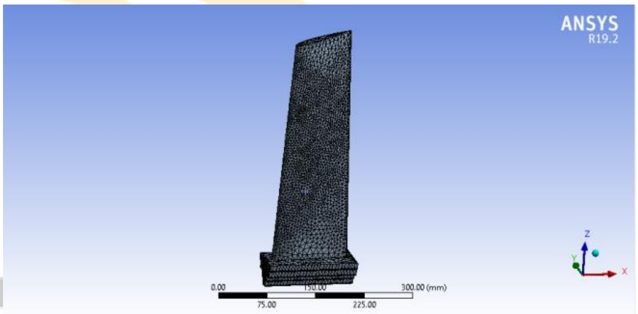
Yield strength: 480Mpa

Thermal conductivity: 57.5 w/m-k

After entering material properties, then need to import iges/step file which is created in solid works, and the imported object is shown in below image.



Meshing

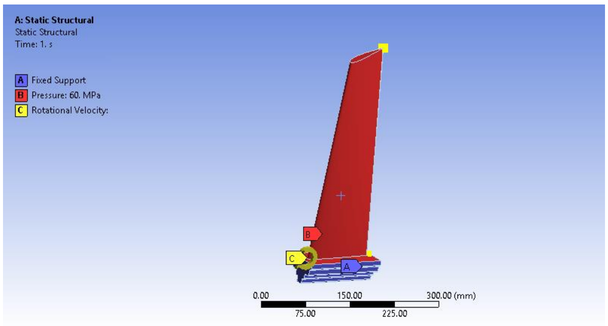


In real time each material is built with internal molecules and they have bonding between them, so that wherever the load applied on object it can transmit the load by these bonding, when it comes to Ansys workbench here material properties can be applied but not their bonding, so that loads cannot transfer from one end to another end, by using this meshing option one big object can convert into small particles, and these small particles named as element, and these elements are connected with nodes, here element size is given as 2.5mm,

No of elements and nodes

Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	2.5 mm
Sizing	
Quality	
Inflation	
Advanced	
Statistics	
Nodes	128938
Elements	72954

Boundary conditions



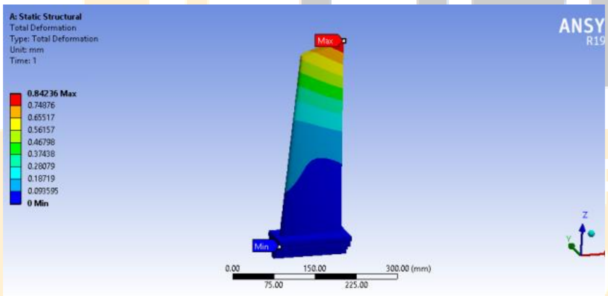
After creating meshing then boundary conditions were applied and here multiple pressure values were applied to calculate maximum bearing capacity of each object, at 60Mpa of pressure with an rotational velocity of 2100RPM, here object got factor of safety value near to 1.5, so that this pressure value is consider to be maximum bearing capacity of this model.

Results

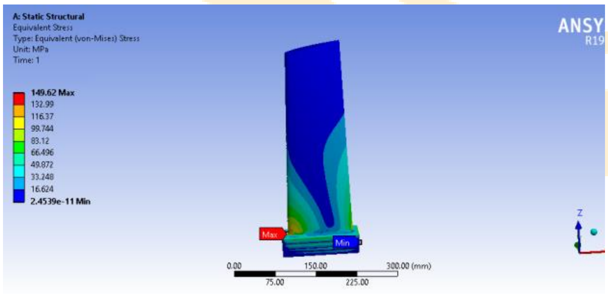
Naca 2412

Steel

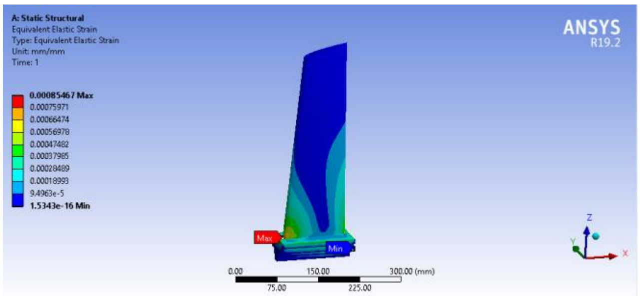
Deformation



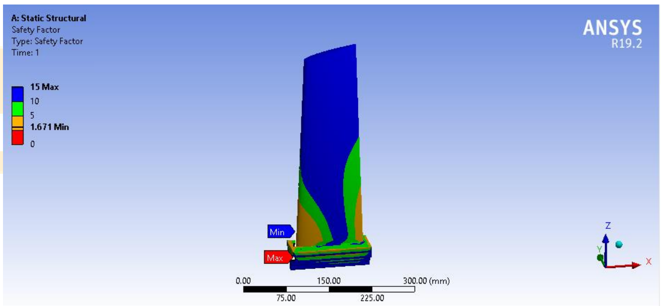
Stress



Strain

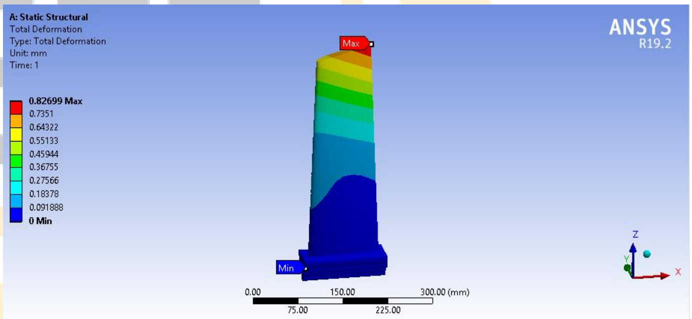


Safety factor

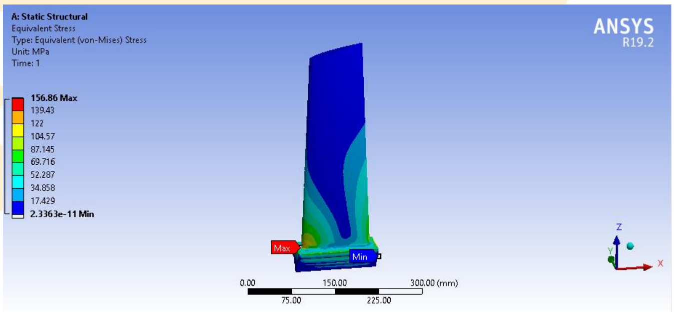


Ti-15mo

Deformation



Stress



Strain

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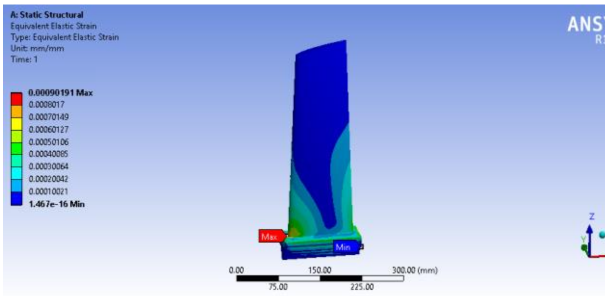
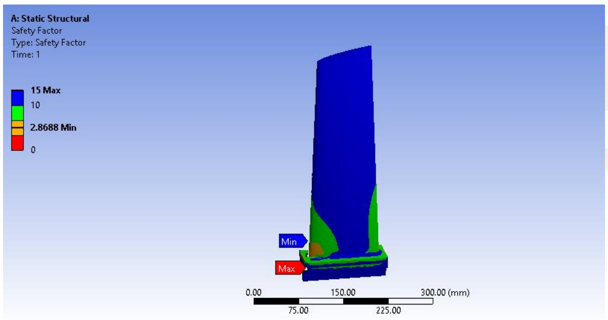


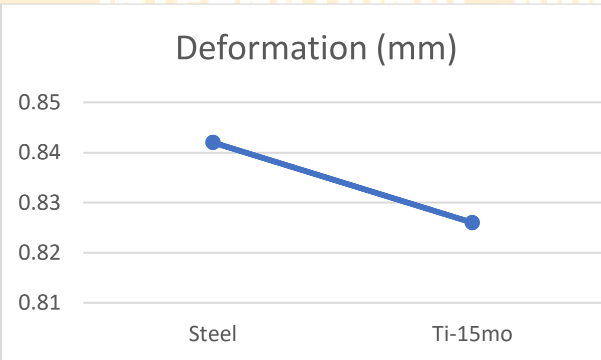
Safety factor

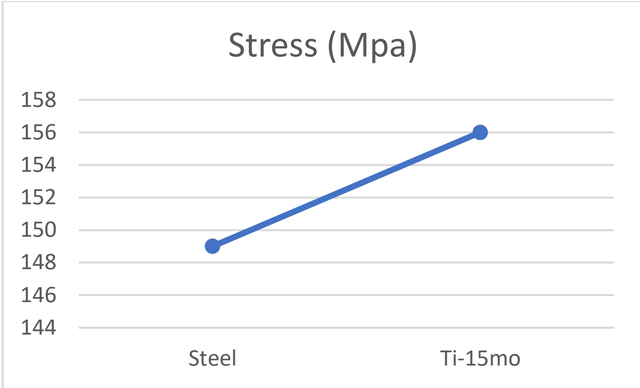


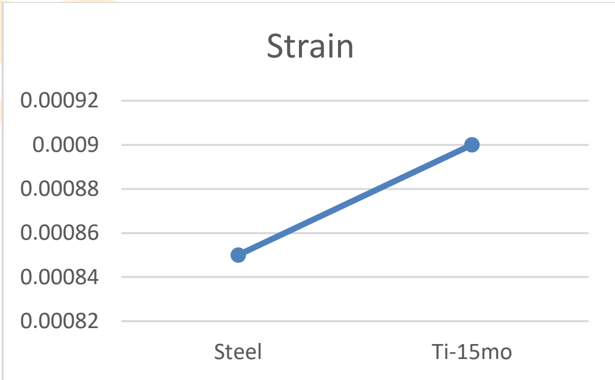
Tables

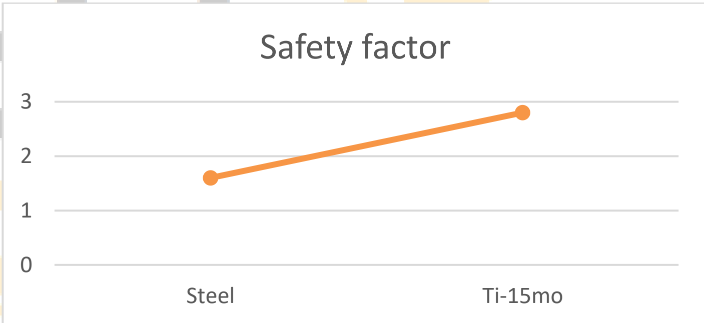
Naca 2412	Steel	Ti-15mo
Stress (Mpa)	149	156
Deformation (mm)	0.842	0.826
Safety factor	1.6	2.8
Strain	0.00085	0.00090

Graphs





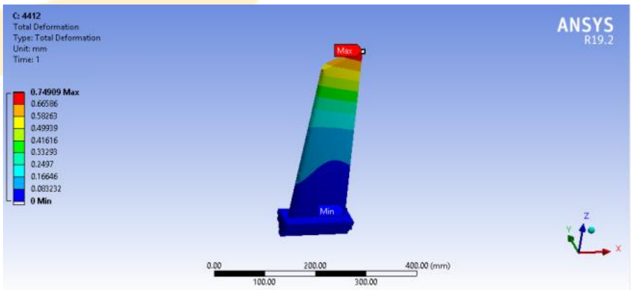




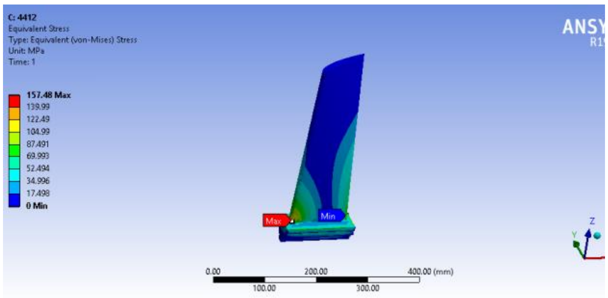
Naca 4412

Steel

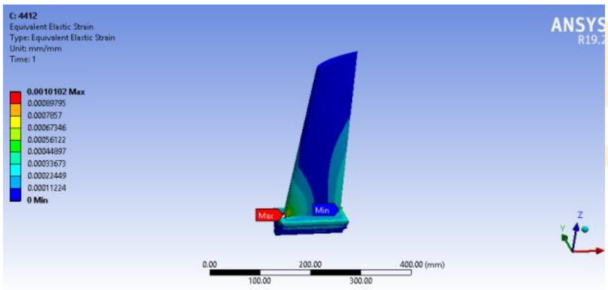
Deformation



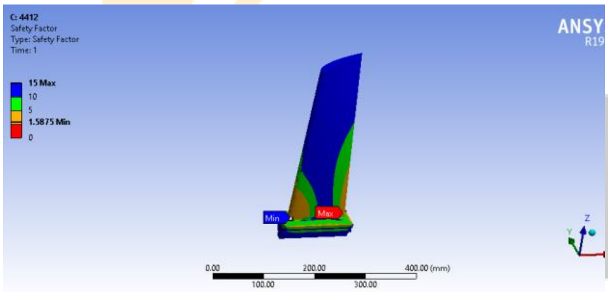
Stress



Strain

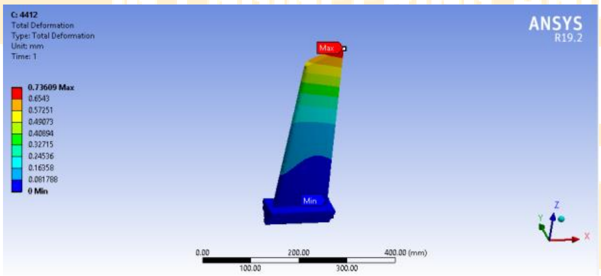


Safety factor

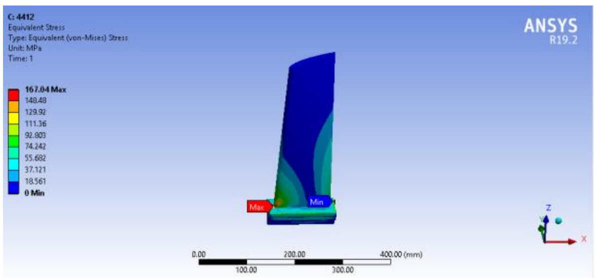


Ti-15mo

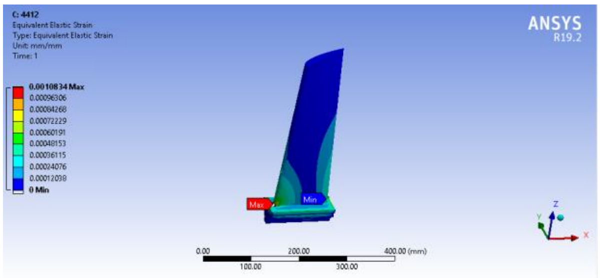
Deformation



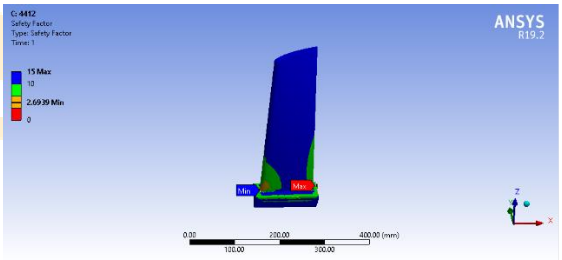
Stress



Strain



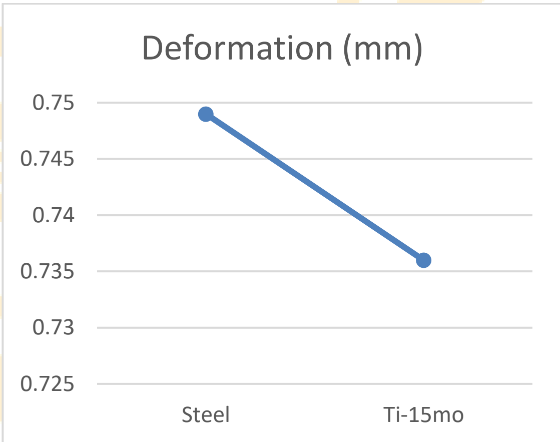
Safety factor



Tables

Naca 4412	Steel	Ti-15mo
Deformation (mm)	0.749	0.736
Strain	0.00101	0.001
Safety factor	1.58	2.69
Stress (Mpa)	157.	167.

Graphs



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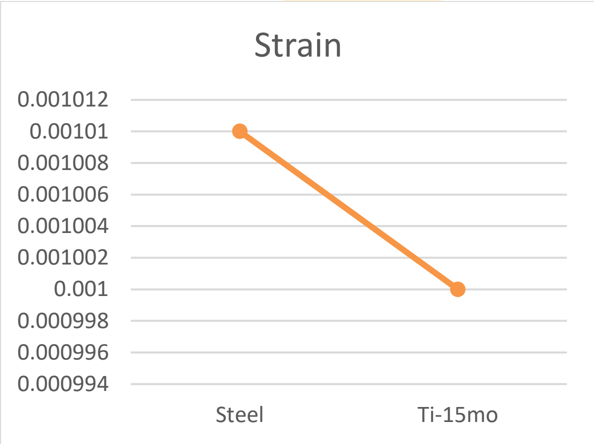
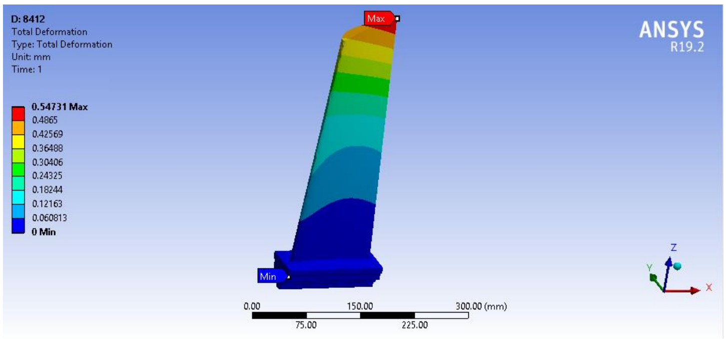


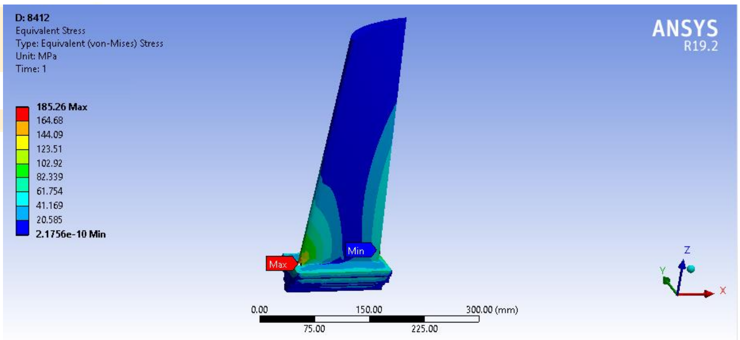
Naca 8412

Steel

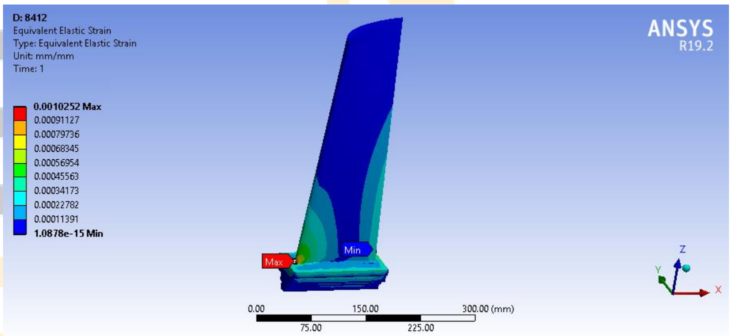
Deformation



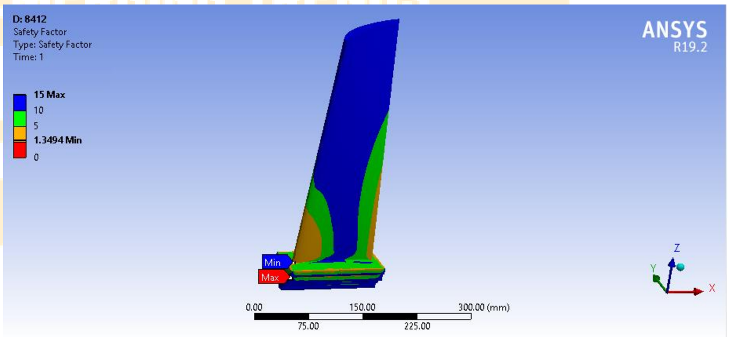
Stress



Strain

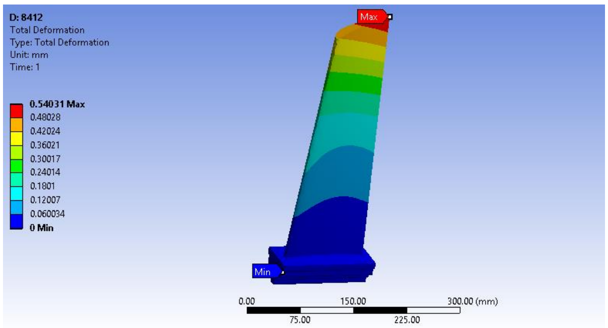


Safety factor

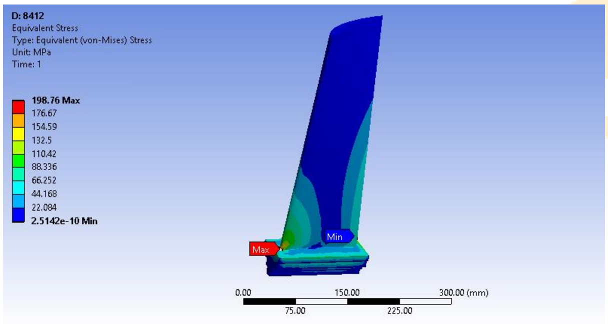


Ti-15mo

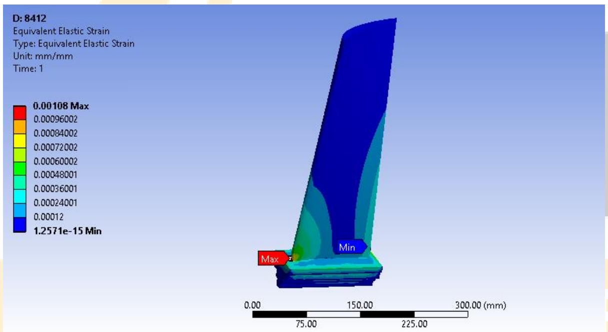
Deformation



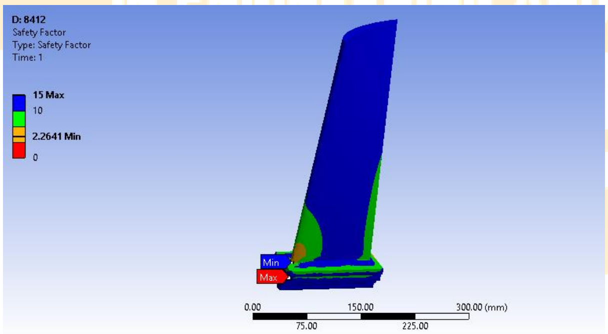
Stress



Strain



Safety factor

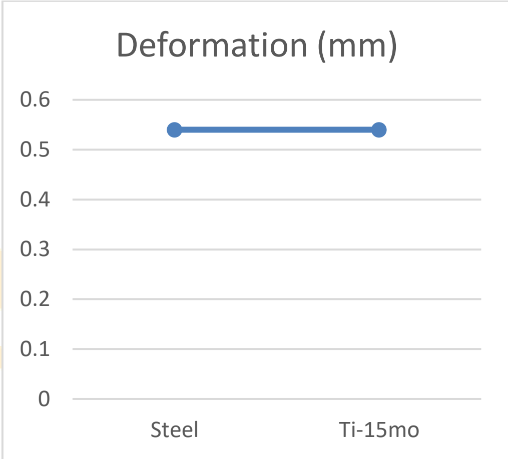


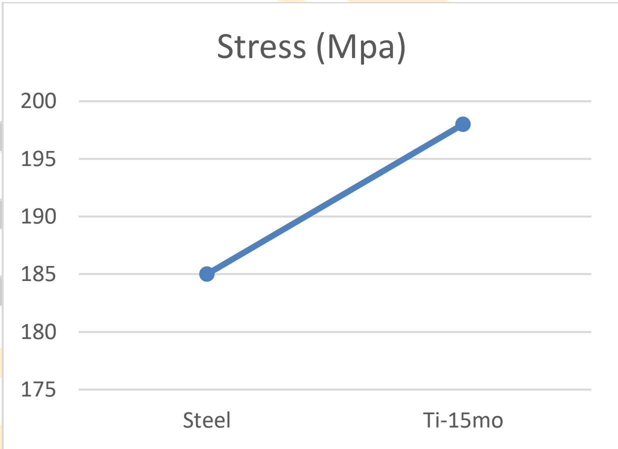
Tables

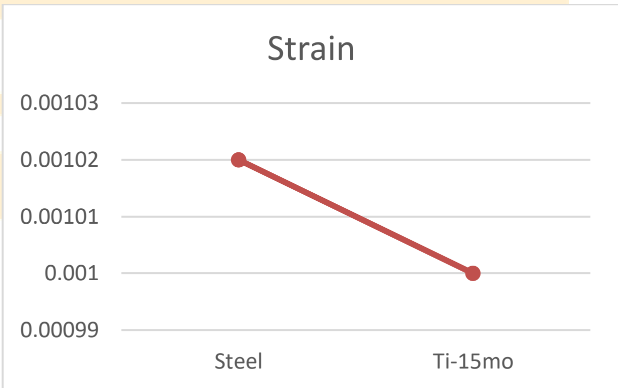
Naca 8412	Steel	Ti-15mo
Deformation (mm)	0.54	0.540
Safety factor	1.34	2.26

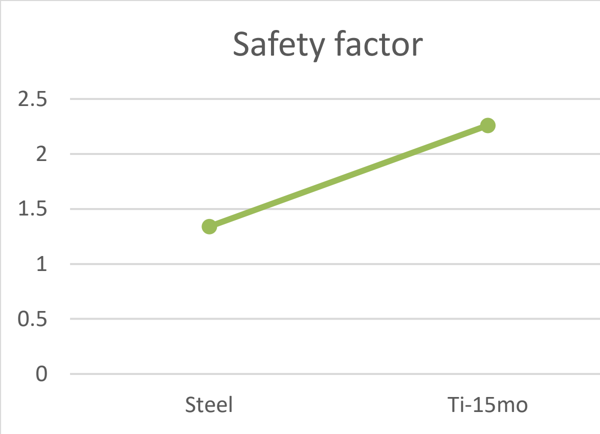
Strain	0.00102	0.001
Stress (Mpa)	185.	198.

Graphs









Comparison and discussion of static analysis results for naca series blades

Naca 2412	Steel	Ti-15mo
Stress (Mpa)	149	156
Deformation (mm)	0.842	0.826
Safety factor	1.6	2.8
Strain	0.00085	0.00090

Naca 4412	Steel	Ti-15mo
Deformation (mm)	0.749	0.736
Strain	0.00101	0.001
Safety factor	1.58	2.69
Stress (Mpa)	157.	167.

Naca 8412	Steel	Ti-15mo
Deformation (mm)	0.54	0.540
Safety factor	1.34	2.26
Strain	0.00102	0.001
Stress (Mpa)	185.	198.

Conclusion

In this study, three NACA series turbine blades—the NACA 2412, the NACA 4412, and the NACA 8412—were designed with the help of the CAD software solid works and then analysed with three distinct boundary conditions—static, thermal, and fluid—by altering the materials. During this process, steel material is considered to be an existing material, and steel Ti-15mo is considered to be a new material to gain a more efficient object.

Based on the findings of the static analysis, three blades are able to withstand an applied boundary condition of 60Mpa of it, and all models have a factor of safety value that is close to 1.5, which means that this pressure is an allowable pressure value. Of these models, the NACA 2412 series has a lower stress value on it, and it is able to withstand more pressure than the other two models. The NACA 8412 blade produces a high amount of stress values for steel material but is

The findings of the thermal study show that the heat transfer rate is higher for steel Ti-15mo than it is for steel material. Furthermore, the naca 8412 series with steel Ti-15mo material has superior heat transfer values than the other two models, although the differences are quite close to each other.

It is not a better way to suggest one airfoil cross section by knowing only the results of static and thermal analysis. In gas turbine selection, the coefficient of lift and drag values also plays an important role while the turbine is rotating about an angular velocity. To know these parameters, you need to know only the results of static and thermal analysis. The cfd study was done using an input velocity of 4.5 metres per second; by knowing these numbers, naca 4412 has higher lift coefficient values and least drag coefficient values.

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