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Structural Analysis of Gas Turbine Blade

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Abstract: ***A turbine blade is a machine component which makes up the turbine section of a gas turbine. These 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 the gas turbine. 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 and thermal barrier coatings. A common failure mode for turbine machine is high cycle of fatigue of compressor and turbine blades due to high dynamic stress caused by blade vibration and temperature has significant effect on gas turbine blades. The stresses with detrimental effect to the nozzle and blade were principally of thermal type, developed due to high temperature gradients across the air foil wall. These generate thermal fatigue mechanism and high steady state load leading to creep mechanism. In this project, a turbine blade is designed and modelled in NX Unigraphics software which is an advanced high-end CAD/CAE/CAM. The design is modified by changing the base of the blade to increase overall efficiency. Since the design of turbo machinery is complex and efficiency is directly related to material performance and material selection is of prime importance. In this project few materials are considered for turbine blade –titanium alloy and Nickel alloy. Optimisation will be done by varying the materials by performing structural analysis and thermal analysis on the turbine blades for both the designs***

Keywords: CAD/CAE/CAM NX Unigraphics

I. INTRODUCTION

A turbine is a rotary engine that extracts energy from a fluid flow and converts it into useful work. The simplest turbines have one moving part, a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades, or the blades react to the flow, so that they move and impart rotational energy to the rotor. Gas, steam, and water turbines usually have a casing around the blades that contains and controls the working fluid. credit for invention of the steam turbine is given both to the british engineer sir Charles parsons (1854-1931), for invention of the reaction turbine and to swedish engineer gustaf de laval(1845-1913), for invention of the impulse turbine .modern steam turbines frequently employ both reaction and impulse in the same unit , typically varying the degree of reaction and impulse from the blade root to its periphery .a working fluid contains potential energy (pressure head) and kinetic energy (velocity head). the fluid may be compressible or incompressible. Several physical principles are employed by turbines to] collect this energy**.**

II. STEAM TURBINE

A steam turbine is a device that extracts thermal energy from pressurized steam and uses it to do mechanical work on a rotating output shaft .Its modern manifestation was invented by Sir Charles Parsons in 1884 .Because the turbine generates rotary motion ,it is particularly suited to be used to drive an electrical generator -about 90% of all electricity generation in the united states is by use of 2 steam turbines .The steam turbine is a form of heat engine that derives much of its improvement in thermodynamic efficiency through the use of multiple stages in the expansion of the steam, which results in a closer approach to the ideal reversible process.

III. GAS TURBINE

A gas turbine, also called a combustion turbine, is a type of internal combustion engine. It has an upstream rotating compressor coupled to a downstream turbine, and a combustion chamber in -between. Gas turbines are sometimes referred to as turbine engines. Such engines usually feature an inlet, fan, compressor, combustor and nozzle (possibly other assemblies) in addition to one or more turbines.

IV. WORKING CYCLE

The Brayton cycle is a thermodynamic cycle that describes the workings of the gas turbine engine, basis of the air breathing jet engine and others. It is named after George Brayton (1830-1892), the American engineer who developed it, although it was originally proposed and patented by Englishman John Baber in 1791. It is also sometimes known as the joule cycle. The Ericsson cycle is similar but uses external heat and incorporates the use of a regenerator.

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The working cycle of the gas turbine engine is similar to that of the four-stroke piston engine. However, in the gas turbine engine, combustion occurs at a constant pressure, whereas in the piston it occurs at a constant volume. Both engine cycles show that in each instance there is induction, compression, combustion and exhaust. These processes are intermittent in case of the piston engine only one stroke is utilized in the production of power, the others being involved in the charging, compressing and exhausting of the working fluid. In contrast, the turbine engine eliminates the three 'idle' strokes, thus enabling more fuel to be burnt in a shorter time; hence it produces a greater power output for a given size of engine. Due to this continuous action of the turbine engine and the fact that the combustion chamber is not an enclosed space, the pressure of the air does not rise, 6 like that of the piston engine, during combustion but its volume does increase. This process is known as heating at constant pressure. Under these conditions there is no peak or fluctuating pressures to be withstood, as is the case with the piston engine with its peak pressures in excess of 1,000 lb. per sq. in. It is these peak pressures which make it necessary for the piston engine to employ cylinders of heavy construction and to use high octane fuels, in contrast to the low octane fuels and the light fabricated combustion chambers used on the turbine engine. The working cycle upon which the gas turbine engine functions is, in its simplest form, represented by the cycle shown on the pressure volume diagram in fig.2-2. Point A represents air at atmospheric pressure that is compressed along the line AB. From B to C heat is added to the air by introducing and burning fuel at constant pressure, there by considerably increasing the volume of air. Pressure losses in the combustion chamber (part 4) or indicated by the drop between B and C. from C to D the gases resulting from combustion expand through the turbine and jet pipe back to atmosphere. During this part of the cycle some of the energy in the expanding gases is turned into mechanical power by the turbine; the remainder, on its discharge to atmosphere, provides a propulsive jet. Because the turbo-jet engine is a heat engine, the higher the temperature of combustion the greater is the expansion of the gases. The combustion temperature, however, must not exceed a value that gives a turbine gas entry temperature suitably for the design and materials of the turbine assembly. The improvements of the gas turbine cycle have historically been aiming at increasing the efficiency, lowering the investment cost, and reducing environmental emissions. To increase efficiencies, turbine designers have worked to increase firing temperatures without damaging threaten their integrity and reliability. Development of advanced cooling techniques and improving materials is two major strategies of 7 solving this problem. The improvements of the individual efficiencies of the main gas turbine components like the compressor and turbine have also helped in increasing the gas turbine efficiency. In addition, improved efficiency can be achieved by modifications to the original simple cycle to recover heat from the turbine exhaust. Examples of this kind of modifications are recuperated gas turbines, exhaust gas heat recovery for generation of steam in a steam turbine bottoming cycle, the STIG cycle, the HAT cycle, and the chemically recuperated cycle. Energy can be extracted in the form of shaft power, compressed air or thrust or any combination of these and used to power aircraft, trains, ships, generators. In a gas turbine engine, a single turbine section is made up of a disk or hub that holds many turbine blades. That turbine section is connected to a compressor section via a shaft (or "spool"), and that compressor section can either be axial or centrifugal. In compressor air is compressed, raising the temperature and pressure of the engine. The pressure and temperature are then greatly increased by combustion of fuel inside the combustor, which sits between the compressor stages and the turbine stages. The high temperature and high-pressure exhaust gases then pass through the turbine stages. The turbine stages extract energy from this flow, lowering the pressure and temperature of the air, and transfer the kinetic energy to the compressor stages along the spool. This process is very similar to how an axial compressor works, only in reverse. There, the high velocity and volume of the gas flow is directed through a nozzle over the turbine's blades, spinning the turbine which powers the compressor and, for some turbines, drives their mechanical output. The energy given up to the turbine comes from the reduction in the temperature and pressure of the exhaust gas. The number of turbine stages varies in different types of engines, with high bypass 8 ratio engines tending to have the most turbine stages. The number of turbine stages can have a great effect on how the turbine blades are designed for each stage. Many gas turbine engines are twin spool designs, meaning that there is a high pressure spool and a low-pressure spool. Other gas turbines used three spools, adding an intermediate pressure spool between the high- and low-pressure spools. The high pressure turbine is exposed to the hottest, highest pressure, air, and the low-pressure turbine is subjected to cooler, low pressure air. The difference in conditions leads the design of high pressure and low-pressure turbine blades to be significantly different in material and cooling choices even though the aero dynamic and thermo dynamic principles are the same.

V. PERFORMANCE AND EFFICIENCY

The type of operation for which the engine is designed dictates the performance requirement of a gas turbine engine. The performance requirement is mainly determined by the amount of shaft horse power (S.H.P) the engine develops for a given set of conditions. The majority of air craft gas turbine engines are rated at standard day conditions of 59 degrees F and 29.92 inches Hg. This provides a baseline to which gas turbine engines of all types can be compared.

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The need for high efficiency in the engine becomes more important as fuels become more costly. Engine efficiency is primarily defined by the specific fuel consumption (S.F.C) of the engine at a given set of conditions. Many factors affect both the efficiency and the performance of the engine. The mass flow rate of air through the engine will dictate engine performance. Any restrictions acting against the smooth flow of air through the engine will limit the engine's performance.9 The pressure ratio of the compressor, the engine operating temperatures (turbine inlet temperature), and the individual component efficiencies will also influence both the performance and the efficiency of the overall engine. all these factors are considered during the design of the engine. An optimum pressure ratio, turbine inlet temperature, and air mass flow rate are selected to obtain the required performance in the most efficient manner. In addition, individual engine components are designed to minimize flow losses to maximize component efficiencies.

VI. ENGINE SECTION

A. *Inlet*

The air inlet duct must provide clean and unrestricted air flow to the engine. Clean and undisturbed inlet airflow extends engine life by preventing erosion, corrosion, and foreign object damage (FOD). Consideration of atmospheric conditions such as dust, salt, industrial pollution, foreign objects (nuts and bolts), and temperature (icing conditions) must be made when designing the inlet system. Fairings should be installed between the engine air inlet housing and the inlet duct to ensure minimum airflow losses to the engine at all airflow conditions. The inlet duct assembly is usually designed and produced as a separate system rather than as part of the design and production of the engine.

B. *Compressor*

The compressor is responsible for providing the turbine with all the air it needs in an efficient manner. In addition, it must supply this air at high static pressures. The example of a large turboprop axial flow compressor will be used. The compressor is assumed to contain fourteen stages of rotor blades and stator vanes. The overall pressure ratio (pressure at the back of compressor compared to pressure at the front of 10 compressor) is approximately 9.5:1. At 100% (>13,000) RPM, the engine compresses approximately 433 cubic feet of air per second. At standard day air conditions, this equals approximately 33pounds of air per second. The compressor also raises temperature by about 550 degrees F as the air is compressed and moved rearward. The power required to drive a compressor of this size at maximum rated power is approximately 7000horse power. In an axial flow compressor, each stage incrementally boosts the pressure from the previous stage.

A single stage of compression consists of a set of rotor blades attached to a rotating disc, followed by stator vanes attached to a stationary ring. The flow area between the compressor blades is slightly divergent. Flow area between compressor vanes is also divergent, but more so than for the blades. In general terms the compressor rotor blades convert mechanical energy into gaseous energy this energy conversion greatly increases total pressure (Pt). Most of the increase is in the form of velocity (Pi), with a small increase in static pressure (Ps) due to the divergence of blade flow paths. The stator vanes slow the air by means of their divergent duct shape, converting the accelerated velocity (Pi) to higher static pressure (Ps). The vanes are positioned at an angle such that the exiting air is directed into the rotor blades of the next stage at the most efficient angle. In addition to the fourteen stages of blades and vanes, the compressor also incorporates the inlet guide vanes and the outlet guide vanes. These vanes, located at the inlet and outlet of the compressor, are neither divergent nor convergent.

The inlet guide vanes direct air to the first stage compressor blades at the "best angle". The 11 outlet guide vanes "straighten" the air to provide the combustor with the proper airflow direction. The efficiency of a compressor is primarily determined by the smoothness of the airflow. During design, every effort is made to keep the air flowing smoothly through the compressor to minimize airflow losses due to friction and turbulence.

This task is a difficult one, since the air is forced to flow into ever-higher pressure zones. Air has the natural tendency to flow toward low-pressure zones.

If air were allowed to flow "backward" into the lower pressure zones, the efficiency of the compressor would decrease tremendously as the energy used to increase the pressure of the air was wasted. To prevent this from occurring, seals are incorporated at the base of each row of vanes to prevent air leakage. In addition, the tip clearances of the rotating blades are also kept at a minimum by the use of coating on the inner surface of the compressor case. All components used in the flow path of the compressor are shaped in the form of air foils to maintain the smoothest air flow possible. Just as is the case for the wings of an airplane, the angle at which the air flows across the air foils is critical to performance. The blade and vanes of the compressor are positioned at the optimum angles to achieve the most efficient airflow at the compressor's maximum rated speed.

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C. Turbine

The turbine converts the gaseous energy of the air/burned fuel mixture out of the combustor into mechanical energy to drive the compressor, driven accessories and through a reduction gear, the propeller. The turbine converts gaseous energy into mechanical energy by expanding the hot, high-pressure gases to a lower temperature and pressure. Each stage of the turbine consists of a row of stationary vanes followed by a row of rotating blades. This is the reverse of the order in the compressor. In the 14 compressor, energy is added to the gas by the rotor blades, and then converted to static pressure by the stator vanes. In the turbine, the stator vanes increase gas velocity, and then the rotor blades extract energy. The vanes and blades are air foils that provide for a smooth flow of the gases. As the airstream enters the turbine section from the combustion section, it is accelerated through the first stage stator vanes. The stator vanes (also called nozzles) form convergent ducts that convert the gaseous heat and pressure energy into higher velocity gas flow (Pi). In addition to accelerating the gas, the vanes "turn" the flow to direct it into the rotor blades at the optimum angle. As the mass of high velocity gas flows across the turbine blades, the gaseous energy is converted to mechanical energy. Velocity, temperature and pressure of the gas are sacrificed in order to rotate the turbine to generate shaft power. All the air must flow across the air foils to achieve maximum efficiency in the turbine. In order to ensure this, seals are used at the base of the vanes to minimize gas flow around the vanes instead of through the intended gas path. In addition, the first three stages of the turbine blades have tip shrouds to minimize gas flow around the blade tips.

D. Exhaust

After the gas has passed through the turbine, it is discharged through the exhaust. Through most of the gaseous energy is converted to mechanical energy by the turbine, a significant amount of power remains in the exhaust gas. This gas energy is accelerated through the convergent duct shape of the exhaust to make it more useful as jet thrust. The principle of equal and opposite reaction means that the force of the exhausted air drives the airplane forward

VII. APPLICTION OF GAS TURBINES

The gas turbines are finding application in various fields such as in Gas Pumping, Marine, Transportation, Auto motives, Regenerator, Aircraft, Power Generation, Jet Propulsion, Turbo Machines, production of heat and power, Paper Drying, Heat Building and Air cooling systems. Fluidized bed combustion, Energy storage device and transformation of the liquid fuel into a clean gaseous fuel are future possible applications. Knowing the fluid condition at exit of each gas turbine, a value of static pressure was assumed at the turbine outlet. From this the corresponding enthalpy from required in the power turbine is calculated. The peripheral speeds of rotor and flow velocities are kept in the reasonable range so as to minimize losses. The blade selected from the direct approach in which the base profilers is taken from 16 the standard profiles available and is analysed later for flow conditions through any of the theoretical flow analysis method such as potential flow approach. The design features of the turbine segment of the gas turbine have been taken from the "Preliminary design of a power turbine for marinisation of an existing turbojet engine". It was observed only for the mechanical stresses effect on the overall stresses in the rotor blades, a detailed study is analysed only for the mechanical stresses but there was no evaluation of thermal stresses. As the temperature has a significant effect on the temperature effects to have a clear understanding of the gas turbine is analysed for the thermal stresses. The first stage rotor blade of the gas turbine is analysed for the mechanical stresses and the radial elongation's resulting from the tangential axial and centrifugal forces. The latest gas turbine in use is having a power output of 160 MW with 35.6 thermal efficiency, 14.6 pressure ration, 1533 turbine inlet temperature, 435 kg/s airflow and 584D exhaust gas temperature. It is having 16 compressor stages, 4- turbine stage and 6 cooled rows.

A. Turbine Blades

Turbine Blades are the most important components in a gas turbine power plant. A blade can be defined as the medium of transfer of energy from the gases to the turbine rotor. The blade is subjected to forces in three directions such as: • The rotor driving forces along the axial direction. • Axial forces cause by the gas flow. • Forces acting normal to the turbine shaft due to the centrifugal forces. • Differential thermal stress, erosion-corrosion and other hostile parameters hampering its smooth functioning.

B. Blades Materials

To obtain a high temperature rise in a stage, which is desirable to minimize the number of stages for a given overall pressure ratio there should be High blade speed. High axial velocity of gases. High fluid deflection in the rotor blades. The stresses developed in the turbines are so high that they require special material and careful designing.

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The designing of the blades is very complicated and the materials chosen should be such that they can withstand high temperatures and have high strength i.e. heat resistant alloys. The turbine blades are subjected to a continuous stream of gas at temperatures of about 1000C and area subjected to a tensile stress of the order.

VIII. INTRODUCTION TO TURBINE BLADE

A 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 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.

A. Materials

Since the design of turbo machinery is complex, and efficiency is directly related to material performance, material selection is of prime importance. Gas and steam turbines exhibits similar problem areas, but these problem areas are of different magnitudes. Turbines components must operate under a variety of stress, temperature and corrosion conditions. Compressor blades operate relatively low temperatures but are highly stressed. The combustor operates at a relatively high temperature and low stress conditions. The turbine blades operate under extreme conditions of stress, temperature and corrosion. These conditions are more extreme in gas turbine than in steam turbine applications. As a result, the material selection for individual components is based on varying criteria in both gas and steam turbines. A design is only as efficient as the performance of the selected component materials. The combustor liner and turbine blades are the most critical components in existing high-performance, long-life gas turbines. The extreme conditions of stress, 19 temperature and corrosion make the gas turbine blade a material challenge. Other turbine components present operational problem areas, but to a lesser degree. For this reason, gas turbine blade metallurgy will be discussed for solutions to problem areas. Definition of potential solutions will also relate to other turbine components. The interaction of a stress, temperature and corrosion yield a complex mechanism that cannot be predicted by existing technology. The required material characteristics in a turbine blade for high performance and long life include limited creep, high rupture strength, resistance to corrosion, good fatigue strength, and low coefficient of thermal strains. The failure mechanism of a turbine blade is related primarily to creep and corrosion and secondary to thermal performance, long life and minimal maintenance. The development of new materials as well as cooling schemes has been the rapid growth of the turbine firing temperature leading to high turbine efficiencies. The stage 1 blade must withstand the most severe combination of temperature, stress and environment; it is generally the limiting component in the machine., shows the trend of firing temperature and blade alloy capability. A superalloy or high performance alloy is an alloy that exhibits mechanical strength and creep (tendency for solids to slowly move or deform under stress) resistance at high temperatures, good surface stability, corrosion and oxidation resistance. Superalloys typically have a matrix with an austenitic face-cantered cubic crystal structure. A superalloy's base alloying element is usually nickel, cobalt or nickel iron. Superalloy development has relied heavily on both chemical and process innovations and has been driven primarily by the aerospace and power industries. 20 Typical applications are in the aerospace, industrial gas turbine and marine turbine industry, e.g. for turbine blades for hot sections of jet engines, bimetallic engine valves for use in diesel and automotive applications. Alloy 718 nickel-based alloy. This nickel-based, precipitation hardened alloy is newest being developed for the next generation of frame type gas turbine machines. This alloy has been used for wheels in aircraft turbines for more than 20 years. Alloys 718 contains high concentrations of alloying elements and is therefore difficult to produce in the very large ingot sizes needed for the large frame turbine wheel and spacer forgings. This effort required close cooperation between the manufacturer and its superalloy metals and large forging suppliers to conduct the solidification and forging flow studies that are necessary to bring into production a new wheel material for large wheels. Menefforts has resulted in the production of the largest ingots ever made and forged into high-quality turbine wheel.

IX. NX SOFTWARE

A. Brief History of NX

NX is one of the world's most advanced and tightly integrated CAD/CAM/CAE product development solution. Spanning the entire range of product development, NX delivers immense value to enterprises of all sizes. It simplifies complex product designs, thus speeding up the process of introducing products to the market. The NX software integrates knowledge-based principles, industrial design, geometric modelling, advanced analysis, graphic simulation, and concurrent engineering. The software has powerful hybrid modelling capabilities by integrating constraint-based feature modelling and explicit geometric modelling. In addition to modelling standard geometry parts, it allows the user to design complex free-form shapes such as air foils and manifolds. It also merges solid and surface modelling techniques into one powerful tool set.

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This self-guiding tutorial provides a step-by-step approach for users to learn NX 10. It is intended for those with no previous experience with NX. However, users of previous versions of NX may also find this tutorial useful for them to learn the new user interfaces and functions. The user will be guided from starting an NX 10 session to creating models and designs that have various applications. Each chapter has components explained with the help of various dialog boxes and screen images. These components are later used in the assembly modelling, machining and finite element analysis. The files of components are also available online to download and use. We 25 first released the tutorial for Unigraphics 18 and later updated for NX 2 followed by the updates for NX 3, NX 5, NX 7 and NX 9. This write-up further updates to NX 10. Our previous efforts to prepare the NX self-guiding tutorial were funded by the National Science Foundation's Advanced Technological Education Program and by the Partners of the Advancement of Collaborative Engineering Education (PACE) program.

B. Product Realization Process

The product realization process can be roughly divided into two phases; design and manufacturing. The design process starts with identification of new customer needs and design variables to be improved, which are identified by the 26 marketing personnel after getting feedback from the customers. Once the relevant design information is gathered, design specifications are formulated. A feasibility study is conducted with relevant design information and detailed design and analyses are performed. The detailed design includes design conceptualization, prospective product drawings, sketches and geometric modelling. Analysis includes stress analysis, interference checking, kinematics analysis, mass property calculations and tolerance analysis, and design optimization. The quality of the results obtained from these activities is directly related to the quality of the analysis and the tools used for conducting the analysis. The manufacturing process starts with the shop-floor activities beginning from production planning, which uses the design process drawings and ends with the actual product. Process planning includes activities like production planning, material procurement, and machine selection. There are varied tasks like procurement of new tools, NC programming and quality checks at various stages during the production process. Process planning includes planning for all CAD is mainly used in for detailed engineering of 2D (or) 3D drawings of physical components. It also frequently allow rotations in 3D viewing of a designed object from any desired angle. It is also used to design objects such as fewellery, furniture etc. it is also used throughout the engineering process, through strength & dynamic analysis of assemblies to definition of manufacturing methods of components. Lower products development costs and a greatly shortened design cycle. The processes used in manufacturing of the product. Parts that pass the quality control inspections are assembled functionally tested, packaged, labelled and shipped to customers. 27 A diagram representing the Product Realization Process (Mastering CAD/CAM, by Ibrahim Zeid, McGraw Hill, 2005) is shown below.

X. FINITE ELEMENT ANALYSIS

A. Getting Started

We begin with starting of an NX 10 session. This chapter will provide the basics required to use any CAD/CAM package. You will learn the preliminary steps to start, to understand and to use the NX 10 package for modelling, drafting, etc. It contains five sub-sections

1) Opening an NX 10 session,
2) Printing, saving, and closing part files,
3) Getting acquainted with the NX 10 user interface
4) Using layers and
5) Understanding important commands and dialogs.

XI. STARTING AN NX 10 SESSION AND OPENING FILES

A. Start an NX 10 Session

1) From the Windows desktop screen, click on Start →All Programs →Siemens NX 10 → NX 10

The main NX 10 Screen will open. This is the Gateway for the NX 10 software. The NX 10 blank screen looks like the figure shown below. There will be several tips displayed on the screen about the special features of the current version. The Gateway also has the Standard Toolbar that will allow you to create a new file or open an existing file. On the left side of the Gateway screen, there is a toolbar called the Resource Bar that has menus related to different modules and the ability to define 34 and change the Role of the software, view History of the software use and so on. This will be explained in detail later in this chapter.

Open a New File

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Let's begin by learning how to open a new part file in NX 10. To create a new file there are three options. ➢ Click on the New button on top of the screen

OR

2) Go through the File drop-down menu at the top-left of the screen and click New

OR

3) Press + N This will open a new session, asking for the type, name and location of the new file to be created. There are numerous types of files in NX 10 to select from the Templates dialogue box located at the centre of the window. The properties of the selected file are displayed below the Preview on the right side. Since we want to work in the modelling environment and create new parts, only specify the units (inches or millimetres) of the working environment and the name and location of the file. The default unit is millimetres

4) Enter an appropriate name and location for the file and click OK

B. Design And Cad Modelling

By using standard assumptions, theoretical calculations are made to obtain the dimensions of the blade geometry. . The design parameters are given in table 1

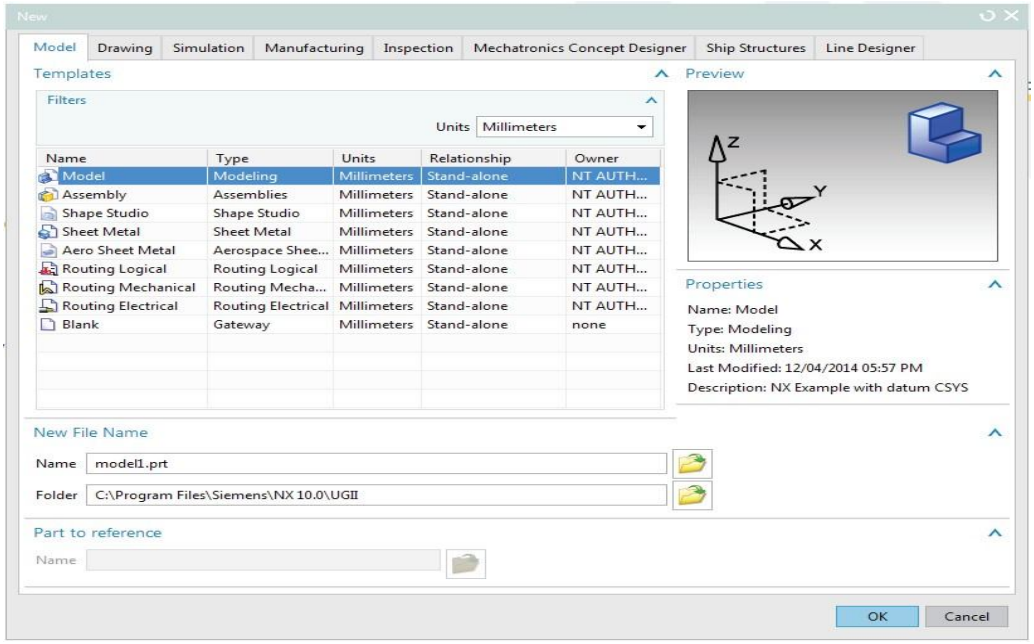


Table No.1

XII. DESIGN AND CAD MODELLING

By using standard assumptions, theoretical calculations are made to obtain the dimensions of the blade geometry. . The design parameters are given in table.2

PARAMETER	VALUE	UNIT
Blade height, h	0.081833	M
Chord width, c	0.02727	M
Pitch, s	0.02264	M
Number of blade	69	
Blade inlet angle	18.3o	Deg
Blade outlet angle	54.56o	Deg
Mean radius, rm	0.2475	M

Table no.2: Parameter value unit

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A. Details Of Turbine Blade Material

The turbine blade is subjected to rotational speed of 10800 rpm and firing temperature of 6190C. Factor of safety

Material properties Titanium

Material Properties	Value	Units
Density	4510	kg/m^3
Modulus of elasticity	105	GPa
Poisson's ratio	0.33	-
Thermal expansion coefficient	0.90e-5	/K
Heat capacity	280	J/kg-K
Thermal conductivity	22	W/m-K
Allowable temperature	2100	°K

Table no.3 Properties of Titanium

Material properties of Nickel super alloy

Material Properties	Value	Units
Density	8500	kg/m^3
Modulus of elasticity	790	GPa
Poisson's ratio	0.31	-
Thermal expansion coefficient	1.70e-5	/K
Heat capacity	360	J/kg-K
Thermal conductivity	90	W/m-K
Allowable temperature	2050	°K

Table no 3

B. Modelling

Figure 1 shows the first stage gas turbine rotor bladeprofile. Gas turbine have used this profiles which is specified by air foil terminology. With the dimensional parameters of the gas turbine rotor blade is modeled by using the Cosmo software.

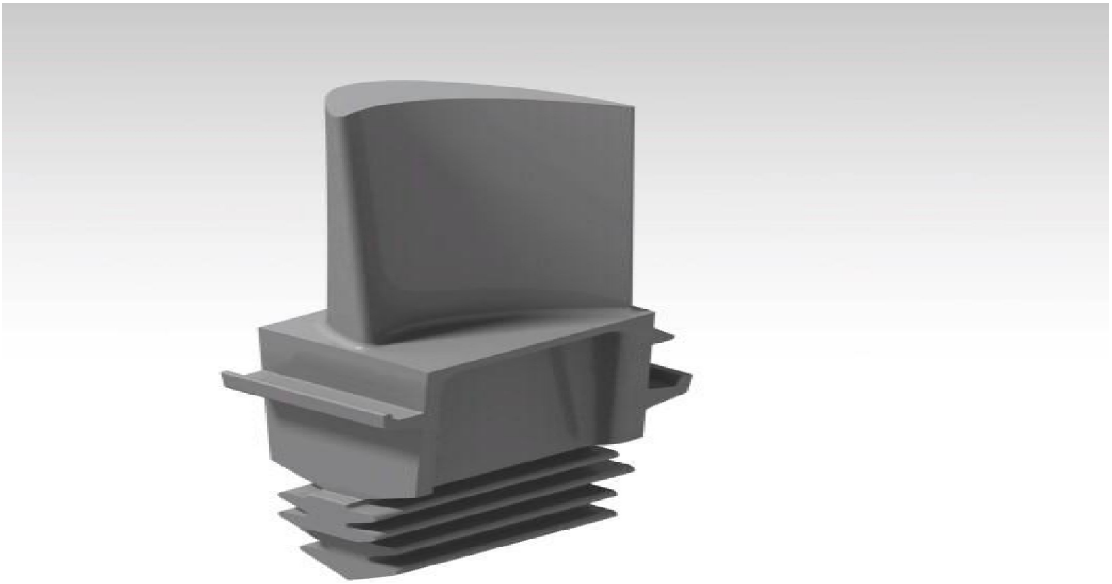


Figure 1

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Symbol	Value	Units
U_{m1}	343.8615	m/sec
α_{2r}	65.5731	deg
β_{2r}	45.2708	deg
α_{2t}	63.5179	deg
β_{2t}	34.9727	deg
α_{3r}	39.3237	deg
β_{3r}	63.3089	deg
α_{3t}	35.7720	deg
β_{3t}	64.0034	deg
θ_{2r}	40.2708	deg
θ_{2t}	44.9727	deg
h_{S1}	0.0595	m
h_{R1}	0.0826	m
n_{S1}	124	blades
n_{R1}	92	blades
w_{R1}	0.0275	m
t_{R1}	0.0129	m

Table No 4 Results Of Turbine First Stage Rotor Blade Profile

C. Evaluation Of Total Thermal Heat Fluxes

The gas turbine rotor blade is analysed for the temperature distributions and total thermal heat fluxesTurbine rotor blade inlet temperature is 1895°K and turbine

$$Nu = 0.664 Re^{0.5} Pr^{1/3} \qquad (18)$$

rotor blade outlet temperature is 1751°K. When the turbine rotor blade is subjected to heat flux and so the Nusselt number is given by,

Reynlods number is less than 5×105. Prandtl number for gas is between 0.7 and 1.

Conduction heat flux isgoverned by Fourier's Law,

$$q''_x = -k \frac{\partial T}{\partial x} \qquad (19)$$

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Convection heat flux is defined by film coefficient h, and the difference between the surface temperature Ts and ambient temperature Tα.

$$q''_{conv} = h(T_\alpha - T_s) \qquad (20)$$

Therefore, the total heat flux for the gas turbine rotor blade is defined by the combination of conduction heat flux and convection heat flux.

$$q''_t = q''_{cond} + q''_{conv} \qquad (21)$$

D. Results Of Total Thermal Heat Fluxes

Type of material	Parameter	Symbol	Value	Units
Copper	Total thermal heat flux	q_t''	2.6453	MW/m^2
Titanium	Total thermal heat flux	q_t''	0.9927	MW/m^2
Nickel	Total thermal heat flux	q_t''	1.9559	MW/m^2

Table no 5 Results of total thermal heat fluxes

XIII. STRUCTURAL ANALYSIS

A. Introduction

1) To perform structural analysis of gas turbine balde we used finite element analysis to find the deformations of the gas turbine blade.

2) Make a copy of the file C:\commun\NX\fem\turbine blade.prt file in your local folder and open it.

Creating a new simulation

a) Click on the application tab located above the tool bar, and then on the design button.

b) The new FEM and simulation dialog box open. In this dialog box, select in the solver environment field NX Nastran design as solver and structural as analysis type.

c) Click ok.

d) The solution dialog box pops-up. Make sure to use default options by clicking on the “Reset” button.

e) Then click ok.

In what follows, we will perform the next couples of steps

- Adding material properties for defining how the gas turbine blade will behave under some constraints.
- Meshing the gas turbine blade from its CAD geometry.
- Applying loads and boundary conditions.
- Computing the FEA.
- Visualizing the results.

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B. Why Structural Analysis

1) Structural analysis is the determination of the effects of loads on physical structure and their components.
2) The results of the analysis are used to verify a structure fitness for use, precluding physical test.
3) Structural analysis is there a key part of the engineering design structure.
4) Structural analysis is important as it provides a basis for structural design and also it evaluates the whether a specific design will be able to withstand external and internal stresses and forces.
5) The structural analysis holes to determine the course of a structural failure.

a) *Classification of Structures:* A structural system is the combination of structural elements and their materials. It is important for a structural engineer to be able to classify a structure by either its form or its function, by recognizing the various elements composing that structure. The structural elements guiding the systemic forces through the materials are not only such as a connecting rod, a truss, a beam, or a column but also a cable, an arch, a cavity or channel, and but an even angle, a surface structure, or a frame.

b) *Loads:* Once the dimensional requirement for a structure have been defined, it becomes necessary to determine the loads the structure must support. Structural design, therefore begins with specifying loads that act on the structure. The design loading for a structure is often specified in building codes. There are two types of code i.e. general building codes and design codes, engineers must satisfy all of the codes requirements in order for the structure to remain reliable. There are two types of loads that structure engineering must encounter in the design. The first type of loads are dead loads that consist of the weights of the various structural members and the weights of any objects that are permanently attached to the structure. For example, columns, beams, girders, the floor slab, roofing, walls, windows, plumbing, electrical fixtures and other miscellaneous attachments. The second type of loads are live which vary in their magnitude and location. There are many different type of live loads like building loads, highway bridge loads, railroad bridge loads, impact loads, wind loads, snow loads, earthquake loads and other natural loads.

c) *Analytical Methods*

- To perform an accurate analysis a structural engineer must determine information such as structural loads, geometry, support conditions and material properties. The results of such analysis typically include support reactions, stresses and displacements. This information is then compared to criteria that indicate the conditions of failure. Advanced structural analysis may examine dynamic response, stability and non-linear behavior. There are three approaches to the analysis: the mechanics of materials approach (also known as strength of materials), the elasticity theory approach (which is actually a special case of the more general field of continuum mechanics), and the finite element approach. The first two make use of analytical formulations which apply mostly simple linear elastic models, leading to closed form solutions, and can often be solved by hand. The finite element approach is actually a numerical method for solving differential equations generated by theories of mechanics such as elasticity theory and strength of materials. However, the finite element method depends heavily on the processing power of computers and is more applicable to structures of arbitrary size and complexity.
- Regardless of approach, the formulation is based on the same three fundamental relations: equilibrium, constitutive, and compatibility. The solutions are approximate when any of these relations are only approximately satisfied, or only an approximation of reality.

C. Material Properties

Click on the assign materials button and choose the nickel super alloy, titanium alloy used to prepare the part.

D. Meshing

1) *About Meshing:* The basic 3-dimensional element are the tetrahedron, quadrilateral pyramid, triangular prism, and hexahedron. They all have triangular and quadrilateral faces.
2) *Tetrahedron:* A tetrahedron has 4 vertices, 6 edges, and is bounded by 4 triangular faces. In most cases a tetrahedral volume mesh can be generated automatically.
3) *Pyramid:* A quadrilaterally-based pyramid has 5 vertices, 8 edges, bounded by 4 triangular and 1 quadrilateral face. These are effectively used as transition elements between square and triangular faced elements and other in hybrid meshes and grids.
4) *Triangular Prism:* A triangular prism has 6 vertices, 9 edges, bounded by 2 triangular and 3 quadrilateral faces. The advantage with this type of layer is that it resolves boundary layer efficiently.

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5) *Hexahedron:* A hexahedron, a topological cube, has 8 vertices, 12 edges bounded by 6 quadrilateral faces. It is also called a hex or brick for the same cell amount, the accuracy of solutions in hexahedral meshes is the highest. The pyramid and triangular prism zones can be considered computationally as degenerate hexahedrons, where some edges have been reduced to zero. Other degenerate forms of a hexahedron may also be represented.

a) Click on the 3D tetrahedral button.
b) Select the part as object to mesh and use CTETRA 10 elements (tetrahedral elements with quadratic shape functions -10 nodes).
c) Set the element size to 1mm and click ok.
d) The meshing of the turbine blade will take a couple of seconds.

E. Loads

1) For the gas turbine blade, the major force acts on the concave surfaces of the turbine blades. This loading can be approximated by normal pressure on all five surfaces.
2) Click on the temperature button under the load type button.
3) In the temperature dialog box, select all the five concave surfaces of the turbine blades and set a temperature of 1751K.

F. Boundary Conditions

1) Click on the fixed constraint button, under the constraint type button.
2) Click on the top surfaces of the gas turbine blade and click ok.

G. The Simulation Navigator

1) The simulation navigator regroups several items.
2) The FEM file which contains (a link to) the CAD geometry of the turbine blade and its corresponding mesh.
3) The CAD geometry of the turbine blade.
4) The associated mesh.
5) The loads and constraints that define the boundary conditions.
6) The solution and results of the simulation.

H. Checking the Consistency of the Model

1) Click on menu- analysis-finite element mode- check- model setup.
2) In the model setup dialog box, just click ok.
3) This will display the result. You will be able to see any errors and warnings in a separate window. In case you get errors or warnings go back to the previous steps and complete the required things. If you do not get errors or warnings you are ready to solve the FEA problem.

I. Solving

1) Click on the solve button.
2) In this solve dialog box, just click ok.
3) This will generate the required files for the NX Nastran solver, which will compute the FEA and return the results to siemens NX. (it may take a couple of seconds).
4) Click on cancel when the analysis job monitor window shows completed.
5) Also, close the information window.

J. Visualizing the Results

1) In the simulation navigator, right-click on result and then open.
2) This will open the post processing navigator.
3) You can, for instance, expand the structural tree and double click on the displacement item to see how the blades have been affected by the applied temperature.
4) Vonmisses stresses are appear in red at the tip of the blades and are about a magnitude of 96000.

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K. Animation

1) Click on the animate button and set the number of frames to 100, and the synchronized frame delay
2) Click ok to launch the animation and click the stop button for stopping it.
3) For comparing the deformed situation from the undeformed one, click on the edit post view button.
4) In the display tab of the post view dialog box, check the show undeformed model and click ok.
5) You should obtain the result.

XIV. RESULTS

We are comparing the results basedon von-misses stresses.on the bases of following cases

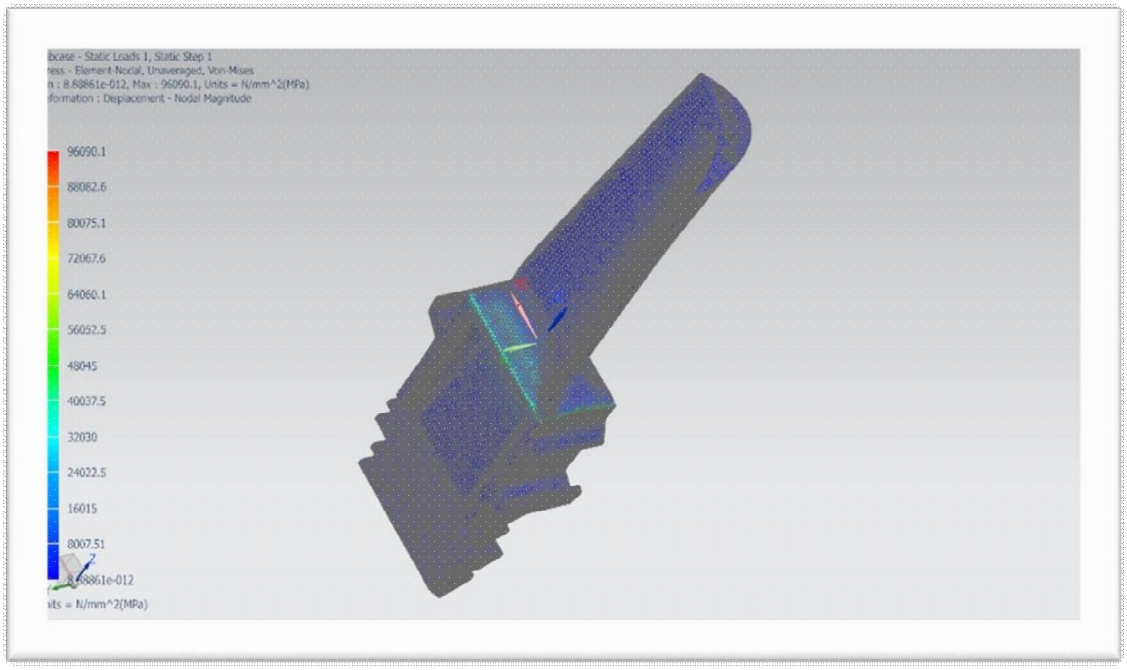


Fig.2 : Nickel super alloy with 4 holes

Nickel super alloy with 4 holes having having von-misses stresses of 96060MPa. This is very large compared to titanium 4 holes.so ,further cases we eliminate titanium for the next cases.

A. Nickel super alloy with 6 holes

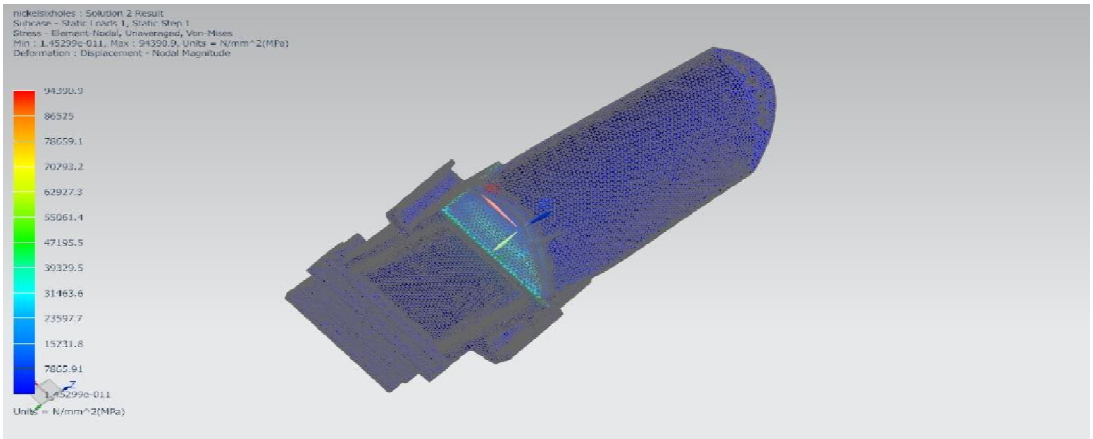


Fig 3: Nickel super alloy with 6 holes

Nickel super alloy with 6 holes having von-misses stresses of 94300MPa.which is quite lesser than nickel super alloy with 4 holes.

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B. Nickel super alloy with no-holes

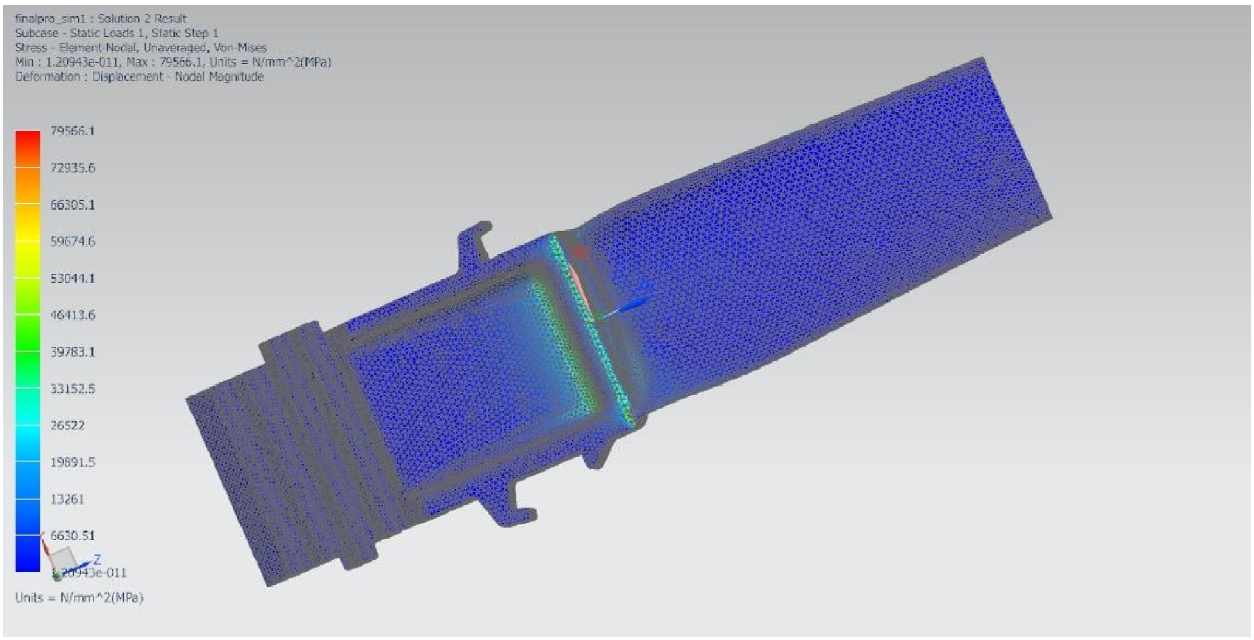


Fig4: Nickel super alloy with No-holes

This analysis showing von-misses stresses of 79066MPa., which is less than both 4 and 6 holes of nickel super alloy.

C. Comparision

s.no	Material	With no holes	4 holes	6 holes
01	Titanium	6640 MPa	9050 MPa	8560MPa
02	Nickel super alloy	76066 MPA	96060MPA	94300MPa

Table no 6: comparison of results

By comparing the above results,
We are concluding that nickel super alloy with 4 holes is more preferable.

XV. CONCLUSION

In our project we have design taken a turbine blade used in gas turbines. Three other models with 4 holes and 6 holes and no-holes are modelled. We have done structural and thermal analysis on all the models of gas turbine blades using Titanium alloy and Nickel super alloy. By observing the analysis results, more the von misses stresses, more the structure is preferable. The stress and deformation values are more for Nickel super alloy.

By comparing all the results, nickel super alloy with 4 holes is more preferable. why because, nickel super alloy with 4 holes can able to with stand more stresses compared to 6 holes .the above phenomenon is because of the more material removed in the 6 holes above the optimum permissible value. So, we are concluding the Nickel super alloy with 4 holes is more preferable.

XVI. FUTURE SCOPE

A. We have done the project on the basis of trail and error method,in the future we should go for OPTIMISATION method in any analysis software

B. In the future the modified blade can undergo ceramic and other metal coating for the sake of increasing the blade life.

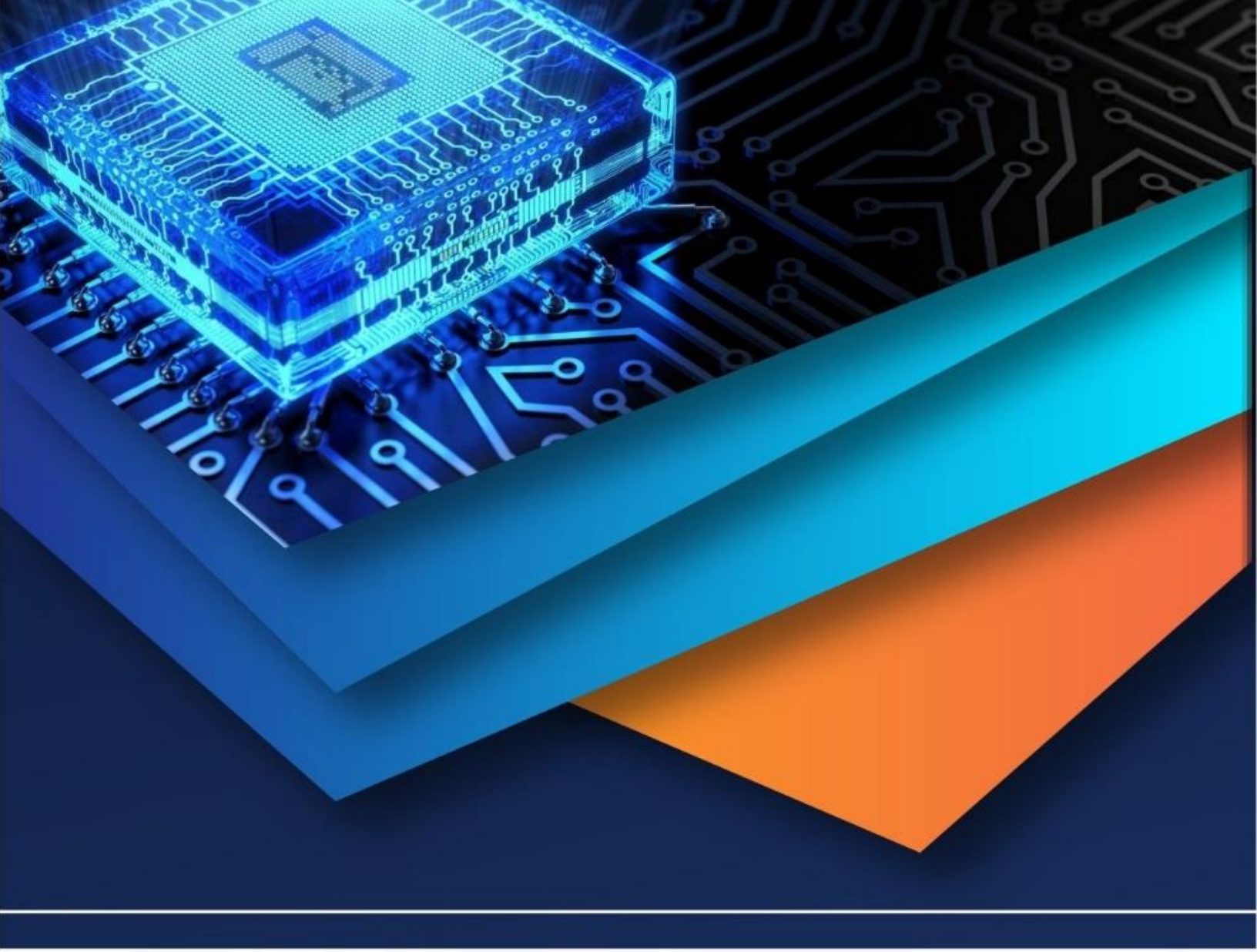
C. For futhur information, stability of the blade can be increased by the changing or modification of locking system therby reduces the vibration induced in the gas turbine blade.

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