# Summer Training Report On Steam Turbines

Compiled and Submitted By –

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# ACKNOWLEDGEMENT

I am highly grateful to B.H.E.L. engineers and technical staff for providing me vital and valuable information about the different facets of an industrial management system.

I express my gratitude to Human Resource and Development department for giving me a chance to feel the industrial environment and its working in B.H.E.L.

My special thanks to **Mr Mohammad Shahid Wali** for sparing time from his busy schedule to help me understand various theoretical and practical aspects of Steam Turbines without whose supervision & guidance it wouldn't have been possible.

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# PREFACE

At very outset of the prologue it becomes imperative to insist that vocational training is an integral part of engineering curriculum. Training allows us to gain an insight into the practical aspects of the various topics, with which we come across while pursuing our B.Tech i.e. vocational training gives us practical implementation of various topics we already have learned and will learn in near future. Vocational training always emphasizes on logic and common sense instead of theoretical aspects of subject.

On my part, I pursued four weeks training at B.H.E.L. Bhopal. The training involved a study of various departments of the organization as per the time logically scheduled and well planned given to us.


Aqib Siddiqui

B.Tech (EE)

Aligarh Muslim University

**Aligarh**

# CERTIFICATE

This is to certify that **Aqib Siddiqui**, student of 3rd year Electrical Engineering from **Zakir Hussain College of Engineering and Technology, Aligarh Muslim University, Aligarh** has successfully completed his Vocational Training at BHEL, Bhopal for 4 weeks from **5th June'14** to **2nd July'14**.

He has completed the whole training as per the guidelines.

Mohammad Shahid Wali
Sr. Purchase Officer
(Training Incharge)

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# BHEL OVERVIEW

BHEL was established more than 50 years ago when its first plant was setup
In Bhopal ushering in the indigenous Heavy Electrical Equipment Industry in India.

BHEL is largest engineering and manufacturing enterprise in India in the
Energy related/infrastructure sector. BHEL was established more than four decades ago ushering in the indigenous Heavy Electrical Equipment industry in India. BHEL has built over the years, a robust domestic market position by becoming the largest supplier of power plant equipment in India, and by developing strong market presence in select segment of the industry sector and the Railway. Currently, 80% of the Nuclear power generation in the country is through BHEL sets.

A dream which has been more than realized with a well-recognized track record of performance it has been earning profits continuously since 1971-72 and achieved a turnover of Rs 2,658 crore for the year 2007-08, showing a growth of 17%.

Bharat Heavy Electricals Limited is country’s ‘Navratna’ company and has earned its place among very prestigious national and international companies. It finds place among the top class companies of the world for manufacture of electrical equipments.

BHEL caters to core sectors of the Indian Economy viz., Power Generation's
& Transmission, Industry, Transportation, Telecommunication, Renewable Energy, Defence, etc. BHEL has already attained ISO 9000 certification for quality management, and ISO 14001 certification for environment management and OHSAS – 18001 certification for Occupational Health and Safety Management Systems. The Company today enjoys national and international presence featuring in the

“Fortune International -500” and is ranked among the top 10 companies in the world, manufacturing power generation equipment. BHEL is the only PSU among the 12 Indian companies to figure in “Forbes Asia Fabulous 50” list.

In the world power scene BHEL ranks among the top ten manufacturers of power plant equipments not only in spectrum of products and services offered, it is right on top. BHEL‘s technological excellence and turnkey capabilities have won it Worldwide recognition. Over 40 countries in world over have placed orders with BHEL covering individual equipment to complete power stations on turnkey basis BHEL has

- ✓ Installed equipment for over 90000MW of power generation-for utilities, captive and industrial users.
- ✓ Supplied over 225000MW a transformer capacity and other equipment operating in transmission and distribution network up to 400Kv (AC & DC).

- ✓ Supplied over 25000 motors with drive control system to power projects, petro chemicals, refineries, steel, aluminium, fertilizers, cement plants etc.
- ✓ Supplied traction electrics and AC/DC locos to power over 12000kms railway network.
- ✓ Supplied over one million valves to power plants and other industries.

BHEL manufactures over 180 products under 30 major product groups and caters to core sectors of the Indian Economy viz., Power Generation & Transmission, Industry, Transportation, Telecommunication, Renewable Energy, etc. The wide network of BHEL's 14 manufacturing divisions, four Power Sector regional centres, over 100 project sites, eight service centres and 18 regional offices, enables the company to promptly serve its customers and provide them with suitable products, systems and services--efficiently and at competitive prices. The high level of quality & reliability of its products is due to the emphasis on design, engineering and manufacturing to international standards by acquiring and adapting some of the best technologies from leading companies in the world, together with technologies developed in its own R&D centres.

- BHEL has acquired certifications to Quality Management Systems (ISO 9001), Environmental Management Systems (ISO 14001) and Occupational Health & Safety Management Systems (OHSAS 18001) and is also well on its journey towards Total Quality Management.
- BHEL vision is to become a world class engineering enterprise, committed to enhancing stakeholder value. The company is striving to give shape to its aspiration and fulfil the expectations of the country to become a global presence.

# VISION

"A world class engineering enterprise committed to enhance stakeholder values."

# MISSION

"To be an Indian multinational engineering providing total business solution through quality product system and services in the field of energy, transportation, industry, infrastructure and other potential area."

# VALUES

- Ensure speed of response.
- Foster learning, creativity and team work.
- Respect for dignity and potential of individuals.
- Loyalty and pride in company.
- Zeal for the change.
- Zeal to excel.
- Integrity and fairness in all matters.
- Strict adherence to commitments.

# BHEL OBJECTIVES

A dynamic organization is one which keeps its aim high, adopts itself quickly to changing environment, so we are in BHEL. The objectives of the company have been redefined in the corporate plane for 90's.

# Growth

To ensure a steady growth by enhancing the competitive edge of BHEL in existing busyness, new area and international market so as to fulfil national expectation from BHEL.

# Profitability

To ensure a reasonable and adequate return on capital employed, primarily through improvements in operation, efficiency, capacity utilization & productivity and to generate adequate internal resources to finance the company's growth.

## Focus

To built a high degree of customer confidence by providing increased value of his money through international standards of product quality performance and superior customer service.

## People Orientation

To enable each employee to achieve his potential, improve his capabilities, understand is role and responsibilities and participate and contribute to the growth and success of the company.

## Technology

To achieve technological excellence in operation of indigenous technologies and efficient absorption and adoption of imparted technologies to suit business.

# Image

To fulfil the expectations, which stack holders like government as owner employee, customer and the country at large have from BHEL.

# BHEL BHOPAL PROFILE

Heavy Electrical Plant, Bhopal is the mother plant of Bharat Heavy Electricals Limited, the largest engineering and manufacturing enterprise in India in the energy-related and infrastructure sector, today. It is located at about

7 kms. From Bhopal Railway station, about 5 kms. from Habibganj Railway station and about 18kms. From Raja Bhoj Airport. With technical assistance from Associated Electricals(India) Ltd., a UK based company, it came into existence on 29th of August, 1956. Pt.Jawaharlal Nehru, first Prime minister of India dedicated this plant to the nation on6th of November, 1960.

BHEL, Bhopal with state-of-the-art facilities, manufactures wide range of electrical equipments. Its product range includes Hydro, Steam, Marine & Nuclear Turbines, Heat Exchangers, Hydro & Turbo Generators, Transformers, Switchgears, Control gears, Transportation Equipment, Capacitors, Bushings, Electrical Motors, Rectifiers, Oil Drilling Rig Equipments and Diesel Generating sets.

# POWER TRANSMISSION AND DISTRIBUTION (T&D)

BHEL offer wide-ranging products and systems for T & D applications Products.
Manufactured include power transformers, instrument transformers, dry type transformers, series – and shunt reactor, capacitor tanks, vacuum – and SF circuit breakers gas insulated switch gears and insulators.
A strong engineering base enables the Company to undertake turnkey delivery of electric substances up to 400 kV level series compensation systems (for increasing power transfer capacity of transmission lines and improving system stability and voltage regulation), shunt compensation systems (for power factor and voltage improvement) and HVDC systems (for economic transfer of bulk power). BHEL has indigenously developed the state-of-the-art controlled shunt reactor (for reactive power management on long transmission lines). Presently a 400 kV Facts

(Flexible AC Transmission System) project under execution.

A wide range of transmission products and systems are produced by BHEL to meet the needs of power transmission and distribution sector.

These include:

- Dry Type Transformers
- SF6 Switch Gears
- 400 KW Transmission Equipment
- High Voltage Direct Current System
- Series and Shunt Compensation Systems

In anticipation of the need for improved substations, a 33 KV gas insulated substation with microprocessors base control and protection system has been done.

# RESEARCH AND DEVELOPMENT (R&D)

To remain competitive and meet customers' expectations, BHEL lays great emphasis on the continuous up gradation of products and related technologies, and development of new products. Research and product development centres at each of the manufacturing divisions play a complementary role.

BHEL’s investment in R&D is amongst the largest in the corporate sector in India.
BHEL's vision is to become a world-class engineering enterprise, committed to enhancing stakeholder value. The company is striving to give shape to its aspirations and fulfil the expectations of the country to become a global player.

The greatest strength of BHEL is its highly skilled and committed 42,600 employees. Every employee is given an equal opportunity to develop himself and grow in his career. Continuous training and retraining, career planning, a positive work culture and participative style of management – all these have engendered development of a committed and motivated workforce setting new benchmarks in terms of productivity, quality and responsiveness.

# PRODUCTS

## Thermal Power Plants

- Steam turbines, boilers and generators of up to 800 MW capacity for utility and combined-cycle applications; Capacity to manufacture boilers and steam turbines with supercritical system cycle parameter and matching generator up to 1000 MW unit size.
- Steam turbines, boilers and generators of CPP applications; capacity to manufacture condensing, extraction, back pressure, injection or any combination of these types of steam turbines.

## Nuclear Power Plants

- Steam generator & Turbine generator up to 700 MW capacity.

## Gas-Based Power Plants

- Gas turbines of up to 280 MW (ISO) advance class rating.
- Gas turbine-based co-generation and combined-cycle systems of industry and utility applications.

## There are other products given as follows

Hydro Power Plants, DG Power Plants, Industrial Sets, Boiler, Boiler Auxiliaries, Piping System, Heat Exchangers and Pressure Vessels Pumps, Power Station Control
Equipment, Switchgear, Bus Ducts, Transformers, Insulators, Industrial and Special
Ceramics, Capacitors, Electrical Machines, Compressors, Control Gear, Silicon
Rectifiers, Thyristor GTO/IGBT Equipment, Power Devices, Transportation
Equipment
Oil Field Equipment, Casting and Forgings, Seamless Steel Tubes, Distributed Power Generation and Small Hydro Plants.

# MAJOR CUSTOMERS OF B.H.E.L

## Supplied to all major utilities in India:

- National Thermal Power Corporation (NTPC)
- PGCIL
- NJPC
- NHPC
- NLC
- NPCIL
- NEEPCO
- APTRANSCO
- APGENCO
- ALL State Electricity Boards (SEBs)

## Abroad:

- TNB, Malaysia
- PPC, Greece
- MEW, Oman
- OCC, Oman
- GECOL, Libya
- Trinidad & Tobago
- New Zealand, etc.

# DIVISIONS OF BHEL

There are 20 Divisions of BHEL, they are as follows:

- HEEP, Haridwar
- HPEP, Hyderabad
- HPBP, Tiruchi
- SSTP & MHD, Tiruchi
- CFFP, Haridwar
- BHEL, Jhansi
- BHEL, Bhopal
- EPD, Bangalore
- ISG, Bangalore
- ED, Bangalore
- BAP, Ranipet
- IP, Jagdishpur
- IOD, New Delhi
- COTT, Hyderabad
- IS, New Delhi
- CFP, Rudrapur
- HERP, Varanasi
- Regional Operations Division ARP, New Delhi

- TPG, Bhopal
- Power Group (Four Regions and PEM)

# STEAM TURBINE

## INTRODUCTION

A turbine is a device that converts chemical energy into mechanical energy, specifically when a rotor of multiple blades or vanes is driven by the movement of a fluid or gas. In the case of a steam turbine, the pressure and flow of newly condensed steam rapidly turns the rotor. This movement is possible because the water to steam conversion results in a rapidly expanding gas. As the turbine's rotor turns, the rotating shaft can work to accomplish numerous applications, often electricity generation.

In a steam turbine, the steam's energy is extracted through the turbine and the steam leaves the turbine at a lower energy state. High pressure and temperature fluid at the inlet of the turbine exit as lower pressure and temperature fluid. The difference is energy converted by the turbine to mechanical rotational energy, less any aerodynamic and mechanical inefficiencies incurred in the process. Since the fluid is at a lower pressure at the exit of the turbine than at the inlet, it is common to say the fluid has been “expanded” across the turbine. Because of the expanding flow, higher volumetric flow occurs at the turbine exit (at least for compressible fluids) leading to the need for larger turbine exit areas than at the inlet.

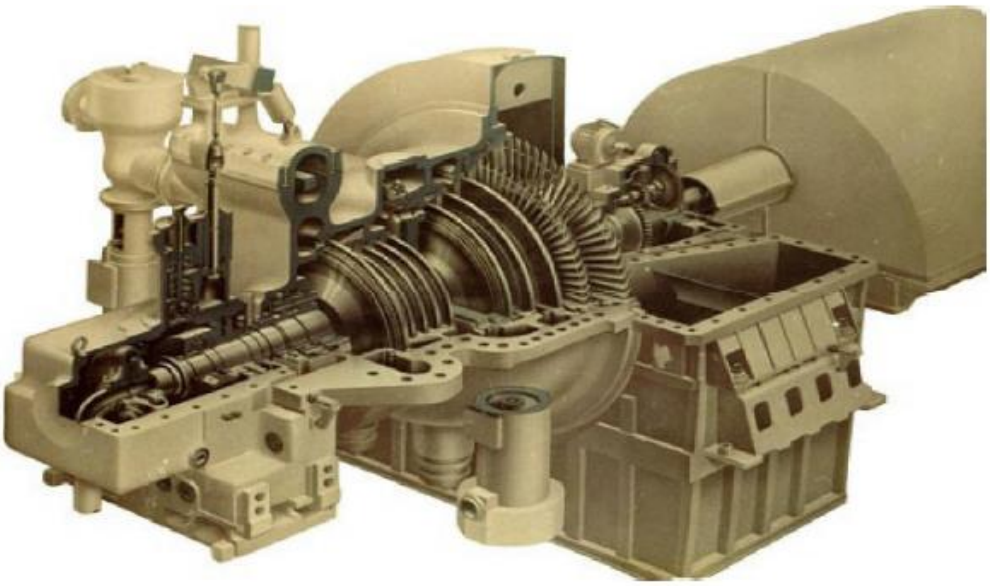


**FIG.1 SECTIONAL VIEW OF A STEAM TURBINE**

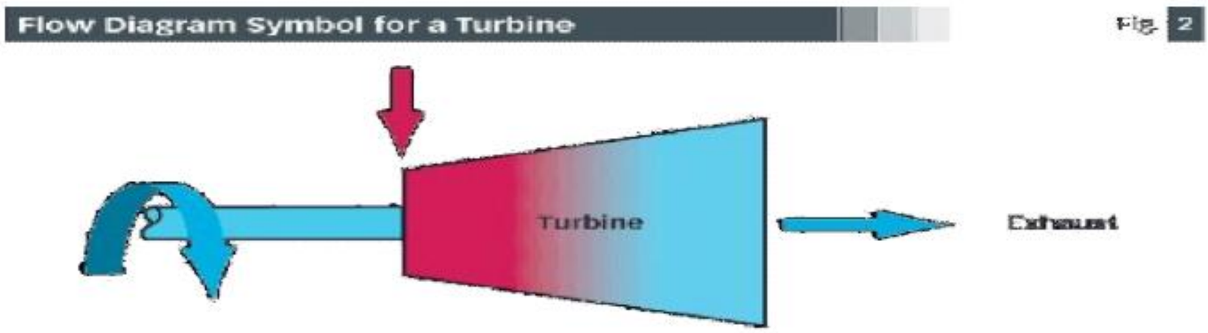



FIG.2 FLOW DIAGRAM OF A STEAM TURBINE

The generic symbol for a turbine used in a flow diagram is shown in Figure above. The symbol diverges with a larger area at the exit than at the inlet. This is how one can tell a turbine symbol from a compressor symbol. In Figure, the graphic is coloured to indicate the general trend of temperature drop through a turbine. In a turbine with a high inlet pressure, the turbine blades convert this pressure energy into velocity or kinetic energy, which causes the blades to rotate. Many green cycles use a turbine in this fashion, although the inlet conditions may not be the same as for a conventional high pressure and temperature steam turbine. Bottoming cycles, for instance, extract fluid energy that is at a lower pressure and temperature than a turbine in a conventional power plant. A bottoming cycle might be used to extract energy from the exhaust gases of a large diesel engine, but the fluid in a bottoming cycle still has sufficient energy to be extracted across a turbine, with the energy converted into rotational energy.

An additional use for turbines in industrial applications that may also be applicable in some green energy systems is to cool a fluid. As previously mentioned, when a turbine extracts energy from a fluid, the fluid temperature is reduced. Some industries, such as the gas processing industry, use turbines as sources of refrigeration, dropping the temperature of the gas going through the turbine. In other words, the primary purpose of the turbine is to reduce the temperature of the working fluid as opposed to providing power. Generally speaking, the higher the pressure ratio across a turbine, the greater the expansion and the greater the temperature drop. Even where turbines are used to cool fluids, the turbines still produce power

and must be connected to a power absorbing device that is part of an overall system.
Also note that turbines in high inlet-pressure applications are sometimes called expanders. The terms “turbine” and “expander” can be used interchangeably for most applications, but expander is not used when referring to kinetic energy applications, as the fluid does not go through significant expansion.

# ADVANTAGES

- ✓ Ability to utilize high pressure and high temperature steam.
- ✓ High efficiency.
- ✓ High rotational speed.
- ✓ High capacity/weight ratio.
- ✓ Smooth, nearly vibration-free operation.
- ✓ No internal lubrication.
- ✓ Oil free exhausts steam.

# DISADVANTAGES

× For slow speed application reduction gears are required. The steam turbine cannot be made reversible. The efficiency of small simple steam turbines is poor.

# STEAM TURBINES THE MAINSTAY OF BHEL

- BHEL has the capability to design, manufacture and commission steam turbines of up to 1000 MW rating for steam parameters ranging from 30 bars to 300 bars pressure and initial & reheat temperatures up to 600 ºC.
- Turbines are built on the building block system, consisting of modules suitable for a range of output and steam parameters.
- For a desired output and steam parameters appropriate turbine blocks can be selected.

# TYPES OF STEAM TURBINE

There are complicated methods to properly harness steam power that give rise to the two primary turbine designs: impulse and reaction turbines. These different designs engage the steam in a different method so as to turn the rotor.

## IMPULSE TURBINE

The principle of the impulse steam turbine consists of a casing containing stationary steam nozzles and a rotor with moving or rotating buckets.

The steam passes through the stationary nozzles and is directed at high velocity against rotor buckets causing the rotor to rotate at high speed.

The following events take place in the nozzles:

1. The steam pressure decreases.
2. The enthalpy of the steam decreases.
3. The steam velocity increases.
4. The volume of the steam increases.

5. There is a conversion of heat energy to kinetic energy as the heat energy from the decrease in steam enthalpy is converted into kinetic energy by the increased steam velocity.

## REACTION PRINCIPLE

A reaction turbine has rows of fixed blades alternating with rows of moving blades. The steam expands first in the stationary or fixed blades where it gains some velocity as it drops in pressure. It then enters the moving blades where its direction of flow is changed thus producing an impulse force on the moving blades. In addition, however, the steam upon passing through the moving blades again expands and further drops in pressure giving a reaction force to the blades. This sequence is repeated as the steam passes through additional rows of fixed and moving blades.

## IMPULSE TURBINE STAGING

In order for the steam to give up all its kinetic energy to the moving blades in an impulse

turbine, it should leave the blades at zero absolute velocity. This condition will exist if the blade velocity is equal to one half of the steam velocity. Therefore, for good efficiency the blade velocity should be about one half of steam velocity.
In order to reduce steam velocity and blade velocity, the following methods may be used:

1. Pressure compounding.
2. Velocity compounding.
3. Pressure-velocity compounding.
4. Pressure Compounding.

# TURBINE PARTS

## TURBINE BLADES

- Cylindrical reaction blades for HP, IP and LP Turbines
- 3-DS blades, in initial stages of HP and IP Turbine, to reduce secondary losses.

- Twisted blade with integral shroud, in last stages of HP, IP and initial stages of
- LP turbines, to reduce profile and Tip leakage losses
- Free standing LP moving blades Tip sections with supersonic design
- Fir-tree root
- Flame hardening of the leading edge
- Banana type hollow guide blade
- Tapered and forward leaning for optimized mass flow distribution
- Suction slits for moisture removal.

## TURBINE CASING

Casings or cylinders are of the horizontal split type. This is not ideal, as the heavy flanges of the joints are slow to follow the temperature changes of the cylinder walls.

However, for assembling and inspection purposes there is no other solution. The casing is heavy in order to withstand the high pressures and temperatures. It is general practice to let the thickness of walls and flanges decrease from inlet- to exhaust-end.

The casing joints are made steam tight, without the use of gaskets, by matching the flange faces very exactly and very smoothly. The bolt holes in the flanges are drilled for smoothly fitting bolts, but dowel pins are often added to secure exact alignment of the flange joint. Double casings are used for very high steam pressures. The high pressure is applied to the inner casing, which is open at the exhaust end, letting the turbine exhaust to the outer casings.

## TURBINE ROTORS

The design of a turbine rotor depends on the operating principle of the turbine. The impulse turbine with pressure drop across the stationary blades must have seals between stationary blades and the rotor. The smaller the sealing area, the smaller the leakage; therefore the stationary blades are mounted in diaphragms with labyrinth seals around the shaft. This construction requires a disc rotor. Basically there are two types of rotor:

- DISC ROTORS

All larger disc rotors are now machined out of a solid forging of nickel steel; this should give the strongest rotor and a fully balanced rotor. It is rather expensive, as the weight of the final rotor is approximately 50% of the initial forging. Older or smaller disc rotors have shaft and discs made in separate pieces with the discs shrunk on the shaft. The bore of the discs is made 0.1% smaller in diameter than the shaft. The discs are then heated until they easily are slid along the shaft and located in the correct position on the shaft and shaft key. A small clearance between the discs prevents thermal stress in the shaft.

- DRUM ROTORS

The first reaction turbines had solid forged drum rotors. They were strong, generally well balanced as they were machined over the total surface. With the increasing size of turbines the solid rotors got too heavy pieces. For good balance the drum must be machined both outside and inside and the drum must be open at one end. The second part of the rotor is the drum end cover with shaft.

# CONSTRUCTIONAL FEATURES OF A BLADE

The blade can be divided into 3 parts:

- The profile, which converts the thermal energy of steam into kinetic energy, with a certain efficiency depending upon the profile shape.
- The root, which fixes the blade to the turbine rotor, giving a proper anchor to the blade, and transmitting the kinetic energy of the blade to the rotor.
- The damping element, which reduces the vibrations which necessarily occur in the blades due to the steam flowing through the blades. These damping elements may be integral with blades, or they may be separate elements mounted between the blades.

Each of these elements will be separately dealt with in the following sections.

## H.P. BLADE PROFILES

In order to understand the further explanation, a familiarity of the terminology used is required. The following terminology is used in the subsequent sections.

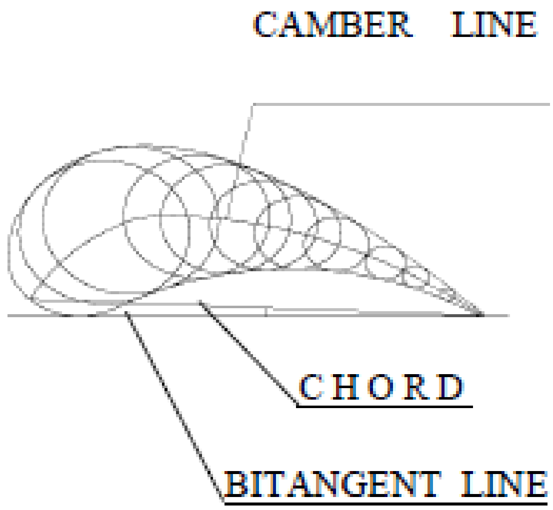



**FIG.3 HIGH PRESSURE BLADE PROFILE**

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 camber line intersects the profile at two points A and B. The line joining these points is called chord, and the length of this line is called the chord length. A line which is tangential to the inlet and outlet edges is called the bit agent line. The angle which this line makes with the circumferential direction is called the setting angle. Pitch of a blade is the circumferential distance between any point on the profile and an identical point on the next blade.

## H.P. 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

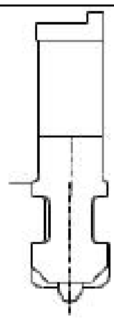
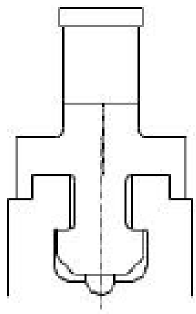
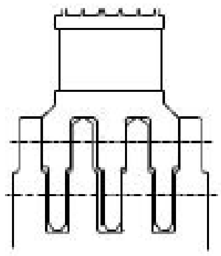
| | |
|---|---|
| T-ROOT |  |
| T-ROOT WITH SIDE GRIP |  |
| FORK ROOT |  |

**TABLE 4 BLADE ROOTS**

## L.P. BLADE PROFILES

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

## LP BLADE ROOTS

The roots of LP blades are as follows:

1) 2 blading:

The roots of both the LP stages in –2 type of LP blading are T-roots.

2) 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 up to 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.

# DYNAMICS IN BLADE

The excitation of any blade comes from different sources. They are:

A) Nozzle-passing excitation: As the blades pass the nozzles of the stage, they encounter flow disturbances due to the pressure variations across the guide blade passage. They also encounter disturbances due to the wakes and eddies in the flow path. These are sufficient to cause excitation in the moving blades. The excitation gets repeated at every pitch of the blade. This is called nozzle-passing frequency excitation. The order of this frequency = no. of guide blades x speed of the machine. Multiples of this frequency are considered for checking for resonance.

B) Excitation due to non-uniformities in guide-blades around the periphery. These can occur due to manufacturing inaccuracies, like pitch errors, setting angle variations, inlet and outlet edge variations, etc.

- → For HP blades, due to the thick and cylindrical cross-sections and short blade heights, the natural frequencies are very high. Nozzle-passing frequencies are therefore necessarily considered, since resonance with the lower natural frequencies occurs only with these orders of excitation.
- → In LP blades, since the blades are thin and long, the natural frequencies are low. The excitation frequencies to be considered are therefore the first few multiples of speed, since the nozzle-passing frequencies only give resonance with very high modes, where the vibration stresses are low.

The damping in any blade can be of any of the following types:
a) Material damping: This type of damping is because of the inherent damping properties of the material which makes up the component.

b) Aerodynamic damping: This is due to the damping of the fluid which surrounds the component in operation.

c) Friction damping: This is due to the rubbing friction between the components under consideration with any other object.

Out of these damping mechanisms, the material and aerodynamic types of damping are very small in magnitude. Friction damping is enormous as compared to the other two types of damping. Because of this reason, the damping elements in blades generally incorporate a feature by which the vibrational energy is dissipated as frictional heat. The frictional damping has a particular characteristic. When the frictional force between the rubbing surfaces is very small as compared to the excitation force, the surfaces slip, resulting in friction damping. However, when the excitation force is small when compared to the frictional force, the surfaces do not slip, resulting in locking of the surfaces.

This condition gives zero friction damping, and only the material and aerodynamic damping exists. In a periodically varying excitation force, it may frequently happen that the force is less than the friction force. During this phase, the damping is very less. At the same time, due to the locking of the rubbing surfaces, the overall stiffness increases and the natural frequency shifts drastically away from the individual value. The response therefore also changes in the locked condition. The resonant response of a system therefore depends upon the amount of damping in the system (which is determined by the relative duration of slip and stick in the system, i.e., the relative magnitude of excitation and friction forces) and the natural frequency of the system (which alters between the individual values and the locked condition value, depending upon the slip or stick condition).

# BLADING MATERIALS

Among the different materials typically used for blading are 403 stainless steel, 422 stainless steel, A-286, and Haynes Satellite 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 Satellite Alloy Number 31 is a cobalt-based super alloy and is used on jet expanders when precision cast blades are needed. The Haynes Satellite 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.

# MANUFACTURING PROCESS

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 effectively adjusted or located in the industry or plant within a well-planned manufacturing organization.

## CLASSIFICATION OF MANUFACTURING PROCESSES

For producing of products materials are needed. It is therefore important to know the characteristics of the available engineering materials. Raw materials used manufacturing of products, tools, machines and equipments in factories or industries are for providing commercial castings, called ingots. Such ingots are then processed in rolling mills to obtain market form of material supply in form of bloom, billets, slabs and rods.

These forms of material supply are further subjected to various manufacturing processes for getting usable metal products of different shapes and sizes in various manufacturing shops. All these processes used in manufacturing concern for changing the ingots into usable products may be classified into six major groups as

- Primary shaping processes
- Secondary machining processes
- Metal forming processes
- Joining processes
- Surface finishing processes and
- Processes effecting change in properties

## PRIMARY SHAPING PROCESSES

Primary shaping processes are manufacturing of a product from an amorphous material. Some processes produces finish products or articles into its usual form whereas others do not, and require further working to finish component to the desired shape and size. The parts produced through these processes may or may not require to undergo further operations. Some of the important primary shaping processes are:

(1) Casting
(2) Powder metallurgy
(3) Plastic technology
(4) Gas cutting
(5) Bending and
(6) Forging.

## SECONDARY OR MACHINING PROCESSES

These secondary processes are mainly required for achieving dimensional accuracy and a very high degree of surface finish. The secondary processes require the use of one or more

machine tools, various single or multi-point cutting tools (cutters), job holding devices, marking and measuring instruments, testing devices and gauges etc. for getting desired dimensional control and required degree of surface finish on the work pieces.
The example of parts produced by machining processes includes hand tools machine tools instruments, automobile parts, nuts, bolts and gears etc. Lot of material is wasted as scrap in the secondary or machining process. Some of the common secondary or machining processes are:

- Turning
- Threading
- Knurling
- Milling
- Drilling
- Boring
- Planning
- Shaping
- Slotting

- Sawing
- Broaching
- Hobbling
- Grinding
- Gear Cutting
- Thread cutting and
- Unconventional machining processes namely machining with Numerical control (NC) machines tools or Computer Numerical Control (CNC) machine tool using ECM, LBM, AJM, USM setups.

# The Different Processes Undergone By A Steam Turbine Are:

## Heavy Machine Shop

In this shop heavy machine work is done with the help of different NC & CNC machines such as centre lathes, vertical and horizontal boring & milling machines. Asia's largest vertical boring machine is installed here and CNC horizontal boring milling machines from Skoda of

Czechoslovakia.

## Over Speed Balancing Tunnel

In this section, rotors of all type of turbines like LP (low pressure), HP (high pressure) & IP (Intermediate pressure) rotors of Steam turbine, rotors of Gas & Hydro turbine are balanced .In a large tunnel, Vacuum of
2 torr is created with the help of pumps & after that rotor is placed on pedestal and rotted with speed of 2500-4500 rpm.

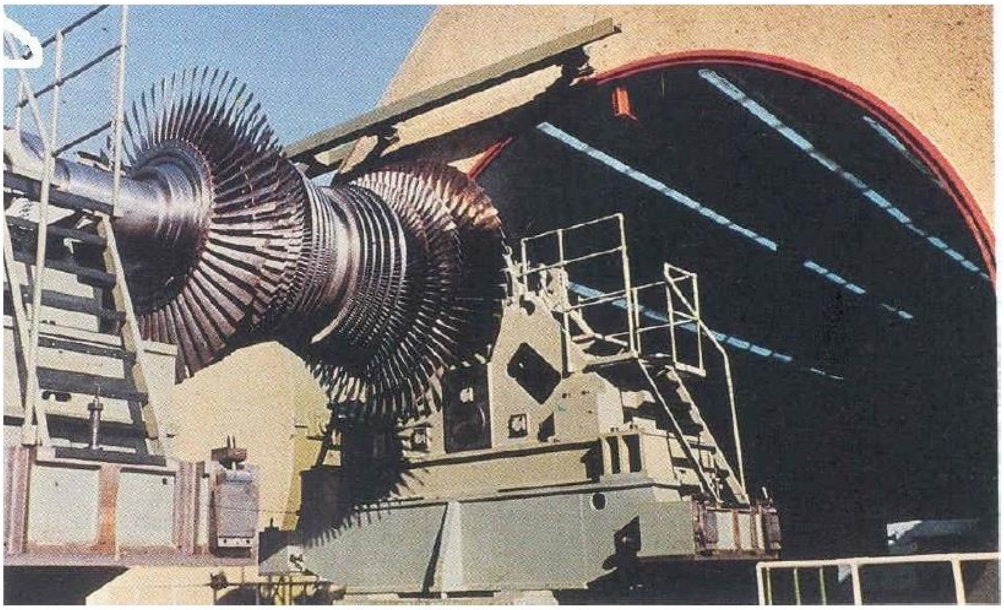


**FIG.4 OVERSPEED AND VACCUM BALANCING TUNNEL**

**For balancing and over speed testing of rotors up to 320 tons in weight, 1800 mm in length and 6900 mm diameter under vacuum conditions of 1 Torr**

**Bearing section** – In this section Journal bearings are manufactured which are used in turbines to overcome the vibration & rolling friction by providing the proper lubrication.

**Turning section** – In this section small lathe machines, milling & boring machines, grinding machines & drilling machines are installed. In this section small jobs are manufactured like rings, studs, disks etc.

**Governing section** – In this section governors are manufactured. These governors are used in turbines for controlling the speed of rotor within the certain limits. 1st all components of governor are made by different operations then these all parts are treated in heat treatment shop for providing the hardness.

**Turbine Blade Manufacturing Shop**- In this shop solid blade of both steam & gas turbine are manufactured. Several CNC & NC machines are installed here such as copying machine, grinding machine, Rhomboid milling machine, Duplex milling machine, T- root machine centre, Horizontal tooling centre, Vertical & horizontal boring machine etc.

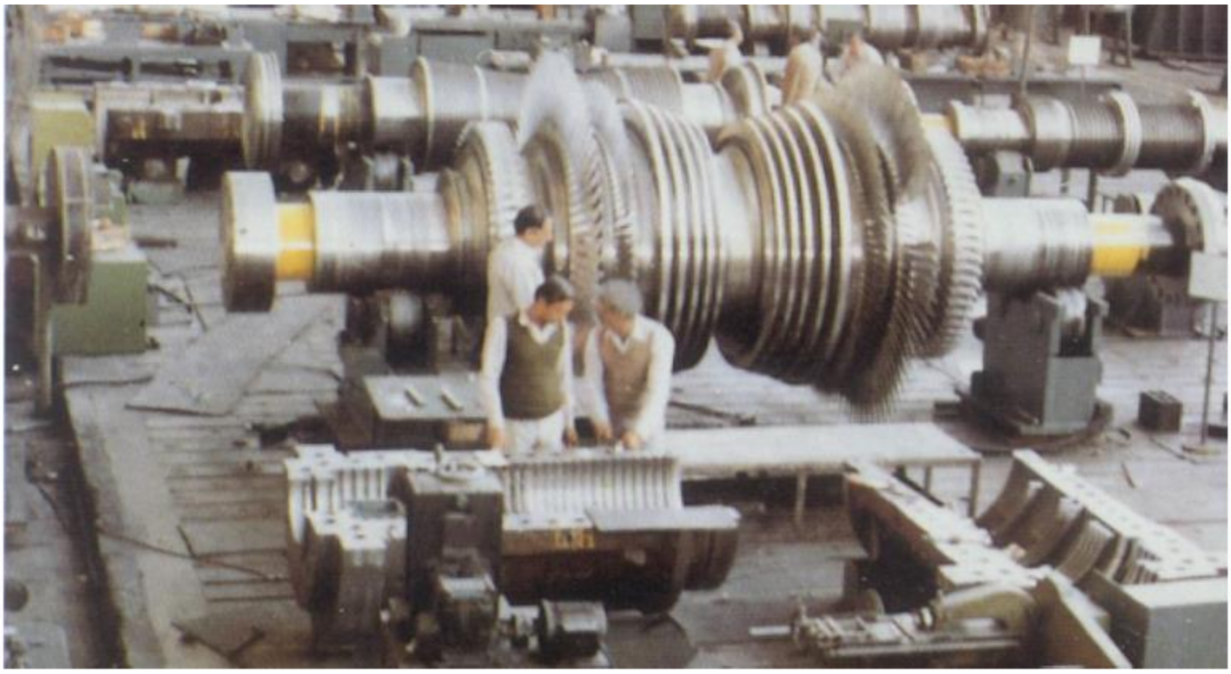


**FIG.5 STEAM TURBINE CASING AND ROTORS IN ASSEMBLY AREA**

**Turning section**- Same as the turning section, there are several small Machine like lathes machines, milling, boring, grinding machines etc.

**FIG.6 CNC ROTOR TURNING LATHE**

# BLADE SHOP

Blade shop is an important shop of Block 3. Blades of all the stages of turbine are made in this shop only. They have a variety of centre lathe and CNC machines to perform the complete operation of blades. The designs of the blades are sent to the shop and the Respective job is distributed to the operators. Operators perform their job in a fixed interval of time.

## TYPES OF BLADES

Basically the design of blades is classified according to the stages of turbine. The size of LP TURBINE BLADES is generally greater than that of HP TURBINE BLADES.
At the first T1, T2, T3 & T4 kinds of blades were used, these were 2nd generation blades.
Then it was replaced by TX, BDS (for HP TURBINE) & F shaped blades. The most modern blades are F & Z shaped blades.


**FIG.7 TYPES OF BLADES**

# OPERATIONS PERFORMED ON BLADES

Some of the important operations performed on blade manufacturing are:-

- Milling
- Blank Cutting
- Grinding of both the surfaces
- Cutting
- Root milling

# MACHINING OF BLADES

Machining of blades is done with the help of Lathe & CNC machines. Some of the machines are:-

- Centre lathe machine
- Vertical Boring machine
- Vertical Milling machine
- CNC lathe machine

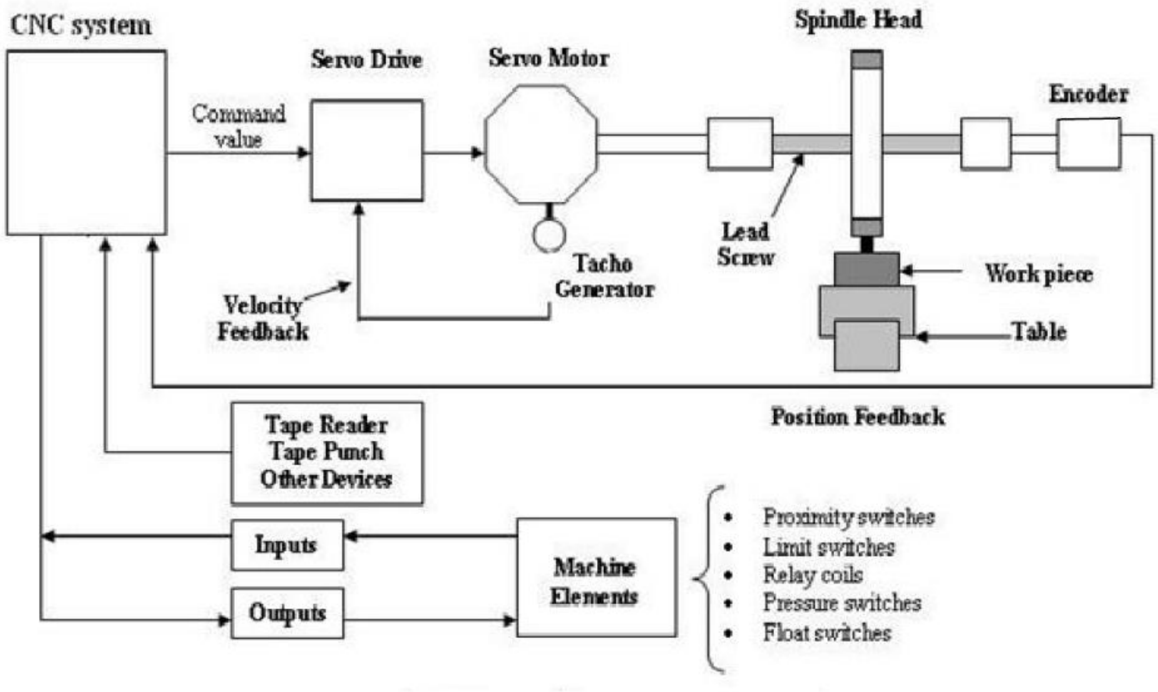



**FIG.8 SCHEMATIC DIAGRAM OF A CNC MACHINE**

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