A MINI PROJECT ON EVALUATION OF STEAM TURBINE MANUFACTURING

A Project Report submitted in the partial fulfillment
Of project based training

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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.
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1. INTRODUCTION TO BHEL

Bharat Heavy Electricals Limited (BHEL) is the largest Engineering and Manufacturing Enterprise in India in the energy related and infrastructure sector today. BHEL is one of the “MAHARATNA” Companies in India, which has played a leading role in the development of Power Generation and Transmission and is poised to help the country achieve its targeted generation capacity of two lakh megawatts by the end of 11th plan. In 2012-13, BHEL has amassed the provisional turnover of Rs 50,015 Crs. with an outstanding Order Book of more than Rs.1,15,180 Crs. It has presence in more than sixty countries spanning all the six continents of the world.

The beginning of BHEL can be traced to its roots in the Planning Commission in Feb. 1947 when the Advisory Board of the Commission recommended the need to set up indigenous power equipment manufacturing plant. With the establishment of Heavy Electricals (India) Limited at Bhopal in 1956 under the collaboration of AEI (UK), India laid its foundation for self sufficiency in production of Heavy Electrical Equipments. In the next five years, three more plants were started by Govt. of India at Tiruchy, Hyderabad and Haridwar under a different company known as Bharat Heavy Electricals Limited. In pursuance of the recommendations of the action committee on Public Enterprises, the operations of all the four plants were integrated from July 1972. The BHEL Corporation was formed in January 1974 and HE(I)L, Bhopal was merged with BHEL.

Today BHEL has 15 manufacturing divisions, 4 Power Sector Regional Centres, 4 Overseas offices, 1 Subsidiary and over 100 project sites, service centers etc. BHEL caters to six major lines of business i.e. Power, Industry, Transmission, Transportation, Oil and Electronics. The company has the capabilities for executing power projects from concept to commissioning.

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.

Product profile of BHEL:

1. Gas Turbines  
2. Steam Turbines  
3. Compressors  
4. Turbo Generators  
5. Heat Exchangers  
6. Pumps  
7. Pulverizers  
8. Switch Gears  
9. Oil Rigs

Evolution and growth of BHEL Hyderabad unit:

The Hyderabad Unit of BHEL is located at Ramachandrapuram which is around 30KM from the historic city of Charminar. Foundation Stone of the Plant was laid in 1959 and the production commenced in the year 1965. The Unit was set up mainly to manufacture 60MW and 110MW Steam Turbo generator sets for State Electricity Boards and also 12 MW TG Sets.

From this small beginning, the Ramachandrapuram Unit has been growing steadily in different phases of development and today it caters to a wide spectrum of business in Power, Industry, Transmission, Oil and Gas.

BHEL – the largest Gas Turbine manufacturer in India, with the state-of-art facilities in all areas of Gas Turbine manufacture provide complete engineering in house for meeting specific customer requirement. With over 100 machines and cumulative fired hours of over four million hours. BHEL has supplied gas turbines for variety of applications in India and abroad. BHEL also has the world’s largest experience of firing highly volatile naphtha fuel on heavy duty gas turbines.

Specific features of BHEL:

1. Capability to fire a wide range of gaseous and liquid fuels and a mix of such fuels ranging from clean fuels like natural gas. Distillate oil, naphtha.
2. Facilities like Black start, fast start and emergency start.
3. Suitable for power generation and mechanical drive applications. Models below 100MW suitable for 50Hz and 60Hz.

4. All machining equipment like generators, compressors etc manufactured in house. Design of combustion system as per international emission norms. Machines designed as per major international codes like API etc.

5. Suitable for IGCC applications.

6. Suitable for indoor and outdoor applications.

7. Use of water or steam injection for abatement of NOX emission and power Augmentation.

BHEL equipped with precision and sophisticated machine tools like CNC Broaching machine5 Axis Milling Machine and over speed vacuum balancing tunnel offers conversion, modification and up gradation services-through joint venture with Gefor all existing gas turbines. Services are also offered for all field support, retrofits and repairs, inspections and technical consultancy on “operation & maintenance of Gas Turbine Based Power Plants”.
2. POWER GENERATION

In power generation mostly steam turbine is used because of its greater thermal efficiency and high 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. Steam turbine has an ability to utilize high pressure and high temperature steam.

The power generation in a steam turbine is at a uniform rate, therefore necessity to use flywheel is not felt. Much higher speeds and greater range of speed is possible for a steam turbine. No internal lubrication is required as there are no rubbing parts in the steam turbine. It can utilise high vacuum very advantageously.

Due to the above said salient features, of all heat engines and prime movers the steam turbine is nearest to the ideal and is widely used in power generation.

2.a Working principle of a steam turbine:

![Figure-1]
The steam turbine is essentially a flow machine in which heat energy in the steam is transferred into kinetic energy and its kinetic energy is utilised to rotate the rotor while steam flows through the turbine. During the flow of steam through the nozzle, the heat energy is converted into kinetic energy. The steam with high velocity enters the turbine blades and suffers a change in direction of motion which gives rise to change of momentum and therefore to a force. This constitutes the driving force of the turbine. This force acting on the blades in the circumferential direction sets up the rotation of the wheels or rotor. As the wheel rotates each one of the blades fixed on the rim of the wheel comes into action of the jet of steam which causes the wheel to rotate continuously.
3. THERMODYNAMICS OF STEAM TURBINE

The steam turbine operates on basic principles of thermodynamics using the part of the Rankin cycle. Superheated vapour (or dry saturated vapour, depending on application) enters the turbine, after it having exited the boiler, at high temperature and high pressure. The high heat/pressure steam is converted into kinetic energy using a nozzle (a fixed nozzle in an impulse type turbine or the fixed blades in a reaction type turbine).

Once the steam has exited the nozzle it is moving at high velocity and is sent to the blades of the turbine. A force is created on the blades due to the pressure of the vapour on the blades causing them to move. A generator or other such device can be placed on the shaft, and the energy that was in the vapour can now be stored and used. The gas exits the turbine as a saturated vapour (or liquid-vapour mix depending on application) at a lower temperature and pressure than it entered with and is sent to the condenser to be cooled. If we look at the first law we can find an equation comparing the rate at which work is developed per unit mass.
3.a T-S diagram for steam

![T-S diagram for steam](image)

**Figure-2**

Rankine cycle with super heat

**Process 1-2:** The working fluid is pumped from low to high pressure.
**Process 2-3:** The high pressure liquid enters a boiler where it is heated at constant pressure by an external heat source to become a dry saturated vapour.
**Process 3-3':** The vapour is superheated.
**Process 3-4 and 3'-4':** The dry saturated vapour expands through a turbine, generating power. This decreases the temperature and pressure of the vapour, and some condensation may occur.
**Process 4-1:** The wet vapour then enters a condenser where it is condensed at a constant pressure to become a saturated liquid.
4. CLASSIFICATION OF STEAM TURBINES

There are several ways in which the steam turbines may be classified. The most important and common division being with respect to the action of the steam, as

- Impulse turbine
- Reaction turbine
- Combination of impulse and reaction turbine

Figure showing the difference between impulse and reaction turbine

4.a IMPULSE TURBINE:

An impulse turbine has fixed nozzles that orient the steam flow into high speed jets. These jets contain significant kinetic energy, which the rotor blades, shaped like buckets, convert into shaft
rotation as the steam jet changes direction. A pressure drop occurs across only the stationary blades, with a net increase in steam velocity across the stage.

As the steam flows through the nozzle its pressure falls from inlet pressure to the exit pressure (atmospheric pressure, or more usually, the condenser vacuum). Due to this higher ratio of expansion of steam in the nozzle the steam leaves the nozzle with a very high velocity. The steam leaving the moving blades has a large portion of the maximum velocity of the steam when leaving the nozzle. The loss of energy due to this higher exit velocity is commonly called the "carry over velocity" or "leaving loss".

The details of simple impulse turbine is shown in the below figure, it consists of set of nozzles and blade ring mounted on a rotor. Steam supplied from the boiler expands through the nozzle to the exit pressure. After the expansion it enters the blades at high velocity, and the blades are shaped such that steam glides over the blades without shock. This provides driving torque on the rotor of the turbine.

In impulse turbine pressure drops only in the nozzles and remains constant over the moving blades, but velocity of steam decrease as the kinetic energy is absorbed by the moving blades.

4.b SIMPLE IMPULSE STEAM TURBINE (DE-LAVAL TURBINE)
4.c REACTION TURBINE:

In the reaction turbine, the rotor blades themselves are arranged to form convergent nozzles. This type of turbine makes use of the reaction force produced as the steam accelerates through the nozzles formed by the rotor. Steam is directed onto the rotor by the fixed vanes of the stator. It leaves the stator as a jet that fills the entire circumference of the rotor.

The steam then changes direction and increases its speed relative to the speed of the blades. A pressure drop occurs across both the stator and the rotor, with steam accelerating through the stator and decelerating through the rotor, with no net change in steam velocity across the stage but with a decrease in both pressure and temperature, reflecting the work performed in the driving of the rotor.

Reaction turbine consists of fixed blades followed by a ring of moving blades. The fixed blades acts as nozzle and allows a relatively small expansion of steam. Further expansion takes place in the moving blades. Thus in the reaction turbine, steam expands continuously and consequently, there is an increase in specific volume as the expansion proceeds, which is expanded by an increase in the size of blades.
As the steam expands through blades relative velocity increases and in the increase of relative velocity is achieved from the enthalpy drop. Due to increase in relative velocity a thrust or reaction force acts on the blades. This reaction force constitutes the driving force.
4.d SIMPLE REACTION STEAM TURBINE (PARSON’S TURBINE)

Figure-5
5. METHODS OF REDUCING ROTOR SPEED

The following methods are used to reduce the speed of an impulse turbine
1. Velocity compounding
2. Pressure compounding
3. Velocity-pressure compounding

5.a Velocity compounding:

Steam is expanded through stationary nozzle from the boiler to condensor pressure. So the pressure in the nozzle drops, the kinetic energy of steam increases due to increase in velocity. This energy is absorbed by row of moving blades. The steam flows through fixed blades. The function of these blades is to re direct the steam flow without altering its velocity to the following next row of moving blades where again work is done on them. This method has the advantage of less initial cost, but its efficiency is low.
5. b Pressure compounding:

Figure shows rings of fixed nozzles incorporated between the rings of moving blades. The steam at boiler pressure enters the first set of nozzles and expands partially. The kinetic energy is absorbed by moving blades. The steam then expands partially in second set of nozzles where pressure again falls and velocity increases, the KE is then absorbed by second ring of moving blades. This is repeated in stage 3 and stem finally leaves the turbine at low velocity and pressure.
5.c Pressure-Velocity compounding:

This method of compounding is the combination of two previously discussed methods. The total drop in steam pressure is divided into stages and velocity obtained in each stage is also compounded. The rings of nozzles are fixed at the beginning of each stage and pressure remains constant during each stage. This method of compounding is used in curits and moore turbine.
6. PARTS OF STEAM TURBINE

1. Casing
2. Rotor
3. Casing sealing glands
4. Governor system
5. Oil ring lubrication system
6. Bearing case
7. Steam chest
8. Over speed trip system

Rotor is one of the critical parts of the steam turbine. All the expansion process is done on the rotor in steam turbine.

Figure-9
Turbine casing

1. Outer casing
2. Exhaust steam part
3. Support blocks
4. Valve box
5. Emergency stop valve case
6. Main steam line connection
7. Hole for servo valves
8. Webs to accommodate the sealing shells
9. Webs to accommodate the blade carriers
10. Housing claws, front
11. Mounts for rear bearing
12. Exhaust steam flang
Blade carrier

Task

The blade carrier accommodates the fixed blades of the turbine blading.

Structure

The blade carriers are axially split and are bolted together steam tight by partial area screws. In the axial direction, the blade carriers are held in the outercasing by a slot-web connection. Vertical support is provided via adjustment elements that are screwed into the pads of the blade carrier bottom. Radial mounting and guidance are ensured by an axial bolt guide in the bottom of the blade carrier and the outer casing.

Figure-11

Blade Carriers
Turbine rotor

Function

The thermal energy contained in the steam is converted into mechanical energy in the blading. The turbine rotor and its moving blades transfers this energy as rotational motion to the driven machine. The basic structure of the turbine rotor is shown in Fig. 1. The number of blade stages shown may vary in the actual design. The actual turbine shaft comprises a monoblock forging.

Steam flows out of the inlet casing across the control stage (8) into the high-pressure nozzle groups (9) and on into the low-pressure nozzle group (10).

The inside (7) and front (5) shaft gland regions are adjacent to the blading regions against the direction of steam flow; the blading regions are bordered by the rear (11) shaft gland region in the direction of steam flow. The front and inside shaft glands are designed as labyrinth seals; the rear gland as a point-to-point seal.

The rotor is supported in two pressure lubricated journal bearings (4 and 12). The axial position of the rotor is fixed by the thrust bearing collars (2). Grooves for the electric speed measurement are provided in the right collar (3). The mechanical overspeed trip (1) and the trip cams for the axial position trips are arranged upstream of the thrust bearing (3).

A toothed wheel (13) for the manual turning gear is shrunk-fit onto the rear end region of the shaft. Primary drive is provided via a coupling hub (14) fit on the shaft that is secured by a shaft nut (15). Balancing planes (6) are available at various positions on the rotor.
Figure-12

Turbine Rotor

1. Overspeed trip
2. Thrust bearing
3. Thrust bearing collar with grooves
4. Front bearing support point
5. Front shaft gland region
6. Balancing planes
7. Inner shaft gland region
8. Control Stage
9. HP nozzle group
10. LP nozzle group
11. Rear shaft gland region
12. Rear point of bearing support
13. Gear for manual turning gear
14. Coupling
15. Shaft nut
Blading

General

The thermal energy contained in the steam is converted into mechanical energy in the blading. The design and quality of the blading are decisive for the level of efficiency and operating reliability of the turbine. High standards are therefore set for the design, construction and manufacture of turbine blades.

Three different types of blades are used for turbine blading:

- Low-reaction nozzle and impulse profiles for the control stage with partial steam admission with nozzle block control;
- Reaction stage with 50% reaction for the drum blading stages with full steam admission.

Throttle-controlled turbines are not equipped with a control stage. All blading rows are design with shrouding. Only stainless Cr steel is used for all of the blading.

Control Stage

The control stage consists of nozzles and moving blades. The nozzles for the inner casing (steam chamber), with a horizontal casing joint) are machined from solid blanks and installed in grooves.

Single-part inner casings are equipped with a three-section nozzle ring, consisting of a middle, outer and inner ring. Profile-shaped openings are countersunk into the middle ring using electrochemical means; the correspondingly shaped profile material is then installed in these openings. The middle ring is joined to the inner and outer ring using electron-beam welding.

Low pressure blading

The last stage of condensing turbines forms a standardized nozzle group, type SL. Both the stationary blading and the moving blading are machined with integral roots and shrouding from solid barstock.

The stationary blades are all designed with plain inverted T-roots. The stationary blades are inserted in appropriate grooves in the stationary
blade carrier and caulked into place with steel caulking material. The shrouding form a closed ring.

Figure-13

Stationary Blade Segemen

Bearings

Front support system

Design

The front bearing support system essentially consists of the following main components:

- Pedestal support
- Bearing housing
- Thrust bearing
- Journal bearing
- Seal ring
Figure-14

Structure Of Front Bearing Support System
**Bearing support system**

The pedestal support provides support for the outer casing and the bearing housing. The front support paws of the outer casing rest on adjusting devices which are coated with lubricating varnish. The centering key for the bearing housing is also used for guiding the outer casing. Its centering guide permits free axial movement and adjusting devices are provided for transverse adjustment to either side.

The bearing housing is supported on the pedestal support, entirely separate from the support paw supports for the outer casing, i.e. at no point is the bearing housing used as a support for the outer casing. This arrangement reliably prevents any tilting of the bearing housing due to thermal expansion of the outer casing.

The bearing housing is aligned parallel to the turbine axis on a centering guide. This centering guide can be moved axially and aligned laterally using adjusting devices. The bearing housing is supported freely on adjusting devices in the pedestal support and is secured against lifting by stud bolts. These stud bolts allow only a slight vertical clearance between the bearing housing and the pedestal support in order to ensure easy sliding. The slide surfaces of the adjusting devices are coated with a special lubricating varnish.

**Bearing housing**

The bearing housing consists of a top and bottom section. The bearing pedestal top section is an oil-tight cover and, at the same time, accommodates the turbine trip gear, transducers for measuring radial and axial displacement, electronic speed measurement and, where required, the grounding brush.

The flange opening at the end of the bearing housing facing away from the turbine is either closed off by a cover plate, or, where required, is used for connection of the reduction gear unit for the pump and/or the speed transducers, or with double power take-off, for attachment of the coupling guards.

The reduction gear unit pinion is connected to the turbine rotor via a flexible rod.
The bearing housing is provided with two hydraulic oil connections for lube oil supply. Inside the bearing housing, the oil is distributed to the turbine and/or reduction gear unit bearing via internal supply lines.

The hydraulic oil for the journal and thrust bearings is throttled and routed to the flanged connections at the bearing housing bottom section. The initial oil pressure required for the journal and thrust bearings is adjusted using two oil flow restrictors integrated into the oil lines.

Connections for pressure gauges are provided downstream of the flow restrictors for measuring the oil pressure upstream of the bearings.

The bearing housing only required one single oil drain line at the end of the housing for the journal and thrust bearings and for the reduction gear unit. Expansion joints are required for the oil connections, as the bearing pedestal is installed so as to permit axial movement. Penetrations are provided where required in the bottom section for the hydrostatic shaft lifting system.

Two long bolts, which are parallel to the turbine axis, connect the front bearing housing rigidly to the outer casing bottom half. The bearing housing therefore follows the movement of the outer casing in the case of thermal expansion. However, due to the centering guide, the bearing housing can only be shifted axially.

Since the two connecting bolts between the outer casing and the bearing housing are located approximately at the support level of bearing housing, no tilting moment acts on the bearing housing during thermal expansion.

**Thrust bearing**

The front bearing housing contains the thrust bearing for the turbine rotor. This is fixed directly by the bearing housing bottom and top sections. The thrust bearing is of the double-sided type with tilting pads. It locates the rotor relative to the casing and absorbs any residual steam thrust from the blading.

The thrust bearing forms the fixed point for the turbine rotor in the front bearing housing. The turbine rotor is carried forward with the bearing housing as the temperature of the turbine casing increases. As the
temperature of the turbine rotor also rises at the same time, also causing expansion, the end result for the rear of the rotor is only a small movement relative to the fixed point of the turbine.

The thrust from the thrust bearing is directed to the outer casing through the connecting bolts. Thrust forces therefore do not exert any tilting moments on the bearing housing.

**Journal bearing**

The journal bearing is an integral part of the bearing pedestal bottom half that is bolted securely to the substructure. This ensures defined bearing support and promotes good running behavior.

The bearing shell for the journal bearing is fixed in place by the bearing housing top section.

The journal bearing is bolted in fixed position on the substructure. This means that the shaft journal expands through the journal bearing shell in response to thermal expansion of the turbine casing.

**Rear support system**

**Design**

The rear bearing support system essentially consists of the following main components:

- Bearing housing
- Journal bearing
- Seal ring
- Shaft turning gear
- Bearing caps

**Bearing support system**

The bearing housing is affixed to the base frame or base plate surfaces that have been appropriately processed. Here, fitted plates are used as filler material that can be used for subsequent alignment work. Adjusting bolts are used for fixation.
**Bearing housing**

The bearing housing consists of a top and bottom section. The bearing housing top section is an oil-tight cover and, at the same time, accommodates the transducers for measuring radial displacement.

The flange opening at the end of the bearing pedestal facing away from the turbine is used for mounting the coupling guard.

The bearing housing is provided with a hydraulic oil connection on the side for lube oil supply. This connection can be provided on the left or right side, depending on the plant-specific requirements. Inside the bearing housing, the oil is distributed to the turbine bearing via internal supply bores.

The hydraulic oil is returned without restriction through the flange connection on the bearing housing bottom section. The requisite initial oil pressure for the journal bearing is adjusted using an oil restrictor integrated into the bearing housing.

Connections for pressure gauges are provided downstream of the flow restrictors for measuring the oil pressure upstream of the bearings. The bearing housing is equipped with a oil drain line on either the left or right side, depending on the specific plant requirements. Expansion joints are not required for the oil connections, as the bearing housing is not subjected to movement.

Penetrations are provided where required in the bearing housing bottom section for the hydrostatic shaft lifting system and for lubrication of the multitooth coupling.

**Journal bearing**

The journal bearing is an integral part of the bearing housing bottom half that is bolted securely to the base frame or base plate. This ensures defined bearing support and promotes good running behavior. The bearing shell for the journal bearing is attached by means of the bearing cap. The journal bearing is bolted in fixed position on the substructure. This means that the shaft journal expands through the journal bearing shell in response to thermal expansion of the turbine rotor.
Seal ring

A seal ring is arranged at the turbine-end face of the bearing housing that acts as a non-contacting shaft seal. Leakage oil is routed through bores to the inside of the bearing housing through the seal tips.

To prevent oil from the journal bearing from splashing on the shaft seal, a split shield plate is installed in the bearing housing directly upstream of the seal ring with only a slight clearance to the turbine rotor. Sealing gas, whose pressure can be monitored at a measurement port, can be applied to the seal ring.

Shaft turning gear

The bearing housing top section can also accommodate a manual or electric tumbler pinion rotor turning gear. An oil turbine rotor turning gear (Pelton wheel) can also be mounted on the end facing away from the turbine.

Venting system

The vacuum in the bearing housing must be regulated when a venting system is provided. The vacuum level should be 15 - 20 mmWs.

6.1 OPERATING AND MAINTENANCE

When warming up a steam turbine for use, the main stream stop valves (after the boiler) have a bypass line to allow superheated steam to slowly bypass the valve and proceed to heat up the lines in the system along with the steam turbine. Also, a turning gear is engaged when there is no steam to the turbine to slowly rotate the turbine to ensure even heating to prevent uneven expansion. After first rotating the turbine by the turning gear, allowing time for the rotor to assume a straight plane (no bowing), then the turning gear is disengaged and steam is admitted to the turbine, first to the astern blades then to the ahead blades slowly rotating the turbine at 10 to 15 RPM to slowly warm the turbine.

Problems with turbines are now rare and maintenance requirements are relatively small. Any imbalance of the rotor can lead to vibration, which in extreme cases can lead to a blade letting go and
punching straight through the casing. It is, however, essential that the turbine be turned with dry steam - that is, superheated steam with minimal liquid water content. If water gets into the steam and is blasted onto the blades (moisture carryover), rapid impingement and erosion of the blades can occur leading to imbalance and catastrophic failure. Also, water entering the blades will result in the destruction of the thrust bearing for the turbine shaft. To prevent this, along with controls and baffles in the boilers to ensure high quality steam, condensate drains are installed in the steam piping leading to the turbine.

**TYPES**

Steam turbines are made in a variety of sizes ranging from small <1 hp (<0.75 kW) units (rare) used as mechanical drives for pumps, compressors and other shaft driven equipment, to 2,000,000 hp (1,500,000 kW) turbines used to generate electricity. There are several classifications for modern steam turbines.

**6.2 Supply and exhaust conditions:**

These types include condensing, no condensing, reheat, extraction and induction. No condensing or back pressure turbines are most widely used for process steam applications. The exhaust pressure is controlled by a regulating valve to suit the needs of the process steam pressure. These are commonly found at refineries, district heating units, pulp and paper plants, and desalination facilities where large amounts of low pressure process steam are available. Condensing turbines are most commonly found in electrical power plants. These turbines exhaust steam in a partially condensed state, typically of a quality near 90%, at a pressure well below atmospheric to a condenser. Reheat turbines are also used almost exclusively in electrical power plants. In a reheat turbine, steam flow exits from a high pressure section of the turbine and is returned to the boiler where additional superheat is added. The steam then goes back into an intermediate pressure section of the turbine and continues its expansion.

Extracting type turbines are common in all applications. In an extracting type turbine, steam is released from various stages of the turbine, and used for industrial process needs or sent to boiler feed water heaters to improve overall cycle efficiency. Extraction flows may be controlled with a valve, or left uncontrolled. Induction turbines introduce low pressure steam at an intermediate stage to produce additional power.
6.3 Advantages of steam turbine include:

1. Ability to utilise high pressure and high temperatures
2. High efficiency.
3. High rotational speed
4. High capacity/weight ratio.
5. Smooth operation.
6. No internal lubrication.
7. Oil free exhaust system
8. Can be built in small or very large units (upto to 1200 MW)

Disadvantages include:

1. For low speed application reduction gears are required.
2. Steam turbine cannot be made reversible.
3. Efficiency of small steam turbine is poor.
7. MANUFACTURING PROCESS

7.a INTRODUCTION

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.

Today’s competitive manufacturing era of high industrial development and research, is being called the age of mechanization, automation and computer integrated manufacturing. Due to new researches in the manufacturing field, the advancement has come to this extent that every different aspect of this technology has become a fullfledged fundamental and advanced study in itself. This has led to introduction of optimized design and manufacturing of new products. New developments in manufacturing areas are deciding to transfer more skill to the machines for considerably reduction of manual labor.

7.b 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

### 7.b.1 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.

### 7. b.2 SECONDARY OR MACHINING PROCESSES

As large number of components require further processing after the primary processes. These components are subjected to one or more number of machining operations in machine shops, to obtain the desired shape and dimensional accuracy on flat and cylindrical jobs. Thus, the jobs undergoing these operations are the roughly finished products received through primary shaping processes. The process of removing the undesired or unwanted material from the work-piece or job or
component to produce a required shape using a cutting tool is known as machining. This can be done by a manual process or by using a machine called machine tool (traditional machines namely lathe, milling machine, drilling, shaper, planner, slotter). In many cases these operations are performed on rods, bars and flat surfaces in machine shops. 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 workpieces. 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
- Hobbing
- 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.
7. c BLOCK 3 LAY-OUT

<table>
<thead>
<tr>
<th>BAY-1</th>
<th>BAY-2</th>
<th>BAY-3</th>
<th>BAY-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMS (Heavy Machine shop)</td>
<td>HMS</td>
<td>BEARING SECTION</td>
<td>BLADE SHOP</td>
</tr>
<tr>
<td>ASSEMBLY SECTION</td>
<td>ASSEMBLY SECTION</td>
<td>TURNING SECTION</td>
<td>TURNING SECTION</td>
</tr>
<tr>
<td>OSBT</td>
<td>OSBT</td>
<td>ASSEMBLY SECTION</td>
<td>ASSEMBLY SECTION</td>
</tr>
<tr>
<td>GOVERNING SECTION</td>
<td>GOVERNING SECTION</td>
<td>HEAT TREATMENT</td>
<td>SECTION</td>
</tr>
</tbody>
</table>

**TABLE 5 LAYOUT OF BLOCK 3**

7.d CLASSIFICATION OF BLOCK 3

- BAY-1 IS FURTHER DIVIDED INTO THREE PARTS

1. **HMS** -
   In this shop heavy machine work is done with the help of different NC & CNC machines such as center 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.

2. **Assembly Section (of hydro turbines)** –
   In this section assembly of hydro turbines are done. Blades of turbine are 1st assemble on the rotor & after it this rotor is transported to balancing tunnel where the balancing is done. After balancing the rotor, rotor & casings both internal & external are transported to the customer. Total assembly of turbine is done in the company which purchased it by B.H.E.L.

3. **OSBT (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,
rots 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. After it in a computer control room the axis of rotation of rotor is seen with help of computer & then balance the rotor by inserting the small balancing weight in the grooves cut on rotor.

□ BAY –2 IS DIVIDED IN TO 2 PARTS:

1. **HMS**– In this shop several components of steam turbine like LP, HP & IP rotors, Internal & external casing are manufactured with the help of different operations carried out through different NC & CNC machines like grinding, drilling, vertical & horizontal milling and boring machines, center lathes, planer, Kopp milling machine.

2. **Assembly section**– In this section assembly of steam turbines up to 1000 MW is assembled. 1st moving blades are inserted in the grooves cut on circumferences of rotor, then rotor is balanced in balancing tunnel in bay-1. After is done in which guide blades are assembled inside the internal casing & then rotor is fitted inside this casing. After it this internal casing with rotor is inserted into the external.

□ BAY 3 IS DIVIDED INTO 3 PARTS:

1. **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.

2. **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.

3. **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. Then these all components are assembled into casing. There are more than 1000 components of Governor.
BAY-4 IS DIVIDED INTO 3 PARTS:

1. TBM (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 center, Horizontal tooling center, Vertical & horizontal boring machine etc.

2. Turning section- Same as the turning section in Bay-3, there are several small Machine like lathes machines, milling, boring, grinding machines etc.

- Heat treatment shop-
  In this section there are several tests performed for checking the hardness of different components. Tests performed are Sterellititing, Nitriding, DP test

7.e 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.

1. At the first T1, T2, T3 & T4 kinds of blades were used, these were 2nd generation blades.
2. Then it was replaced by TX, BDS (for HP TURBINE) & F shaped blades. The most modern blades are F & Z shaped blades.

7.f 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
7.9 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

Figure-15
SCHEMATIC DIAGRAM OF A CNC MACHINE
8. APPLICATIONS

To drive large centrifugal pumps, such as feed water pumps at a thermal power plant. A small industrial steam turbine (right) directly linked to a generator (left). This turbine generator set of 1910 produced 250 kW of electrical power. Electrical power stations use large steam turbines driving electric generators to produce most (about 80%) of the world's electricity. The advent of large steam turbines made central-station electricity generation practical, since reciprocating steam engines of large rating became very bulky, and operated at slow speeds. Most central stations are fossil fuel power plants and nuclear power plants; some installations use geothermal steam, or use concentrated solar power (CSP) to create the steam. Steam turbines can also be used directly.

The turbines used for electric power generation are most often directly coupled to their generators. As the generators must rotate at constant synchronous speeds according to the frequency of the electric power system, the most common speeds are 3000 RPM for 50 Hz systems and 3600 RPM for 60 Hz systems. Since nuclear reactors have lower temperature limits than fossil-fired plants, with lower steam quality, the turbine generator sets may be arranged to operate at half these speeds, but with four-pole generators, to reduce erosion of turbine blades.

8.1 Marine propulsion

In ships, compelling advantages of steam turbines over reciprocating engines are smaller size, lower maintenance, lighter weight, and lower vibration. A steam turbine is only efficient when operating in the thousands of RPM, while the most effective propeller designs are for speeds less than 100 RPM; consequently, precise (thus expensive) reduction gears are usually required, although several ships, such as Turbine, had direct drive from the steam turbine to the propeller shafts. Another alternative is turbo-electric drive, where an electrical generator run by the high-speed turbine is used to run one or more slow-speed electric motors connected to the propeller shafts; precision gear cutting may be a production bottleneck during wartime. The purchase
cost is offset by much lower fuel and maintenance requirements and the small size of a turbine when compared to a reciprocating engine having an equivalent power. However, diesel engines are capable of higher efficiencies: propulsion steam turbine cycle efficiencies have yet to break 50%, yet diesel engines routinely exceed 50%, especially in marine applications.

Nuclear-powered ships and submarines use a nuclear reactor to create steam. Nuclear power is often chosen where diesel power would be impractical (as in submarine applications) or the logistics of refuelling pose significant problems (for example, icebreakers). It has been estimated that the reactor fuel for the Royal Navy’s Vanguard class submarine is sufficient to last 40 circumnavigations of the globe – potentially sufficient for the vessel's entire service life.

8.2 Locomotives:

Steam turbine locomotive. A steam turbine locomotive engine is a steam locomotive driven by a steam turbine. The main advantages of a steam turbine locomotive are better rotational balance and reduced hammer blow on the track. However, a disadvantage is less flexible power output power so that turbine locomotives were best suited for long-haul operations at a constant output power.
CONCLUSION

Gone through rigorous one month training under the guidance of capable engineers and workers of BHEL HYDERABAD in Block-1 “EVALUATION OF TURBINE MANUFACTURING CYCLE” headed by Senior Engineer of department Mr. T.M. RAO situated in Ramachandrapuram, Hyderabad, Andhra Pradesh.

The training was specified under the Turbine Manufacturing Department. Working under the department I came to know about the basic grinding, scaling and machining processes which was shown on heavy to medium machines. Duty lathes were planted in the same line where the specified work was undertaken.

The training brought to my knowledge the various machining and fabrication processes went not only in the manufacturing of blades but other parts of the turbine.