

## Analysis Of Steam Turbines

<sup>1</sup>A.Sudheer Reddy <sup>2</sup>MD.Imran Ahmed <sup>3</sup>T.Sharath Kumar

<sup>4</sup>A.Vamshi Krishna Reddy, <sup>5</sup>V.V Prathibha Bharathi

<sup>1234</sup> Dept. Of Mechanical Engineering, CMEC, Hyderabad, AP, India.

<sup>5</sup> Associate prof. Dept.Of Mechanical Engineering, MRCE, Hyderabad, AP, India.

**Abstract:-** Steam turbine is an excellent prime mover to convert heat energy of steam to mechanical energy. Of all heat engines and prime movers the steam turbine is nearest to the ideal and it is widely used in power plants and in all industries where power is needed for process.

In power generation mostly steam turbine is used because of its greater thermal efficiency and higher power-to-weight ratio. Because the turbine generates rotary motion, it is particularly suited to be used to drive an electrical generator – about 80% of all electricity generation in the world is by use of steam turbines.

Rotor is the heart of the steam turbine and it affects the efficiency of the steam turbine. In this project we have mainly discussed about the working process of a steam turbine. The thermal efficiency of a steam turbine is much higher than that of a steam engine.

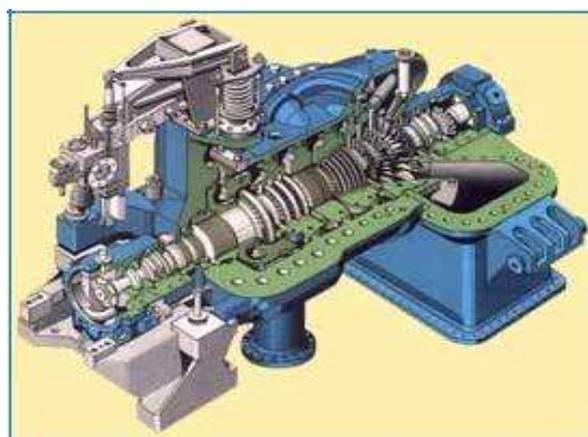
**Keywords:-** Turbine, pressure, blades, rotor.

### I. INTRODUCTION

A steam turbine is a mechanical device that converts thermal energy in pressurized steam into useful mechanical work. The steam turbine derives much of its better thermodynamic efficiency because of the use of multiple stages in the expansion of the steam. This results in a closer approach to the ideal reversible process. Steam turbines are made in a variety of sizes ranging from small 0.75 kW units used as mechanical drives for pumps, compressors and other shaft driven equipment, to 150 MW turbines used to generate electricity. Steam turbines are widely used for marine applications for vessel propulsion systems. In recent times gas turbines, as developed for aerospace applications, are being used more and more in the field of power generation once dominated by steam turbines.

### II. PRINCIPLE

The steam energy is converted mechanical work by expansion through the turbine. The expansion takes place through a series of fixed blades (nozzles) and moving blades each row of fixed blades and moving blades is called a stage. The moving blades rotate on the central turbine rotor and the fixed blades are concentrically arranged within the circular turbine casing which is substantially designed to withstand the steam pressure.



**Figure: Half sectional view of steam turbine**

### III. CLASSIFICATION OF STEAM TURBINES

Steam turbines may be classified into different categories depending on their construction, the process by which heat drop is achieved, the initial and final conditions of steam used and their industrial usage as follows:

**A. According to the Number of pressure stages:**

Single – stage turbines with one or more velocity stages usually of small power capacities, mostly used for driving centrifugal compressors, blowers and other similar machinery.

Multistage impulse and Reaction turbines, made in a wide range of power capacities varying from small to large.

**B. According to the direction of steam flow:**

Axial turbines, in which the steam flows in a direction parallel to the axis of the turbine.

Radial turbines, in which the steam flows in a direction perpendicular to the axis of the turbine. One or more low pressure stages in such turbines are made axial.

**C. According to the Number of cylinders:**

- Single cylinder turbines
- Multi cylinder (2, 3 and 4 cylinders) turbines, which can have single shaft, i.e. rotors mounted of the same shaft, or multiaxial, having separate rotor shaft and have their cylinders placed parallel to each other.

**D. According to the method of governing:**

- Turbines with nozzle governing.
- Turbines with bypass governing in which steam besides being fed to the first stage is also directly led to one, two or even three intermediate stages of the turbine.

**E. According to the Principle of Action of Steam:**

- Impulse turbines.
- Axial Reaction turbines.
- Radial reaction turbines without any stationary guide blades.
- Radial reaction turbines having stationary guide blades.

**F. According to the Heat Drop Process:**

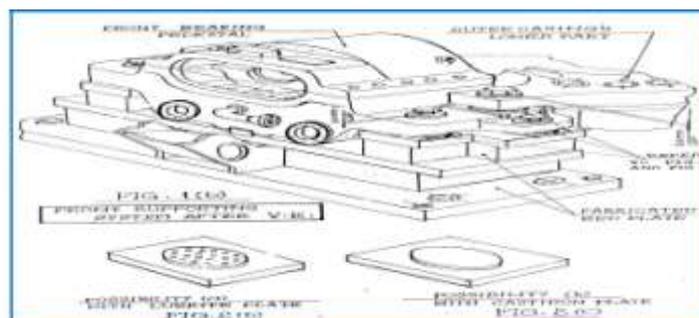
- Condensing turbines with exhaust steam let into condenser with Regenerators, Condensing turbines with one or two intermediate stage extractions at specific pressures for industrial and heating purposes.
- Back pressure turbines, the exhaust steam from which is utilized for industrial and heating purposes.
- Back – pressure turbines with steam extraction from intermediate stages at specific pressures.
- Low – pressure (Exhaust pressure) turbines in which the exhaust steam from reciprocating steam engines, power hammers, presses, etc is utilized for power generation.
- Mixed – pressure with two or three pressure extractions with supply of exhaust steam to its intermediate stages.

**G. According to the Steam Conditions at inlet:**

- Low – pressure turbines using at pressures 1.2 to 2 ata.
- Medium – pressure turbines using steam at pressure up to 4.0 ata.
- High – pressure turbines using steam at above 40 ata.
- Very high pressure turbines using steam up to 40 ata and higher pressure and temperature.

**H. According to their Usage in industry:**

- Stationary turbines with constant speed of rotation primarily used for driving alternators.
- Stationary turbines with variable speeds meant for driving turbo blowers, air circulators, pumps etc.
- Non stationary turbines with variable speeds employed in steamers, ships, railway (turbo) locomotives etc.



#### IV. TYPES OF STEAM TURBINES

The necessity to keep down the production costs lead to standardization of the types of steam turbines, such as back pressure, condensing, extraction back pressure and extraction condensing, injection condensing

- Condensing turbines
- Back pressure turbines
- Multiple extraction turbines
- Injection condensing turbines for combined cycle plant
- Reheat condensing turbines for utility type

Most of the industrial steam turbines are high speed turbines for the power output range of 1-30MW with speed reduction by turbo gears which in turn means smaller sizes and higher efficiency for the turbine for the output of 30MW and above the turbine speed is 3000rpm.

#### V. VARIOUS PARTS OF STEAM TURBINE

**a) Nozzle:** The nozzle expands steam of comparatively low velocity and high static pressure within considerable increase in velocity. The nozzle is so positioned as to direct the flow of steam into the rotor passage.

**b) Diffuser:**

- It is a mechanical device that is designed to control the characteristics of steam at the entrance to a thermodynamic open system. Diffusers are used to slow the steam's velocity and to enhance its mixing into the surrounding steam. In contrast, a nozzle is often intended to increase the discharge velocity and to direct the flow in one particular direction.

- Flow through nozzles and diffusers may or may not be assumed to be adiabatic. Frictional effects may sometimes be important, but usually they are neglected. However, the external work transfer is always assumed to be zero. It is also assumed that changes in thermal energy are significantly greater than changes in potential energy and therefore the latter can usually be neglected for the purpose of analysis.

**c) Blades Or Buckets:** The blades or buckets form the rotor flow passage and serves to change the direction and hence the momentum of the steam received in the stationary nozzles.

**d) Guide Or Guide blades:** Often a turbine is arranged with a series of rotor flow passages. Intervening between the blades comprising the rotor passages are rows of stationary guide blades. The purpose of this guide is to reverse the direction of steam leaving the preceding moving blade row so that general direction of steam leaving the preceding moving blade rows is similar. If guide blades were not provided, opposing force would be exerted on the rotor which would largely negate each other.

**e) Casing Shell Or Cylinder:** The turbine enclosure is generally called the casing although the other two names are in common use. The nozzle and guide are fixed on casing, which in addition to confining the steam serves as support for the bearings. Sometimes the word cylinder is restricted as a cylindrical form attached to inside of the casing to which the guides are fixed.

**f) Shaft, Rotor, Spindle:** These terms are applied to the rotating assembly which carries the blades.

**g) Disc Or Wheel:** The moving blades are attached to the disc which in turn is keyed to the shaft.

**h) Diaphragm:** The diaphragm which is fixed to the cylinder or casing contains the nozzle and serves to confine the steam flow to nozzle passage.

**i) Packing:** Packing in the form of carbon rings minimizes the leaking in the annular space between the diaphragm and shaft.

**j) Thrust Bearings:** Usually a combination of Kingsbury and collar types absorbs the axial forces.

**k) Exhaust Hood:** The exhaust hood is the portion of the casing which collects and delivers the exhaust steam to exhaust pipe or condenser.

**l) Steam Chest:** The steam chest is the supply chamber from which steam is admitted to the nozzles.

**m) Governor:** The governing system may be designated to control steam flow so as to maintain constant speed with load fluctuations to maintain constant pressure with variation of demand for processed steam or both.

**n) Throttle Or Stop Valves:** The throttle and stop valves are located in the steam supply line to the turbine. The stop valve is hydraulically operated quick opening and shutting valves designed to be either fully opened or shut. On small turbines the stop valves may be manually operated but in any case is intended for emergency use or when fully shut down. The throttle valve is used in smaller turbines in addition to stop valve as a means of regulating steam flow during the starting or stopping the operation.

### VI. CYCLES USED IN STEAM TURBINES

Steam turbine power plants are based on the Rankine cycle investigated by a Scotch Engineer and Scientist William Rankine (1820 -1872). Rankine cycle for Steam turbine power plant with ideal turbines and pumps and superheated and saturated steam as a working fluid respectively as shown below. A conventional power plant steam for such a consideration is also shown:

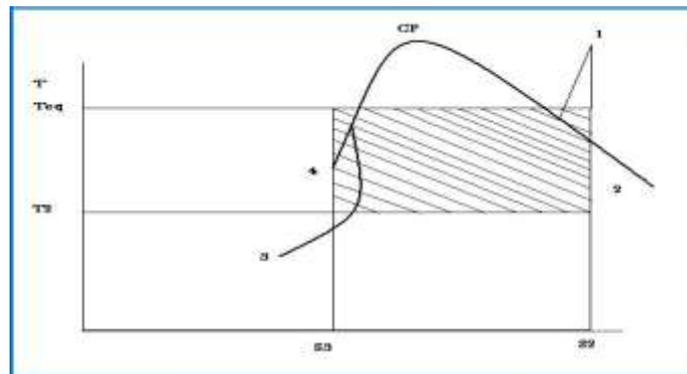


Figure: Ideal Rankine cycle for superheated steam on T-S axes.

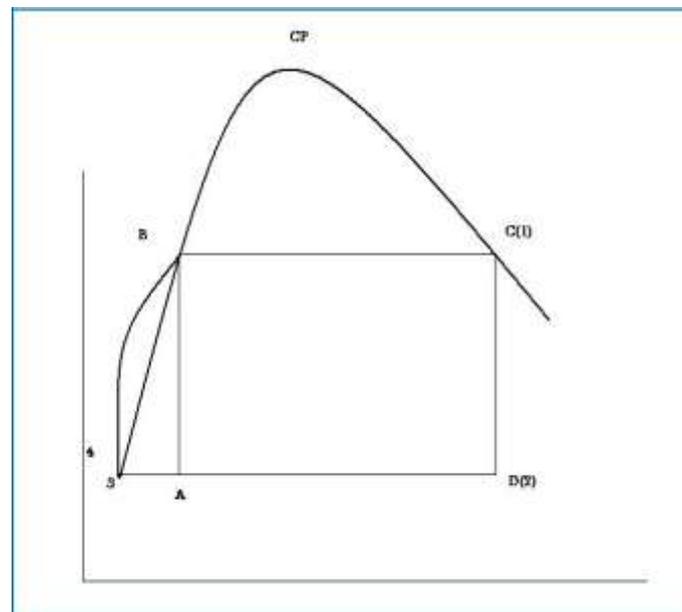


Figure: Ideal Rankine cycle for saturated steam on T-S axes

The steam turbine is fed with steam under temperature  $t_1$ , pressure  $p_1$ , and enthalpy  $h_1$ . Expanding within the turbine, steam produces work  $W_t$  and goes into the condenser under conditions  $p_2$  and  $h_2$ . Hence it rejects heat  $Q_r$  to cooling water and the resulted condensate with enthalpy  $h_3 \ll h_2$ , but with the same  $t_3=t_2$  and pressure  $p_3=p_2$  comes to the pump. At the expense of the pump work  $W_p$ , the feed water pressure and enthalpy rise to values  $p_4$  and  $h_4$  with which feed water enters the steam generators where it is heated and evaporated due to the heat added  $Q_a$ .

Ideal Rankine cycle with superheated steam as a working fluid consists of the following processes: 1-2 Adiabatic reversible expansion in the turbine

2-3 Isothermal (under constant temperature) and isobaric (under constant pressure)  
Heat rejection within the condenser.

3-4 Adiabatic reversible compression to the saturated liquid to the steam generator  
Pressure by the pump.

4-B-C-1 Isobaric heat addition in the steam generator

4-B: Heating feed water in economizer

B-C: Heating in boiler

C-1: Heating in super heater

For saturated – steam cycle the steam expansion process in the turbine begins from C, and with complete condensation in 3 with subsequent compression by the pump.

Thermal efficiency of ideal Rankine cycle for superheated –steam turbine power plant can be defined as:

$$\begin{aligned} n_{th} &= \frac{d W_{net}}{Q_a} = \frac{(W_T - W_P)}{Q_a} = \frac{(h_1 - h_2) - (h_4 - h_3)}{(h_1 - h_4)} \\ &= \{(h_1 - h_2) / (h_1 - h_4)\} \times \{1 - (h_4 - h_3) / (h_1 - h_2)\} \\ &= n_{th} \times (1 - W_P / Q_a) \end{aligned}$$

Here  $n_{th}$  is the gross thermal efficiency that is without regard to the expense of energy with in the cycle. If pump working is neglected, then the efficiency,

$$n_{th} = (h_1 - h_2) / (h_1 - h_4)$$

**STEAM REHEAT**

In the cycle with steam reheat instead of through adiabatic steam expansion from initial steam pressure  $p_1$  to end pressure  $p_2$ , steam expands within the HP turbine part to the intermediate pressure (point5) and then is heated isothermally to steam reheat temperature (point 6) and then expands within IP-LP part to same end pressure  $p_2$  as shown below. In this case, for ideal cycle the thermal efficiency is approximately given by:

$$n_{th} = \frac{(h_1 - h_5) + (h_6 - h_2)}{(h_1 - h_4) + (h_6 - h_5)}$$

Conventional power plant scheme

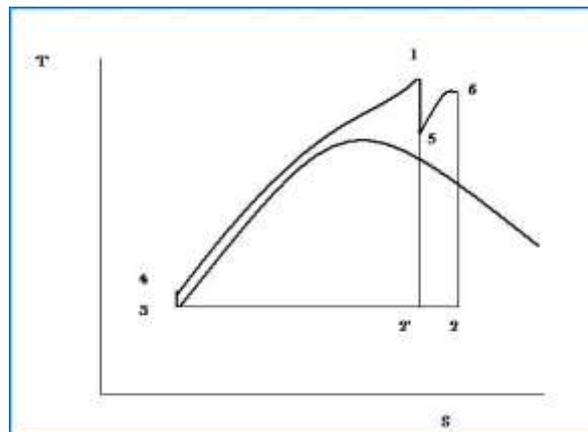


Figure: Ideal Rankine cycles for steam reheat

**VII. CATEGORIES IN STEAM TURBINE**

Industrial steam turbine are categorized into different series

like -2 series

-3 series

-4 series

**2 Series Turbines:**

These series of turbines are of standard type and have been designed for the best efficiency for range parameters. Based upon the inlet conditions like pressure temperature, material selection is varied. Designs

being the standard further based on then steam flow quantities size of the turbine is selected .in these series of turbines the fixed blade grooves are machined directly in the outer casing and guide blades are inserted.

Different sizes of -2 types of turbines are:

G250-2	EK/K 600-2
G300-2	EK/K 800-2
G400-2	EK/K 1000-2
G500-2	EK/K 1100-2
G800-2	EK/K 1400-2
	EK/K 1800-2

“G” stands for back pressure turbine

“K” stands for condensing turbines

“E” stands for controlled extraction

The number besides the letter indicates the area of the exhaust of the turbines

### **3 Series Turbine:**

Based on customer's requirements and steps involved in design, the turbine is divided into different sections: inlet section, transition, exhaust or condensing section .these sections can be combined with each other. The figure shows the various sections of these series and possible combinations of withy one size of admission section. the admission sections are supplied in two versions, one for normal initial steam conditions up to 100 bar / 510 deg C and for high steam initial steam conditions up to 140 bar /540deg C .the size of the section is geometrically graded in the ratio to 1.25 to form different sizes of section .The parts associated with front section as front bearing pedestal, control valves, safety devices like emergency stop valves are fixed for a particular size. Also the same is done for the exhaust sections. With this arrangement for a particular front and rear section selected the connecting parts to the sections are common from case to case. now the length of the middle are transition section can varied based upon the number of blade stages required and the number of extractions required . with this concepts, besides optimizing the flow path, the use of standard and proven components like casings , guide blade carriers , bearing pedestals, nozzles, servo- motors, stop and governing valves fro a particular model are ensured .unlike the -2 series the blade grooves in these turbines are made in the guide blade carriers which is supported in outer casing .

Robust drum type rotors with integral shrouds, labyrinth glands for sealing of rotor ends and inter stage blading, ensure greater reliability and efficiency. These turbines usually employ a gear box between turbine and generator to achieve optimum efficiencies.

### **4 Series Turbines:**

These types of series are called as centre admission steam turbines with counter flow for the mid range of power, between 30MW to 150 MW. Using these concepts results in the compact single casing solution in many cases up to 100 MW. The flow path is initially towards the front and in inner casing after being admitted in the centre.

The steam reverses the direction on the reaching the end of inner casing to flow around inner casing and expands towards the rear end of the turbine. This process of reverse flow of steam helps in control the axial thrust to a large extent. The rear portion of the turbine is constructed based upon the building block principle as explained in -3 series, front being a standard fro particular range of inlet parameters. These turbines are directly coupled to the generator. The valve blocks in these turbines are separate and hence faster startups of the turbine .these turbines are best suited for combined cycle plant application.

### **New Series Turbine:**

These types of turbines have been developed by BHEL in the range of 15 to 20 MW to cater the special requirements of industries like sugar and cement w.r.t low inlet parameters and high extraction requirements for operation during season and power generation during off season periods. In view of the above certain costs saving features have been incorporated. the outer casing casting have been simplified by separating the valve chest the valve chest is cast separately and bolted to the outer casing there by limiting the importance of selection of material to valve chest . The middle section and the rear section of the turbine are based on the building block concept as that of -3 turbines.

These turbines operate in the speed range of 6000 to 8000rpm. The flow path design of the above turbines confirms to the SIEMENS design practices. provision has been given for an extraction, which is useful for the process of NOX control CCP applications .the detailed design analysis is done with flow path design , mechanical design which includes rotor dynamics , design analysis by finite element methods and computational fluid dynamics for flow analysis.

### VIII. STEPS INVOLVED IN THE DESIGN OF STEAM TURBINES

1. Perform thermodynamic and axial thrust calculations to decide diameters and axial length of blading.
2. Perform rotor dynamic calculation and suggest any change of lengths and diameters to repeat step one.
3. Select suitable turbine extensions and diameters to meet above blading geometry.
4. Select suitable materials to meet steam parameters.
5. Select suitable governing system and protection system.
6. Prepare ordering / manufacturing documents incorporating above selections.

### IX. TURBINE BLADES

Blades are the heart of a turbine, as they are the principal elements that convert the energy of working fluid into kinetic energy. The efficiency and reliability of a turbine depend on the proper design of the blades. It is therefore necessary for all engineers involved in the turbines engineering to have an overview of the importance and the basic design aspects of the steam turbine blades, Blade design is a multi-disciplinary task. It involves the thermodynamic, aerodynamic, mechanical and material science disciplines. A total development of a new blade is therefore possible only when experts of all these fields come together as a team. The number of turbine stages can have a great effect on how the turbine blades are designed for each stage. The number of stages depends upon the load we have and the quantity of power we required. Too many stages may also develop bending moment and high torque which in turn the reason of failure of the entire unit of the plant.



**Figure: Assembled guide blades in inner casing**

Efficiency of the turbine is depends on the following parameters.

- Inlet and outlet angle of the blade
- Surface finishing of the blade
- Profile of the blade

#### **Blade Material and Blade Types:**

Among the different materials typically used for blading are 403 stainless steel, 422 stainless steel, A-286, and Haynes Stellite Alloy Number 31 and titanium alloy. The 403 stainless steel is essentially the industry's standard blade material and, on impulse steam turbines, it is probably found on over 90 percent of all the stages. It is used because of its high yield strength, endurance limit, ductility, toughness, erosion and corrosion resistance, and damping. It is used within a Brinell hardness range of 207 to 248 to maximize its damping and corrosion resistance. The 422 stainless steel material is applied only on high temperature stages (between 700 and 900°F or 371 and 482°C), where its higher yield, endurance, creep and rupture strengths are needed. The A-286 material is a nickel-based super alloy that is generally used in hot gas expanders with stage temperatures between 900 and 1150°F (482 and 621°C). The Haynes Stellite Alloy Number 31 is a cobalt-based super alloy and is used on jet expanders when precision cast blades are needed. The Haynes Stellite Number 31 is used at stage temperatures between 900 and 1200°F (482 and 649°C). Another blade material is titanium. Its high strength, low density, and good erosion resistance make it a good candidate for high speed or long-last stage blading. Blades are made of alloy steel which mainly contains carbon, chromium, nickel, molybdenum X20 and x20 are the material specification which contains the alloying elements in given percentage.

material	C	Ni	Cr	Mo	Mn	Si	V
X20	0.22	0.8	12-13	0.8-1.2	0.3	0.1-0.5	
X22	0.8	0.3-0.5	11.5-11.9	0.8-1.20	0.3	0.1-0.5	0.25-0.35

X20 and x22 are the material specification which contains the alloying elements in given percentage.

Proper selection of blade material plays a n important role in blade design. The factors that influence the selection of blade materials are: -

- 1) Method of manufacture
- 2) Ease of machining
- 3) The ability to produce blade sections free from flaws.
- 4) Ductility both allow of rolling of shapes.
- 5) The capacity for being welded.
- 6) Ease of forging easily.
- 7) Condition of operations.
- 8) Suitable tensile strength at high temperature.
- 9) Resistance to creep.
- 10) Cost

**Mechanical Properties:**

All the Among the different materials typically used for blading are 403 stainless steel, 422 stainless steel, A-286, and Haynes Stellite Alloy Number 31 and titanium alloy. The 403 stainless steel is essentially the industry’s standard blade material and, on impulse steam turbines, it is probably found on over 90 percent of all the stages. It is used because of its high yield strength, endurance limit, ductility, toughness, erosion and corrosion resistance, and damping. It is used within a Brinell hardness range of 207 to 248 to maximize its damping and corrosion resistance. The 422 stainless steel material is applied only on high temperature stages (between 700 and 900°F or 371 and 482°C), where its higher yield, endurance, creep and rupture strengths are needed. The A-286 material is a nickel-based super alloy that is generally used in hot gas expanders with stage temperatures between 900 and 1150°F (482 and 621°C). The Haynes Stellite Alloy Number 31 is a cobalt-based super alloy and is used on jet expanders when precision cast blades are needed. The Haynes Stellite Number 31 is used at stage temperatures between 900 and 1200°F (482 and 649°C). Another blade material is titanium. Its high strength, low density, and good erosion resistance make it a good candidate for high speed or long-last stage blading. Blades are made of alloy steel which mainly contains carbon, chromium, nickel, molybdenum X20 and x20 are the material specification which contains the alloying elements in given percentage.

Tensile strength: 95 kgf/mm<sup>2</sup>  
 0.2 Yield stress: 70 kgf/mm<sup>2</sup>  
 Impact : 05 kg/mm<sup>2</sup>.  
 Elongation, ( l=5d): 15% min.  
 Reduction in area: 50% min  
 BHN: 270.

**Types Of Blades:**

Blades are classified on the basis of following application

- 1) Pressure at stages
  - HP BLADES (high pressure blades)
  - IP BLADES (intermediate pressure blades)
  - LP BLADES (low pressure blades)

2) Their function in the turbine

Steam turbine moving blades

- Blades from the bar stock
  - Rhomboid blades
  - Curved blades
  - Twisted profile blades
  - Drawn profile blades
- Forged blades

- Original forging
- Precision forging blades

**Constructional Features Of Blades:**

High pressure blades is mainly divided into three parts

a) **Profile:** The profile which converts thermal energy of steam into kinetic energy and with certain efficiency depending on the shape of profile.

b) **Root:** The root which fixes into the turbine rotor which gives the proper anchor to the blade and transmitting the kinetic energy of blade to the rotor.

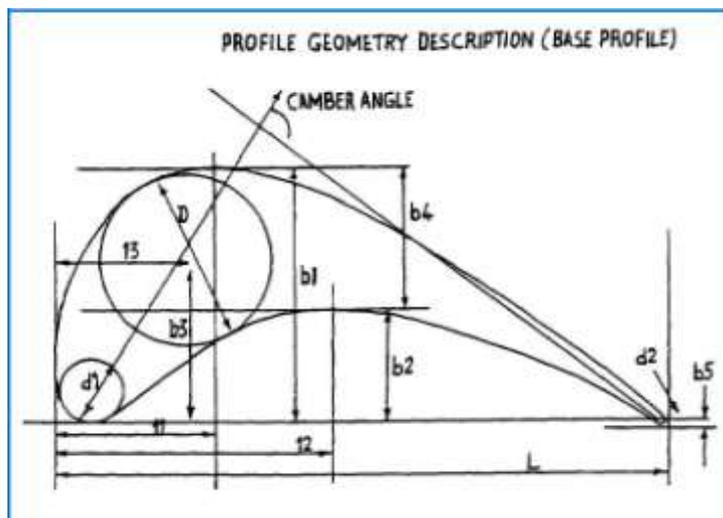
Different kinds of roots of blades used are

- T-root
- Double T-root
- Fork root
- Firtree root
- Dove tail root

c) **Shroud:** The dampening element which reduces the vibration the vibration occurs in the blade which forms due to the flowing of high pressure steam through the blades. This dampening element may be integral with the blade or that may be separate element mounted between the blades.

**High Pressure Blades:**

High pressure blades are designed on the pressure it can sustain. These blades are mounted in the starting stage of turbine rotor. The number of stages of high pressure blades can be determined by designing. The constructional features of high pressure blades are different from LP blades. Further understanding of blade require following terminologies to be known.



**1. Camber Line:**

If circles are drawn tangential to the suction side and pressure side profiles of a blade and their centres are joined by a curve, this curve is called the camber line. This line is intersecting at the two points A and B of the profile. The line joining these two points is called chord and the length of these point is called chord length.

**2. Bitangent Line:**

The line joining the inlet and outlet edges of the profile is called bitangent line.

**3. Setting Line:**

The angle which line makes with the periphery of the profile is called setting angle or profile angle.

**4. Pitch:**

Pitch is the circumferential distance between any point on the profile and an identical point the next profile.

## X. CLASSIFICATION OF PROFILE

There are two types of profile one is impulse and other is reaction

### **Impulse profile:**

In impulse type of profile the entire heat drop of steam take place in stationary blades only. Though the theoretical impulse blades have zero pressure drop in the moving blades, practically, for the flow to take place across the moving blades, there must be a small pressure drop across the moving blades also. Therefore, the impulse stages in practice have a small degree of reaction. These stages are therefore more accurately, though less widely, described as low-reaction stages. In impulse blades nozzles direct the steam towards the rotors, which are reequipped with concave panels called buckets. The nozzles are able to project a jet of steam that spins the rotor at a loss of roughly 10 percent energy. As the jets change their position, they can increase or decrease the rate of rotor spin.

### **Reaction profile:**

In the reaction type of blades, the heat drop of the stage is distributed almost equally between the guide and moving blades. The steam nozzles are attached to the rotor blades on opposite sides. The nozzles are so positioned that when they release jets of steam, they propel the rotor in a spinning motion that keeps it rotating as long as the steam expelled from the jet of the nozzle.

### **Hp Blade Roots:**

The root is a part of the blade that fixes the blade to the rotor or stator. Its design depends upon the centrifugal and steam bending forces of the blade. It should be designed such that the material in the blade root as well as the rotor / stator claw and any fixing element are in the safe limits to avoid failure.

The roots are T-root and Fork-root. The fork root has a higher load-carrying capacity than the T-root. It was found that machining this T-root with side grip is more of a problem. It has to be machined by broaching, and the broaching machine available could not handle the sizes of the root. The typical roots used for the HP moving blades for various steam turbine applications are shown in the following figure.



**Figure: Root of HP moving blade**

### **Lp Blade Profile:**

The LP blade profiles of moving blades are twisted and tapered. These blades are used when blade height-to-mean stage diameter ratio ( $h/D_m$ ) exceeds 0.2.

LP blades are manufactured machining and forging. It depends on the capacity of the turbine for which these blades are to be manufactured. Generally for small capacity steam turbine these blades are manufactured by machining but some LP blades are manufactured by forging and form a twisted shape.

### **Lp Blade Roots:**

The roots of LP blades are as follows:

- -2 blading: The roots of both the LP stages in -2 type of LP blading are T-roots.
- -3 blading: The last stage LP blade of HK, SK and LK blades have a fork-root.
- SK blades have 4-fork roots for all sizes. HK blades have 4-fork roots upto 56 size, where modified profiles are used. Beyond this size, HK blades have 3 fork roots. LK blades have 3-fork roots for all sizes. The roots of the LP blades of preceding stages are of T-roots
- SK BLADES: SK blades have large blade width in compare to its profile.
- HK BLADES: HK blades have equal blade width and profile.

## XI. MANUFACTURING PROCESS OF BLADES

Manufacturing process is that part of the production process which is directly concerned with the change of form or dimensions of the part being produced. It does not include the transportation, handling or storage of parts, as they are not directly concerned with the changes into the form or dimensions of the part produced. Manufacturing is the backbone of any industrialized nation. Manufacturing and Technical staff in industry must know the various manufacturing processes, materials being processed, tools and equipments for manufacturing different components or products with optimal process plan using proper precautions and specified safety rules to avoid accidents. Beside above, all kinds of the future engineers must know the basic requirements of workshop activities in term of man, machine, material, methods, money and other infrastructure facilities needed to be positioned properly for optimal shop layouts or plant layout and other support services.

### *Various Tools Used For Manufacturing Of Turbine Blades:*

a) **Band saw machine:**



**Holding device: Hydraulic device**

**Cutter: H.S.Tool cutter**

**Operation: Cutting into length**

b) **Duplex milling machine:**



**Holding device: Hydraulic device**

**Cutter: Tee max cutter**

**Operation: Size milling**

c) **Segmental grinding machine:**

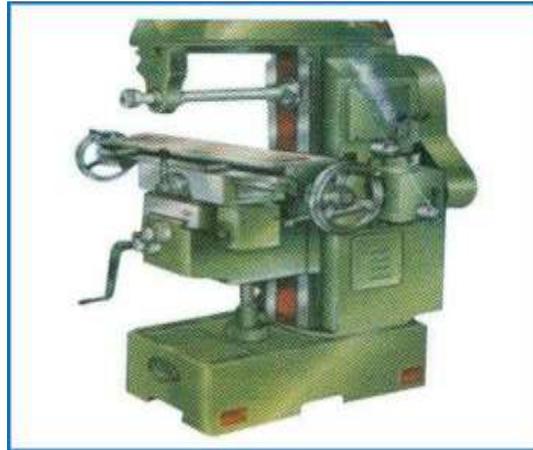


**Holding device: Magnetic base**

**Cutter: Segments**

**Operation: Face grinding**

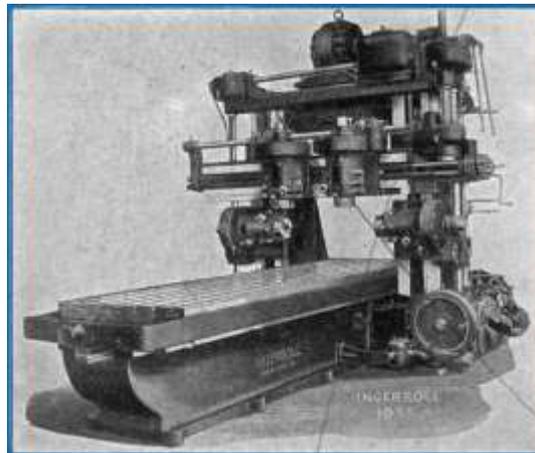
d) **Horizontal milling machine:**



**Holding device:** Angular fixture, Fixture, Pneumatic vice

**Cutter:** Slab mill cutter, Slitting saw cutter, Interlocking cutter, side end mill cutter, form cutter, Fly tool.  
**Operation:** Rhomboid milling, Slitting, Length cutting, form milling, convex milling and concave milling

e) **Four spindle milling machine:**



**Holding device:** Fixture

**Cutter:** Root mill cutter

**Operation:** Root milling

f) **Vertical milling machine:**



**Holding device:** Machine vice, fixture

**Cutter:** Tee max cutter, shell and mill cutter, ball nose end mill

**Operation:** Size milling, profile milling, taper milling, widening root radius

g) Surface grinding machine:



**Holding device: Magnetic base**  
**Cutter: Side & face cutter, form cutter**  
**Operation: Step milling**

h) Face lathe machine:



**Holding device: Fixture**  
**Cutter: Root radius turning tool**  
**Operation: Root radius turning**

i) Copy milling machine:



**Holding device: Hydraulic fixture**  
**Cutter: Special flower type mill cutter**  
**Operation: Profile milling**

## **XII. STEPS INVOLVED IN MACHINING OF STEAM TURBINE BLADE**

- Cutting to bar size
- Size Milling
- Size Grinding
- Rhomboidal milling
- Rhomboidal grinding
- Size cutting or Blade length cutting
- Root milling
- Width milling
- Back Profile milling (convex)
- Canal Profile milling (concave)
- Back width
- Canal width
- Root radius
- Taper milling
- Taper grinding
- Fitting and polishing

### **1) Cutting To Bar Size:**

This is the initial process that is processed over the raw material to cut in to the required size of bar. Band saw machine is used to do this process. A continues hacksaw blade made f H.S.S is rotated and pressed over the bar at the desired locations to cut the bar to the required size.

### **2) Size Milling:**

Size milling is the starting operation of blade manufacturing which is done over a conventional milling or CNC milling machine. As the name appears this operation sizes the bar into the required thickness and width of the blade if thickness has very less allowance for milling then it directly passes to grinding operation. Thus we can say it is a roughing operation Size milling operation required a slab end mill cutter to give required size..Size milling operation to get required size some allowance is given on the basic size of the bar that is +0.5mm. After completion of milling operation its size is ensured.

#### **Steps Of Size Milling:-**

- Clamp the work piece in the vice
- Firmly tight the work piece in the vice
- Give depth of cut as per suitability
- Start the machine and switch on the supply of coolant
- Feed the material in the longitudinal axis
- After completion of operation stop the machine
- Check the size of the work piece

### **3) Size Grinding:**

Size grinding is the next operation of the blade in which the size of blade is maintained by grinding. In milling operation size of the blade is not equally machined to its proper size that's why we give some extra allowance for grinding.

#### **Steps Of Size Grinding**

- Remove the burrs of work piece with emery paper
- Hold the job on the magnetic base.
- Switch on the magnetic supply to clamp the blade bars
- Give depth of cut to the grinding segments in microns
- Start the coolant supply
- Start the feed
- Check the size of the blade bars after completion

### **4) Rhomboidal Milling:**

Rhomboidal milling is the operation in which material is given a rhombus shape on milling machine. This rhomboidal shape is given to form a profile of the blade. An angular fixture is used to give a rhomboidal shape. Rhomboidal fixture has an angular swivel arrangement which can be rotated at a certain angle in both the direction against vertical plane. After setting at a particular given angle bar is clamped in the fixture and milling

operation. As we set the angle to certain degree with vertical plane of the cutter it cut the bars at an angle given on both side of the bar after completion of this operation the bars are formed into the rhomboidal shape. Rhomboidal angle is depends upon the profile angle for different blades. It is generally used around 20 degree, 22 degree etc.

**Steps Of Rhomboidal Milling:**

- Adjust the fixture at given rhomboidal angle
- Check the angle with bevel protractor
- Clamp the blade bars in the fixture
- Give depth of cut
- Start the machine and coolant supply
- Give feed to the machine.
- Repeat depth of cut till the required size is produced

**5) Rhomboidal Grinding:**

Rhomboidal grinding is the operation same as size grinding in this operation the bar is maintained at its size of rhomboidal grinding. This is finishing operation of the blade. Allowance for grinding is given around 0.5 to 0.8 mm.

**6) Blade Length Cutting:**

Blade length cutting is the operation in which the bar is cut into the required blade length on the milling machine. The tool used for this operation is slitting saw cutter which has carbide bits mounted on the cutter. Bending may be in the blade if we cut the bar in the starting stages of operation of the blade.

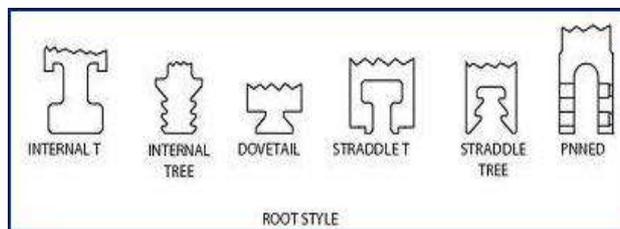
**7) Root Milling**

In the machining of the rotor a form cutter is used which has the same form which is to be produced on the blade. For this purpose a special type of machine used. four spindle or two spindle root milling machine is used. Root milling machine consist of two or four spindles and table which is moves in longitudinal direction. Upper two spindles are attached to the upper head and lower spindle attached to the lower head. A special type of fixture is used for this is mounted on the table of the machine. The root width is maintained by keeping distance equal to the width of the blade between cutters. The extra metal is removed by the cutter. Depth of cut is given in vertical direction for giving depth of cut cutters initially touches the bar and then depth of cut is given. There two depth of cut is given in case of blade which has the higher thickness.

Depth of cut= (blade width – root width)/2

**Steps Of The Root Milling:**

- Clamp the blades in the fixture.
- Ensure the blades are firmly clamped
- Touches the cutters to the blade
- Give depth of cut which is to be given
- Switch on the machine
- Give feed to the machine
- Switch on the coolant supply.
- Take out the job and switch off all the system after completion of operation.



**8) Root Radius:**

Blades are assembled in the rotor for forming a turbine. To assemble these blades these blades should form a circle of radius equal to the rotor as its diameter increases as per the row of blades. Root radius helps in the assembly of blades in the rotor by giving a radius on the root on the lower face of root. This radius should be correct to assemble neither it will create a problem while assembly. In root radius end mill cutter is used on CNC machine in which it moves in all three axis

In starting it moves in Z-axis for depth of cut after that it moves in radially for this it moves in two-axis simultaneously at a time to form a radius in X-axis and Y-axis.

**9) Taper Milling:**

Taper milling is also a milling operation which is done over a milling machine. This operation also help in the forming a circle of radius equal to the rotor. Taper is given on the blades when these blades are connected to each other they form a circle of diameter equal to the diameter of rotor. For tapering sine bars are used. Taper is given in Y axis. The value of taper which is given in the drawing we select the sine bar and adjust the fixture by placing the sine bar which gives the taper which is to be produced.

**Steps Of Taper Milling**

- Select the sine bar value from the drawing
- Place this sine bar at the bottom of the sine bar roller
- Automatically fixture come to the slope which is given by taper milling
- Clamp the maximum blades can clamped at a time on the fixture.
- Start the machine, give depth of cut and supply coolant
- Start feed mechanism
- Remove the blades after completion of the operation
- Check the minimum pitch of the blade

**10) Fitting And Polishing:**

Fitting is the pre-final stage of the assembling of blades to the turbine. Here in this process all the blades are inserted in the groves of rotor and small brass tips are fitted under the blade root and chipping is done to make the blade tightly fixed in to the rotor. For the last blade of every row chipping is not possible so small holes are drilled either side of the blade on rotor and these holes are filled with bolt's or brass tip's.

Polishing is usually a multistage process. The first stage starts with a rough abrasive and each subsequent stage uses a finer abrasive until the desired finish is achieved. The rough pass removes surface defects like pits, nicks, lines and scratches. The finer abrasives leave very thin lines that are not visible to the naked eye. Lubricants like wax and kerosene are used as lubricating and cooling media during these operations. Polishing operations for items such as chisels, hammers, screwdrivers, wrenches, etc., are given a fine finish but not plated. In order to achieve this finish four operations are required: roughing, dry fining, greasing, and coloring. For an extra fine polish the greasing operation may be broken up into two operations: rough greasing and fine greasing.

**XIII. APPLICATIONS OF STEAM TURBINES:**

The steam turbines are utilized in several industries viz.. Paper, fertilizers, chemical petro chemicals, sugars, refinery, metallurgical etc foe power generation and mechanical drives already described. The following illustration explains the selection - application criteria of industrial turbines

**XIV. ADVANTAGES OF STEAM TURBINES:**

- Thermal Efficiency of a Steam Turbine is higher than that of a Reciprocating Engine.
- The Steam Turbine develops power at a uniform rate and hence does not required Flywheel.
- No internal lubrication is required for Steam Turbine as there is no rubbing parts inside.
- No heavy foundation is required for Turbine because of the perfect balancing of the different parts.
- If the Steam Turbine is properly designed and constructed then it is the most durable Prime Mover.
- Much higher speed may be developed and a far greater range of speed is possible than in the case of Reciprocating Engine.
- There are some frictional losses in Reciprocating Engine as some arrangements are required for conversion of Reciprocating Motion into circular motion. But in Steam Turbine no friction losses are there.
- Steam Turbine are quite suitable for large Thermal Power Plant as they can be built in size from few Horse Power to over 200000 HP in signal unit.

**XV. DISADVANTAGES OF STEAM TURBINES:**

Steam turbines have a few drawbacks, although approximately 80 percent of the world's electricity is reliant on steam turbines.

- Not Profitable Smaller Turbines
- Side Effect of Low Pressure Steam Turbine
- Possibilities of Complete Mechanical Failure
- Load Change Behavior

## **XVI. CONCLUSION**

I have finally acquired knowledge over **Steam turbines** and its manufacturing process which had led me know many unknown things that actually be followed during the production procedure and also about the various materials used. This paper has attempted to cover some of the issues related to **Steam turbines** which a designer should be aware of. It is hoped that this notes helps a working Engineer have a better insight into the various aspects of the **Steam turbines**, so that the related issues can be tackled with better knowledge and confidence.

## **REFERENCE**

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