STUDY ON DESIGN AND ANALYSIS OF STEAM TURBINE BLADE TO FIND ITS FREQUENCY AND DEFORMATIONS

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ABSTRACT

Steam turbines are becoming widely used for combined power generation and heat applications. The turbine blades are responsible for extracting energy from the high temperature steam produced by the combustor. Operating the steam turbine blade at high temperatures would provide better efficiency and maximum work output. These turbine blades are required to withstand large centrifugal forces, elevated temperatures and are operated in aggressive environments. To survive in this difficult environment, turbine blades often made from exotic materials. In this paper, four materials such as Niobium, Silicon carbide, titanium and aluminum have been considered for the purpose of frequency, modal analysis. The turbine blade is analyzed for its structural performance by mode condition. The stresses induced in the turbine blade made up of niobium and silicon carbide are well within the safe limits. Finally, it could be concluded that the niobium, silicon carbide which is being used in manufacturing of the turbine blade of turbine engine as the best suitable material. This project explains study, designing and analysis of turbine blade, Catia V5 R20 software is used to design the blade with the help of 2D and 3D commands and the analysis of blade is done in ANSYS 15.0 software by meshing the blade and applying the boundary conditions. Steam turbine blade design, cycle and operation of steam turbine was studied and reported.

Keywords: *Frequency of turbine blade, turbine materials, study of turbine blades*

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1. INTRODUCTION

Steam turbine is prime-mover which converts heat energy of steam to mechanical energy. When steam is allowed to expand through an orifice then heat energy (enthalpy), is converted into kinetic energy. This kinetic energy of steam is changed to mechanical energy through the impact (impulse) or reaction of steam against the blades. The force of steam is used to spin the turbine blades which spin the generator, producing electricity.

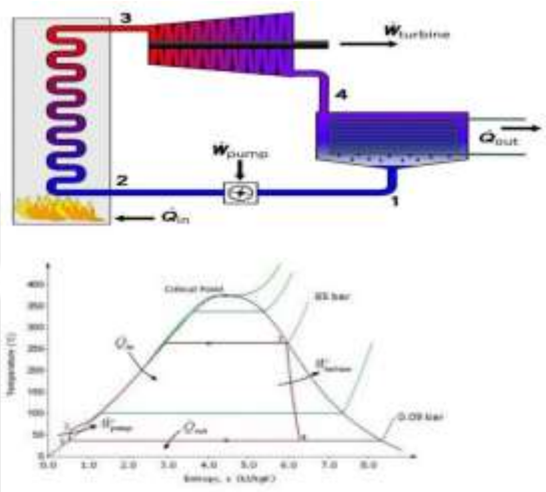
2.1.WORKING PRINCIPLE:

When steam is allowed to expand through a narrow orifice, it assumes kinetic energy at the expense of its enthalpy. This K.E of steam is changed to mechanical energy through the impact (impulse) or reaction of steam against the blades.It should be realized that the blade of the turbine obtains no motive force from the static pressure of the steam (or) from any impact of the steam jet. The blades are designed in such a way, that steam will glide on and off the blade without any tendency to strike it.As the steam moves over the blades, its direction is continuously changing and centrifugal pressure exerted as the result is normal to the blade is thus the resultant of all the centrifugal. Forces adding the change of momentum. This causes the rotational motion of the blades. The total power plant was operated by the ranking cycle.

2.2 RANKINE CYCLE:

Ranking cycle is a model that is used to predict the performance of steam turbine system. That ranking cycle is an idealized thermodynamic cycle of a heat engine that converts heat energy into mechanical work. The heat is supplied externally to a closed loop, which usually used water as the working fluid.

Fig. 1: T-S diagram of a typical Ranking cycle



THROTTLE GOVERNING – LARGE TURBINES :

In larger steam turbines an oil operated servo mechanism is used in order to enhance the lever sensitivity. The use of a relay system magnifies the small deflections of the lever connected to the governor sleeve. The differential lever is connected at both the ends to the governor sleeve and the throttle valve spindle respectively. The pilot valves spindle is also connected to the same lever at some intermediate position. Both the pilot valves cover one port each in the oil chamber. The outlets of the oil chamber are connected to an oil drain tank through pipes. The decrease in load during operation of the turbine will bring about increase in the shaft speed thereby lifting the governor sleeve. Deflection occurs in the lever and due to this the pilot valve spindle raises up opening the upper port for oil entry and lower port for oil exit. Pressurized oil from the oil tank enters the cylinder and pushes the relay piston downwards. As the relay piston moves the throttle valve spindle attached to it also descends and partially closes the valve. Thus the steam flow rates can be controlled. When the load on the turbine increases the deflections in the lever are such that the lower port is opened for oil entry and upper port for oil exit. The relay piston moves upwards and the throttle valve spindle ascend upwards opening the valve.

NOZZLE GOVERNING:

In nozzle governing the flow rate of steam is regulated by opening and shutting of sets of nozzles rather than regulating its pressure. In this method groups of two, three or more nozzles form a set and each set is controlled by a separate valve. The actuation of individual valve closes 14 the corresponding set of nozzle thereby controlling the flow rate. In actual turbine, nozzle governing is applied only to the first stage whereas the subsequent stages remain unaffected. Since no regulation to the pressure is applied, the advantage of this method lies in the exploitation of full boiler pressure and temperature. Figure shows the mechanism of nozzle governing applied to steam turbines. As shown in the figure the three sets of nozzles are controlled by means of three separate valves.

3. INTRODUCTION TO CATIA

CATIA is a robust application that enables you to create rich and complex designs. The goals of the CATIA course are to teach you how to build parts and assemblies in CATIA, and how to make simple drawings of those parts and assemblies. This course focuses on the fundamental skills and concepts that enable you to create a solid foundation for your designs

CATIA is mechanical design software. It is a feature- based, parametric solid modeling design tool that takes advantage of the easy-to-learn Windows graphical user interface. You can create fully associative 3-D solid models with or without constraints while utilizing automatic or user-defined

relations to capture design intent. To further clarify this definition, the italic terms above will be further defined: Feature-based Like an assembly is made up of a number of individual parts, a CATIA document is made up of individual elements. These elements are called features. When creating a document, you can add features such as pads, pockets, holes, ribs, fillets, chamfers, and drafts. As the features are created, they are applied directly to the work piece.

Features can be classified as sketched-based or dress- up:

Sketched-based features are based on a 2D sketch. Generally, the sketch is transformed into a 3D solid by extruding, rotating, sweeping, or lofting. Dress-up features are features that are created directly on the solid model. Fillets and chamfers are examples of this type of feature.

4. PEDESTAL, BASE PLATE AND FIXED POINTS

The Turbines rest on the pedestals. The front pedestal houses the governor. The center pedestal houses the combined journal and thrust bearing and the other pedestals contain one journal bearing each. All pedestals are of fabricated construction. The front pedestal and the center pedestal slide over their respective base plates, which are fixed to the foundation. While the LP front and rear pedestals themselves are fixed to the foundation. On the rotating system the fixed point is provided by the thrust bearing. The LP pedestals also carry the shaft seal housing which is joined to the LP outer casing with compensators. Hence these gland clearances remain unaffected by any deformation of LP cylinder during operation.

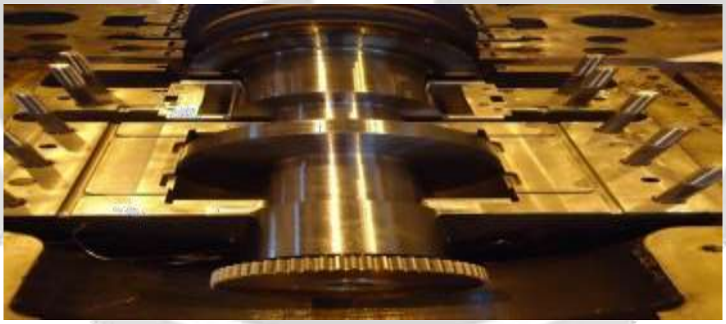


Fig 2. Turbine base plate with front bearing pedestal

STEAM TURBINE BLADES:

A **turbine blade** is the individual component which makes up the turbine section of a steam turbine. The blades are responsible for extracting energy from the high temperature, high pressure steam produced by the combustor (boiler). To survive in this difficult environment, turbine blades often use exotic materials like nickel, chromium, titanium. The high temperatures and high stresses of operation, steam turbine materials become damaged in course of time. To limit creep, thermal coatings and super alloys with ***grain boundary strengthening*** are used in blade designs. Protective coatings are used to reduce the thermal damage and to limit oxidation. These coatings are often stabilized zirconium dioxide-based ceramics. Using a thermal protective coating limits the temperature exposure of the nickel super alloy. This reduces the creep on the blades. Oxidation coatings limit efficiency losses caused by a buildup on the outside of the blades, which is especially important in the high-temperature environment. The nickel-based blades are alloyed with aluminum and titanium to improve strength and creep resistance. The microstructure of these alloys is composed of different regions of composition. An uniform dispersion of the **gamma-prime phase**

– a combination of nickel, aluminum, and titanium promotes the strength and creep resistance of the blade due to the microstructure.

GLANDS:

In the HP the seals consist of a series of sealing strips caulked alternatively in the shaft and into stationary rings. In the case of LP glands sealing strips are fitted in the stationary rings only. Each sealing ring consists of 6 or 8 segments and is carried in grooves in the casing to allow radial movement. Each segment is held in position against a shoulder by two coil springs. Both fixed and moving blades are fitted with a continuous shroud in which steps have been machined to produce a labyrinth. The sealing strips are caulked into the casing and shaft opposite to the blade and are of stainless steel which can be easily replaced.

Turbine shaft glands are sealed with auxiliary steam supplied by an Electro hydraulically controlled seal steam pressure control valve. A pressure of 0.01kg/cm2 is maintained in the seals. Above a load of 80 the turbine becomes self-sealing. The leak off steam from HP glands is used for sealing LP glands. The steam pressure in the header is then maintained constant by means of a leak off control valve which is also controlled by the same Electro hydraulic controller, controlling seal steam pressure control valve. The last stage leak off of all shaft seals is sent to the gland steam condenser for regenerative condensate heating. Since the shaft (rotor) is made in small parts due to forging limitations and other technological and economic reasons, the couplings are required between any two rotors. The coupling permits angular misalignment, transmit axial thrust and ensures axial location. The couplings are either rigid or semi flexible.

5. ANSYS OF TURBINE BLADE

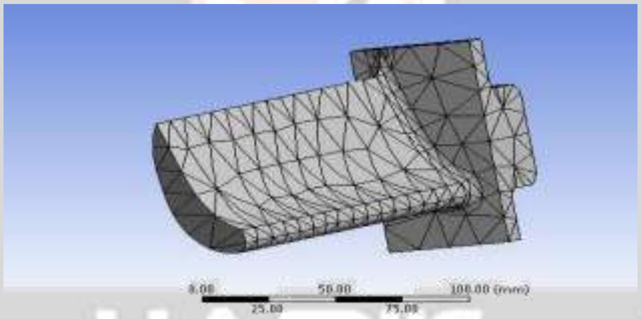
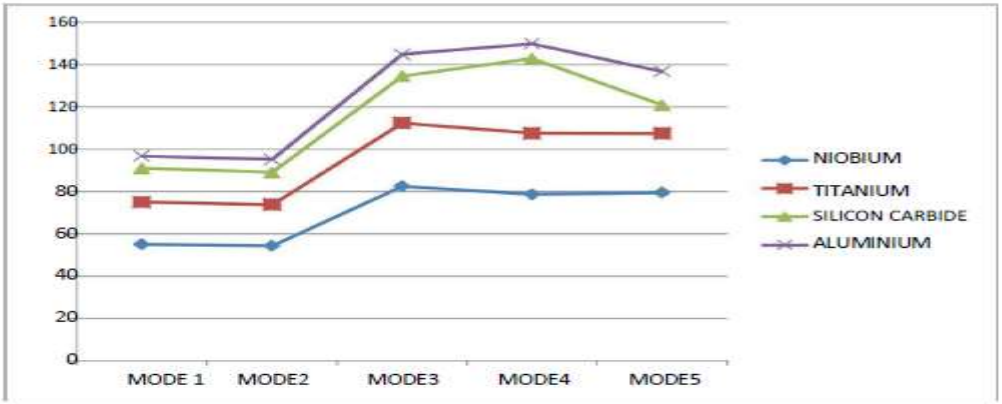


Fig 3.: Mesh figure in ansys

6. RESULTS

6.1 COMPARING THE DEFORMATIONS OF MATERIALS

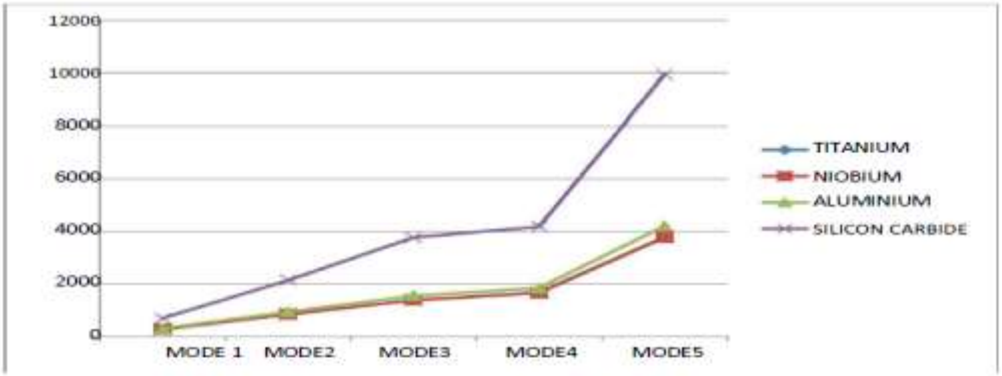


Graph showing the values of deformation along Y-Axis and the different 5 modes along X-Axis

MODES/ MATERIA L	ALUMI NIUM	SILICO N CARBI DE	TITANI UM	NIOBI UM
MODE 1	**96.802**	**91.021**	**75.038**	**55.138**
MODE2	**95.239**	**89.105**	**73.905**	**54.347**
MODE3	**144.97**	**134.67**	**112.46**	**82.655**
MODE4	**139.91**	**143.01**	**107.6**	**78.679**
MODE5	**136.83**	**120.93**	**107.49**	**79.61**

Form above table we can observe that niobium is having less deformation 55.138 at mode 1 and titanium has deformation of 75.038 and silicon carbide has deformation of 91.021 and aluminum has deformation of 96.802 and by these values we can say that niobium has less deformation when compared with other materials.

6.2 COMPARING THE FREQUENCEYS OF MATERIALS



Graph showing the values of frequencey along Y-Axis and the different 5 modes along X-Axis

MODES/ MATERIA L	ALUMI NIUM	SILICO N CARBI DE	TITANI UM	NIOBI UM
MODE 1	**308.61**	**693.37**	**278.69**	**280.81**
MODE2	**945.4**	**2152.6**	**851.76**	**856.9**
MODE3	**1558.8**	**3771.**	**1391.4**	**1391.2**
MODE4	**1845.5**	**4190.4**	**1664.**	**1675.1**
MODE5	**4220.5**	**9941.3**	**3781.4**	**3790.1**

Observing the above table niobium has frequency range of 280.81 , titanium has the range of 278.69, aluminium has 308.61 and silicon carbide has range of 693.37 at mode1. Niobium and titanium has nearby frequency range by which we can say both materials which are considered can be used for manufacturing of blades and further thermal values can be considered and analysis process can be carried out.

7. CONCLUSION

In this project, I studied the 32MW regenerative steam turbine safe running operation procedure, start-up, shutdown, safety protections, troubles and their remedies.

The work presented in the report is an attempt at designing, study of steam turbine and its blades of a given dimension. Extensive literature review was carried out to study the various aspects and applications of turbines. A suitable design procedure was chosen from the available methods to design different parts of turbine. CATIA is used extensively for making parts with diff types of operations. Then all the parts are assembled for making a complete turbine in CATIA Assembly section. Then they send for rapid prototyping.

1. By observing the deformation values of the four materials considered niobium has less deformation and silicon carbide is also have the nearest value when compared with niobium.
2. Considering the density of the four materials niobium has the high density value where as silicon carbide is having less.
3. Considering the strength of materials silicon carbide, niobium, and titanium can be used for the manufacturing of turbine blades.
4. Frequency range of niobium (280.3), titanium (278.9) are having equal by this we can also justify that these two materials can be used for the process of manufacturing.

Turbines are relatively new in the market and are attracting wide attention due to their varied applications. Development of a sophisticated engineering product like turbine blade is a continuous process. A lot of work is yet to be done on the design aspects before the turbine can be readied for market consumption. The design procedure has to take into various other parameters to make it suitable for practical applications. Also, manufacturing of such complex shapes of minute size is another ongoing research work. Further research into the design and manufacture process would result in production of even better turbine blade.

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