International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 09, September-2019

Dimensional Analysis and Lower half Control Valve Seats Replacement in High-Pressure Turbine

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***Abstract*— A Steam turbine which extracts thermal energy of steam and converts pressurized steam into mechanical energy. Further mechanical energy is produced, the same used to run an electrical generator. Steam turbine is directly coupled with an electrical generator. Hence, produced mechanical energy is converted into electrical energy. Steam is obtained from water by heating in the boiler. From boiler high-pressure & temperature steam is delivered which is used at steam turbine inlet to rotate steam turbine shaft. As connected directly steam turbine with generator, Hence, generator shaft is rotated. The steam so used to produce electricity.**

In this project work studied overall layout and its working on M/s. Tuticorin Thermal Power Station (TTPS) having 210 MW Leningrated Metal Works (LMW) steam turbines supplied by M/s. Bharat Heavy Electricals Limited, Haridwar. High pressure and temperature (130 Kg/ Cmsq. & 540°C) steam is used, which may affect steam turbine components (Emergency stop valve, Control valve, turbine blading etc.,). Also, which affects power generation.

Our project work aims on analyzing HP turbine control valve dimensions and HP turbine Control valves steam passing. Thermodynamic analysis of control valve, assumptions and specifications. Experimental results on control valve mass flowrate. Flow regions and patterns. Flow asymmetry Graphical representation. Due to steam passing, it is very difficult to control the turbine speed by governor. Further it is leading to un-controlled turbine speed and which damages the turbo-generator components. The steam turbine components damage may expedite emergency stop valve components, Control valve Components, HP Nozzles, Stationary and Moving blades. Expected with different points regarding steam passing and having highly risk to operate the turbo-generator. Proper tight sealing surface is required to stop steam passages, when the valves are in closed condition. Worked on rectifying the above by analyzing the control valve dimensions and valve seats replacement in case of lower half casing in Tuticorin thermal power station.

I INTRODUCTION

A Steam turbine, mechanical prime mover which is operating by supplying pressurized steam energy. The steam turbine produces mechanical work by utilizing high-pressure & temperature steam at inlet. It includes multiple stages (stationary and rotating blades), where steam is expanding while passing and to produce better thermodynamic efficiency. Steam turbines are used for driving electrical generators, Further electricity is produced. Also, used as prime mover to drive compressors and pumps in case of petroleum refineries, Fertilizers plants and other process industries. These are used to produce higher amount (>100 MW) of power, also considered as turbomachines. Steam turbines handles maximum power demand. Steam turbine is heat engine, here steam energy is transferring into kinetic energy after passing through steam nozzle. The produced kinetic energy is converted as force, which impinges on moving blades ring assembly, those fixed on rotating turbine rotor element. Steam turbine capacity ranges are from 1 MW to 1000 MW. Generally, 1 MW, 2.5 MW, 5 MW, 10 MW, 30 MW, 120 MW, 210 MW, 350 MW, 350 MW, 500 MW, 660 MW, 1000 MW are available commonly.

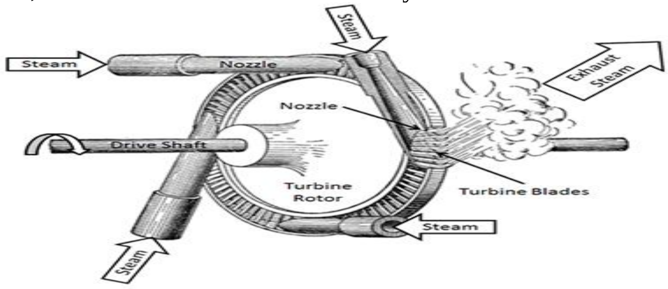

Fig.1. Impulse steam turbine

Steam turbine has a row nozzles ring, a moving blades row those fixed on rotor and casings (Bottom and top). The main objective of steam turbine technology is to extract maximum energy from the working fluid, and to transfer it into useful work to obtain maximum efficiency. From boiler high-pressure & temperature steam is entered and expanded in the nozzle, Here steam pressure reduction occurs and thermal energy of steam is transferred into kinetic energy, this results emitting high velocity steam jet which is impinging on the moving blades attached on rotor. Turbine rotor rested on bearings.

Some driven machines such as electric generators, Centrifugal pumps, Centrifugal compressors and Gas compressors etc., are operating under steady conditions in terms of output offer constant resistance. Importantly, These machines are also high speed machines. Accordingly Steam turbines are, from every point of view, perfectly suitable as a prime mover for driving such machines. The uniform turning movement and accordingly uniform speed are very important requirements for a prime mover to drive such machines.

The only parts of steam turbine those requires lubrication system are the bearings supporting the rotor, the governor shaft bearings and gear wheels. The lubricating oil is stored in oil tank, circulated around the system, is heated with

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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heaters and cooled, uses filters for cleanliness and so used for long periods running.

The working fluid used in Steam turbine is Steam. In Steam turbine directly used working fluid's energy to rotate the steam turbine blades. Steam turbine undergoes a fluid process expansion by the pressure drop and flow continuously. Steam turbine is the machine which uses external combustion method. In Steam turbine heating of steam (working fluid) is performed outside the steam turbine.

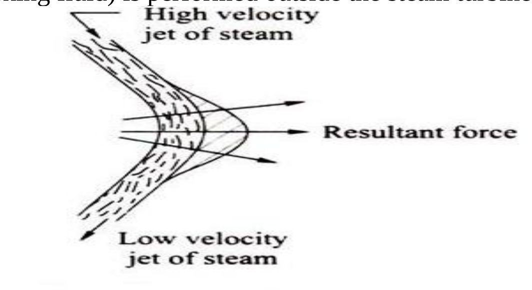

Fig. 2. Steam turbine working principle

Working fluid (Steam) enters inside the steam turbine through a steam nozzle. Entered steam in the steam nozzle, transferred into kinematic energy by expanding. At exit of nozzle, Steam pressure is smaller when comparing with steam pressure at entry. But, Steam velocity at nozzle exit is greater than at the time of entry at inlet. The steam leaves out from the nozzle is directed on the steam turbine blades with arche shaped and fitted around the turbine wheels. Steam flows in between the blade gaps is directed follows the curve on the turbine blades. Steam velocity rise changes the force that improves and then turbine shaft will rotate.

Steam turbines working principle depends on steam dynamic action. A high-velocity steam is delivered from steam nozzles and it strikes on the moving blades, those were fitted on a wheel or disc which is mounted on turbine rotor shaft. Delivered High-velocity steam develops dynamic pressure on the moving blades row in which both blades and turbine rotor shaft started to rotate in the same direction. Initially, in a steam turbine pressure energy of steam is extracted and then it is transferred into kinetic energy by allowing steam to flow through the steam nozzles. The conversion of kinetic energy does mechanical work to the rotor blades and the rotor is connected to a steam turbine generator which acts as a mediator. Turbine generator collects mechanical energy from the rotor and converts into electrical energy. Since the construction of steam turbine is simple, its vibration is much less than the other engine for same rotating speed. Though different types of governing system are used to improve turbine speed.

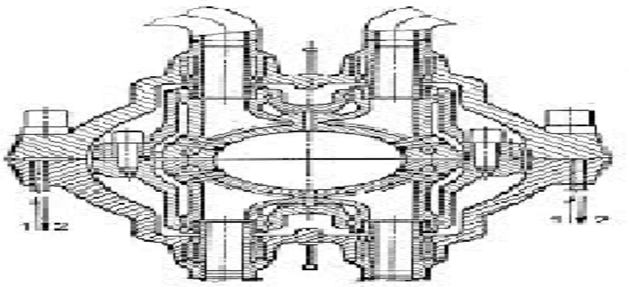

Fig. 3. Steam turbine operation

High-pressure & temperature steam is entered inside the Steam turbine as shown in below. Steam is passed through the multi (one

stage is having one row moving blades and stationary blades). Thermal energy is converted as Mechanical energy. Further steam turbines Mechanical energy which runs the electrical generator.

II COMMON MEASURING INSTRUMENTS USED

Usually the below mentioned Measuring instruments were used in performing Steam turbine Major and Minor inspections. These are highly precision measuring instruments. Hence It is required to calibrate periodically.

1. Vernier Calipers
2. Depth Vernier Caliper
3. Outside Micrometer
4. Inside Micrometer
5. Depth Micrometer
6. Dial Gauges
7. Precision Master Level
8. Slip Gauge or Gauge Blocks
9. Feeler Gauge

III THREE GENERAL TYPES OF FIT

In manufacturing industry, the new manufactured components required to assemble with one another during their assembly. The dimensional difference in between the two assembling components those are to be assembled, they are termed as the hole and the shaft. Before assembly, the dimensional difference is obtained and termed as fit. An ideal fit is required for proper functioning of the assembled components. Hence, identified three basic fits types can be used, depending on the actual limit of the shaft or hole. Three general fits are:

- Clearance Fit
- Interference Fit
- Transition Fit

Clearance Fit

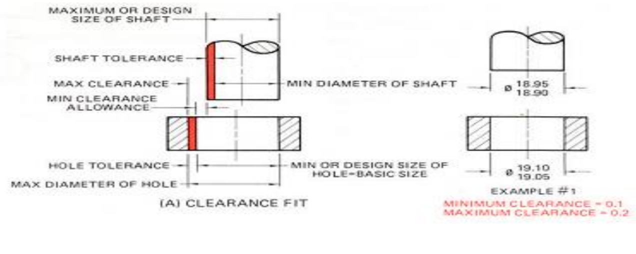

Fig. 4. Clearance fit

The largest permissible shaft size (diameter) is smaller than the smallest hole size (diameter). Clearance fit always provides clearance in between shaft and hole. Small clearances in between components are provided for precision fit that can easily be assembles without the application of tools. Large clearances are provided to allow existing relative motions. Example: A shaft rotating in a bush.

In clearance fit the difference between the sizes (diameters) is always positive. The clearance fit is shown in above Fig. 1.16 clearance fit. Clearance fit occurs when two toleranced mating parts will always leave a space or clearance assembled.

Interference Fit

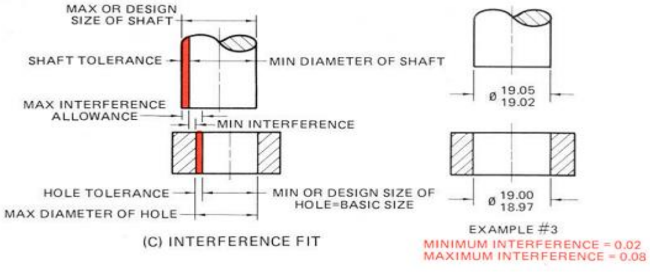

Fig. 5. Interference fit

The minimum permissible diameter of the shaft exceeds the maximum allowable diameter of the hole.

This type of fit always provides interference. Interference fit is a form of a tight fit. Tools are required for the precise assembly of two parts with an interference fit.

When two mating parts are assembled with an interference fit, it will be an almost permanent assembly, that is, the parts will not come apart or move during use. To assemble the parts with interference, heating or cooling may be required. In an interference fit the difference between the sizes is always negative. Interference fit occurs when two toleranced mating parts will always interfere when assembled.

IV CONSTRUCTION OF STEAM TURBINES

CROSS SECTIONAL VIEW OF STEAM TURBINE:

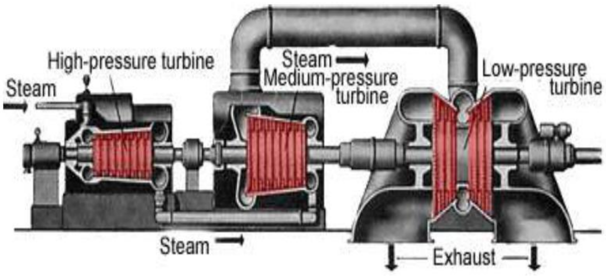

Fig. 6. Construction of steam turbines

The main components of steam turbines are given below:

1. Cylinders or Casings,
2. Turbine rotors,
3. Diaphragms and Liners,
4. Blades,
5. Sealings,
6. Emergency stop valves (ESV's) and Control valves (CV's),
7. Governing & protection system,
8. Steam turbine Supervisory System,
9. Bearings, and
10. Barring gear

1. Cylinders or Casings

HP, IP and LP turbine casings importantly a pressure vessel, those weight being supported at both ends. HP Cylinder, IP Cylinder and LP Cylinder are designed to get very much stiff in longitudinal direction and to withstand hoop stress in transverse plane to maintain accurate clearance between fixed and rotating components.

2. Turbine rotors

If the turbine is impulse type the rotor is disc type, this means blades are carried in the discs, which may be integral forged with the shaft or shrinked on the shaft. If the turbine is reaction type, the rotor is drum type, this means blades are directly carried on the rotor.

3. Liners and Diaphragms

In reaction turbines, guide blades are directly carried in the casings and hence liners and diaphragms are not generally used. In impulse turbines, most of the pressure drop of a stage takes in guide blades resulting in higher deflection of guide blades. Additional bending strength to guide blades is provided by diaphragms. Welded diaphragms /fixed blades are used in higher temperature zones while casted diaphragms are used in low temperature zones. ESV's are supplied either single (1 no.) seat type or double (2 no's) seat type. Single seat type ESV's are preferred, though these require higher force for opening or closing. Two to four diaphragms are housed in a liner which in turn is housed in the turbine casing. Liners and casing, provide chamber for bleed steam. Also, saves casing from higher speed steam erosion. With the use of lines, matching of casing also becomes much simpler.

4. Blades

Blades fitted in the stationary part or fixed part are termed as guide blades or nozzles and fitted in the turbine rotors are called moving or rotating or working blades. Most costly components of steam turbine are blades.

Blades are three types:

a) Cylindrical blades – These are Constant profile blades.
b) Tapered cylindrical blades – These are tapered but similar profile blades.
c) Twisted blades – These are twisted blades and varying profile. Blades consists three main parts, they are:
   i) Aerofoil: It is working part of blade.
   ii) Root: This means the blade portion which is hold with the casing or disc or drum.
   iii) Shroud: It can be either rivetted by tenon to main blades or it can be machined integrally with the blade.

5. Shaft sealings

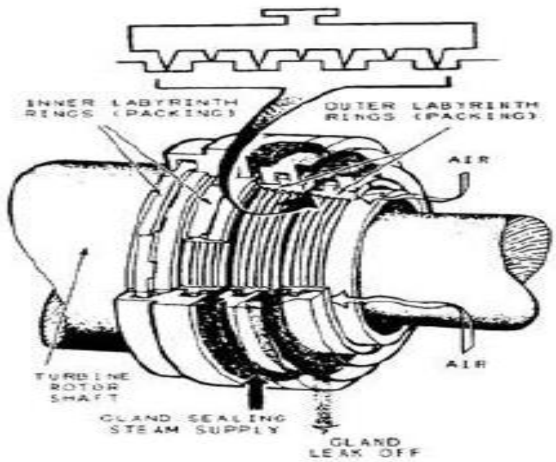

Fig. 7. Shaft sealings

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Sealings are provided in the steam turbine casings to eliminate the possible chances of steam leakage to atmosphere from inlet to and exhaust ends of the cylinders. For this, labyrinth glands are made, those are assembled with radial clearance type, hence these results trouble free and frictionless sealing. On each steam gland sealing consists no.of sealing rings divided into segments. Backed each segment by two flat springs. The sealing rings are housed in grooves machined in gland bodies which are in turn housed in the steam turbine casing or bolted to the casing at the ends.
Supply steam to the steam sealing chamber /space at 1.030 to 1.050 Kg/cm2 abs and at temperature 130ºC to 150 ºC from the header, where pressure is maintained constant with the help of an electronic regulator. Air-steam mixture is sucked out from the last seal chamber/ room by the application of a special steam ejector, then passed to gland vent condenser. Line arrangement has been made / prepared to supply steam live conditions at front sealing side of HPT and IPT rotors to control differential expansions, when rotor goes under contraction during a trip out or sharp load reduction.

6. Emergency stop valves (ESV's) & Control valves (CV's)

Steam turbines are supplied with installed emergency stop valves (ESV's) are used to stop steam supply. Control valves are used to control / regulate steam supply. In case of reheat turbines, Emergency stop valves (ESV's) are also provided in hot re-heat line.
Steam chests can be integral with the turbine casings or separate casing connected to turbine casing by flexible pipelines. Usually steam strainers are also housed in steam chest, but sometimes separate casings are used to house steam strainers.
Emergency stop valves (ESV's) are actuated by controlled servomotor and by protection system. Control valves (CV's) are actuated /working by the connected governing system through servomotors pipe connections to regulate / control steam supply as per requirement by the load. ESV's are supplied either single (1 no.) valve seat type or double (2 no's) seat type. Single seat type ESV's are preferred, though these require higher force for opening or closing.

7. Governing & protection system

Governing system is provided on utility steam turbines to maintain speed rated at all the loads and to provide pre-determined load sharing among the turbines operating in the grid. Governing system has speed control in parallel to speed governing to maintain constant speed at all the loads when turbo-generator is running in isolation and changes load sharing of the turbine when running in parallel.
Steam turbine is installed with a high response hydro-mechanical system of automatic governing which ensures smooth and stable operation of the turbo-generator under all operating conditions. The governing system is capable to sustain 100% load dump from the generator without operating the protection system and thus enables quick reloading of the turbo-generator. Steam turbine is also arranged with reliable protection device those ensures the stoppage of steam turbine under emergency operation conditions. Each unit of the system is thoroughly tested and then adjusted at the manufacturer's shop. Protection system trips the turbine by stopping steam supply to it, in abnormal conditions faced during operation of steam turbine. Usually protection system trips turbine at 10% over speed, excessive axial shift due to thrust bearing failure, very poor vacuum and very low pressure in lube oil lines.

8. Steam turbine supervisory system

Steam turbine Supervisory instrumentation is provided for indicating and recording of important parameters like vibrations, eccentricity, differential expansion, overall expansion, valve positioned stresses in major components. Hooked up with arranged indicators are connected suitable alarms and tripping mechanisms for cautioning the operation team and tripping the steam turbine, if these values once reach alarmingly inadmissible values.

9. Bearings

HPT, IPT & LPT turbine rotors were supported on total five bearings. The second bearing is a combined type radial-thrust bearing, remaining bearings are termed as journal bearings. Turbine rotors are assembled inside the bearings. High-pressure and intermediate pressure turbine rotors are joined by rigid coupling.
Lube oil is supplied to the journal and thrust bearings at pressure about 1 Kg/cm2 and the quantity of oil going to each bearing is controlled by the orifice plate fixed at its inlet end. Journal bearings are manufactured in two halves and usually consist bearing body faced with antifriction tin based babbitting to decrease coefficient of friction. Bearing's body matches with adjustable seating assembly in the pedestals. Bearings are usually designed forced lubricated type and had provision for admitting jacking oil. Thrust bearings are usually Mitchel type and are usually combined type with journal bearings, housed in machined spherically steel shell.
Journal bearing numbers are 1,3,4 and 5 consists of outer shell made from cast iron with an inner shell which is lined up with white metal. Both the shells are separated or split at half joint and properly secured by bolts. The pads on the outer shell are machined to bore diameter of bearing pedestals. For the fine alignment steel shims are provided under the pads.

10. Baring gear

Barring gear rotates the steam turbine rotors at slow speed when steam turbine rotors are ready to start or when shutdown takes place. Barring gear allows uniform heating or cooling of the turbine rotors to avoid turbine rotors distortion. Usually barring gear consists motor driven driving unit, which consists of speed reduction assembly and automatic engaging / dis-engagement arrangement. To avoid turbine rotors distortion very slow speed i.e. 3 RPM are enough.

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V. HPT CONTROL VALVES LOCATION

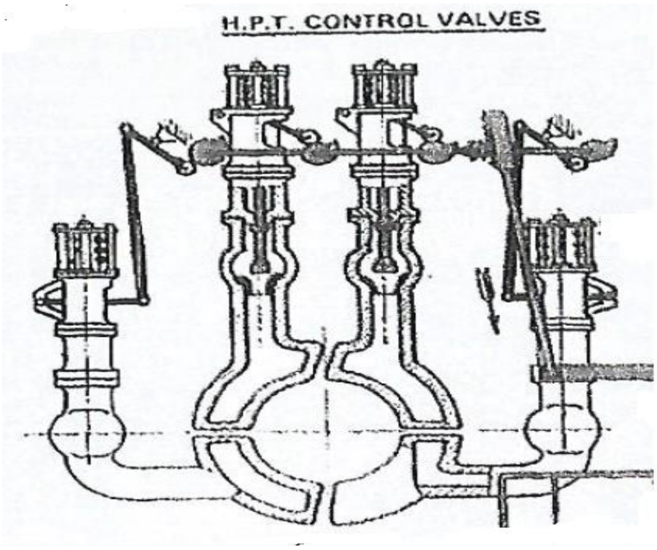

Fig. 8. HPT Control valves

CONSTRUCTION

Control valves are equipped on the steam turbine shell to regulate / control the steam flow into steam turbine. Control valves are enabled to enter high-pressure & temperature steam to steam turbine. Steam piping and suitable valves arranged to deliver steam into steam turbine. Steam pipes carries steam from the boiler to very close to the turbine, called ''Steam Chest''. It has thick-walled casing divided into rooms that houses Emergency Stop valves (ESV's) and Control valves (CV's). Steam chests are assembled with steam strainers to stop entering foreign particles into the steam turbine. After passing emergency stop valves, steam passes through control valves to enter inside the steam turbine. Emergency stop valves (ESV's) and Control valves (CV's) are opened hydraulically against the spring action or force.

Several different arrangements are utilized for functioning Control valves mechanism. These include a single inlet valve with a separate actuator, cam lift inlet valve assembled, and bar lift inlet valve assemblies. The control valve assembly normally mounted on the steam chest that may be integral to shell or bolted to it. Control valves lifting arrangement utilizes cams, bushings, and bearings those are mounted on the camshaft to regulate / control the position or movement of each control valve. A hydraulic servomotor drives a rack & pinion connection to the camshaft to indicate the position desired by the governor. In the lifting bar control valves arrangement, a hydraulic cylinder or servomotor which uses to lift all control valves at a time those were attached to the bar, Also the collars on each control valve stems are set at unequal heights or distances. Hence opening sequencing is different for steam admitting during starting and load changes. `Also, Control vales are used to perform Start-up activities, increasing & decreasing power and maintaining speed control with the turbine governor system.

PURPOSE

- By means of controlled opening of the control valves 4 no's the steam flow can be adjusted to the desired turbine output power.
- To meet different output requirements, the different sectional admission areas of the valves can be opened by lifting the four valves.
- The valve seats have been designed in the form of venturi nozzles, in order to keep fluid losses to a minimum.
- Control valves are the elements in the mainstream steam supply pipeline in between emergency stop valve and steam turbine.
- Control valves will be in closed position, when steam turbine is under shutdown.
- Control valves are mounted vertically on the steam chest of steam turbine.
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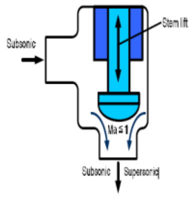
VI THERMODYNAMIC ANALYSIS OF CONTROL VALVE, ASSUMPTIONS AND SIMPLIFICATION



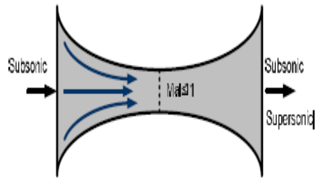


Fig. 9. Flow condition in a control valve
Fig. 10. Flow condition in a convergent divergent nozzle

Above shown Fig. 9 flow condition in a control valve and considered steam as working fluid. The Control valve steam flow can be regarded as choked flow with varying in cross-sectional area. The choked flow corresponds to fluid speed below or same as the acoustic velocity at the throat. The choked flow is characterized by the critical pressure and compressibility. According to the mechanism of choked flow, the flow velocity cannot exceed the speed of sound when the area of throat is constant. As the inlet mass flow rate increases, the throat flow attains the acoustic velocity. Then the outlet flow velocity exceeds the acoustic velocity as shown in Fig.9 Steam flow condition in a control valve and Fig. 10 flow condition in a convergent-divergent nozzle. This mechanism is useful in controlling the flow rate in area changing conditions such as nozzle and orifices. Thus, in this study, it is assumed that the steam flow is characterized by the choked flow. The flow states can divide into choked flow and supersonic flow.

Firstly, the effect of heat transfer was neglected. The speed of steam passing through the control valve is extremely high, whereas their conductivity is very low compared with very high enthalpy of steam. Secondly, the viscosity of steam at the given conditions was ignored. The two assumptions lead to the following isentropic process described by

$$h_o = h_i + \frac{V_i^2}{2} = h_e + \frac{V_e^2}{2} \quad (1)$$

$$\dot{m} = \rho_i A_i V_i = \rho_e A_e V_e = constant \quad (2)$$

Thus, a simple linear scaling may be applied to the experimental geometries and conditions as follows. the flow area of control valve is now only a function of fluid dynamic properties because the thermal effect has already been neglected pursuant to the first assumption.

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$$\frac{\dot{m}_m}{\dot{m}_p} = \frac{\rho_{i,m} A_{i,m} V_{i,m}}{\rho_{i,p} A_{i,p} V_{i,p}} = \frac{\rho_{e,m} A_{e,m} V_{e,m}}{\rho_{e,p} A_{e,p} V_{e,p}} \quad (3)$$

Finally, the following simplification is adopted as

$$p = \rho RT \quad (4)$$

$$pv^{\kappa} = constant \quad (5)$$

$$Ma = \frac{V}{a} \quad (6)$$

If the area of prototype and model are equal, the relationship of mass flow between the prototype and model can be expressed as only a function of density and velocity as in equation (3). According to equations (4), (5) and (6) etc., the ideal gas law, the density and velocity can also be changed to functions of temperature and pressure. Thus, the pressure and temperature conditions do not relate with the geometric conditions. In case of temperature, it only affects the density. Thus, the geometric values of the prototype can easily be determined for the experiment using linear scaling method.

VII HPT CONTROL VALVE – DIMENSIONAL INSPECTION

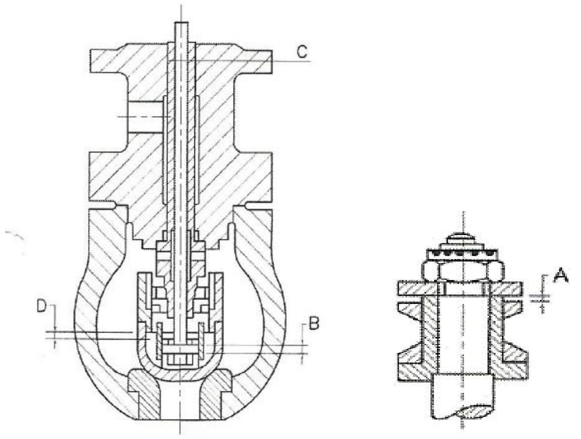

Fig. 10 HPT Control valve dimensional inspection locations

Table 1 HPT Control valve dimensions

Description	Steam Clearance, C	Idle Stroke, B	Washer Clearance, A	Relief valve stroke, D
HPCV – 1	0.40	0.10	0.05	4.00
HPCV – 2	0.44	0.12	0.05	4.10
HPCV – 3	0.43	0.11	0.05	4.20
HPCV – 4	042	0.15	0.05	4.05

HPT Control Valve – Recommendations

Control valves recommended to be operated routinely at regular planned intervals to reduce the potential for Control valves to stick. This means the Control valves frequently to be operated to avoid sticking. Valve sticking results, uneven load increasing and decreasing which is harmful for steam turbine operation.

VIII Lower Half Control Valve Seats Replacement

Control Valves – Introduction

Steam turbine HP control valves regulates the Steam flow which is entering into the HP turbine so that steam turbine speed can be controlled. Also, Control Valves increases or decreases load as per requirement. Load variation during the operating condition of steam turbines can have considerable impact significantly on its running performance. In practical requirements, the load varies frequently from the designed and thus there exists always a considerable difference from the desired running performance of the turbine by varying HP control valve opening. In 210 MW turbo-generator set, there are two sets of control valves. They are HP turbine control valves and IP turbine control valves. Venturi valves are widely used in modern large steam turbines as steam turbine governor valves to regulate the steam flow entering into the steam turbine

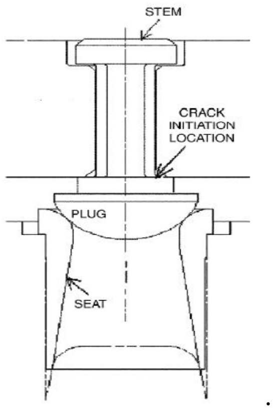

Fig. 11 Cross-section of venturi valve

Above shown Fig. 11 Cross-section of venturi valve shows the control valve has a moving component, stationary valve seat and valve case. The closure head is called the plug which is operated through the closure stem from the fully closed to the fully open position in response to desired turbine output. The valve seat is importantly a converging-diverging type nozzle with a very short converging section and is mounted on the bottom of the valve case. This design is able to allow and minimizes the total pressure loss. Control valves are operated in sequence. All valves are in closed position with initial clearances as shown in Fig. 10 HPT Control Valves Dimensional Inspection locations, When the steam turbine is not running position. The control valve opening is controlled by CVSM and Cam mechanism. When the cam mechanism is operated, the control valve no:1 is opened, Valve no:2 is second, Valve no:3 is third and Valve no:4 is last. Each valve starts to open as the previous valve is almost fully open. Thus, there is overlap.

IX CONTROL VALVES - FUNCTION AND WORKING

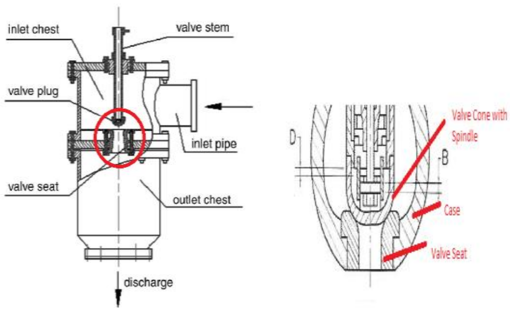

Fig. 12 Control valves seat arrangement

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HPT control valves operated through Control Valve Servomotor (CVSM). HP control valves are connected with Control valve servomotor which is used for operating the HPT and IPT control valves. Valve opening and closing is done by governing system of the Turbine. Each Control valve consists of valve cone with spindle which moves inside valve seat to regulate the steam flow by varying the gap in between valve cone and valve seat.

X EXPERIMENTAL RESULTS ON MASS FLOWRATE

The non-dimensionalized mass flowrate, this means the maximum choked mass flowrate at different openings divided by the mass flowrate at a large valve opening at h/D = 0.738 is shown in Graph 1. Choked mass flowrate variation with valve opening. The opening ratio is defined as the control valve lift from the closed position ‘’h’’ divided by the valve plug diameter ‘’D’’. The maximum flowrate increases quickly before 30 percentage opening, then slowly to about 50 percentage opening and remains constant at greater openings. Thus 50 percentage opening can be defined as the fully open for this valve.

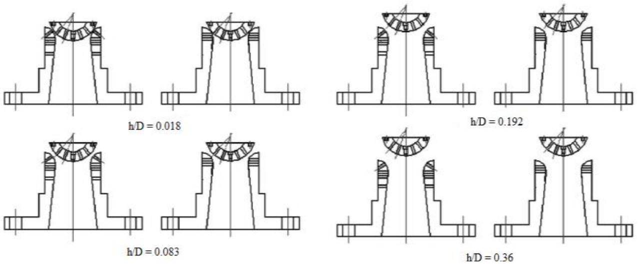
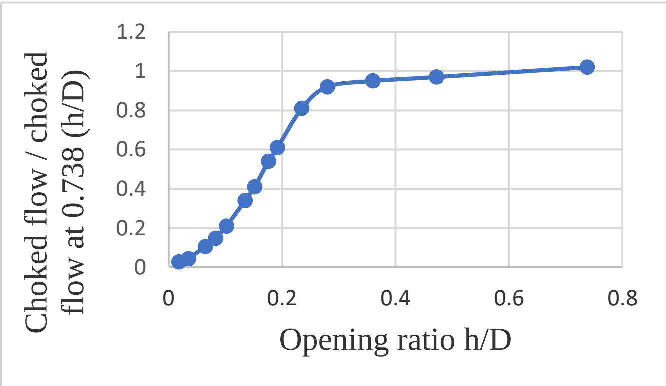


Fig. 13 Static pressure sensor positions at different valve openings

Graph 1 Choked mass flowrate variation with valve opening



XI HPT CONTROL VALVE DAMAGES

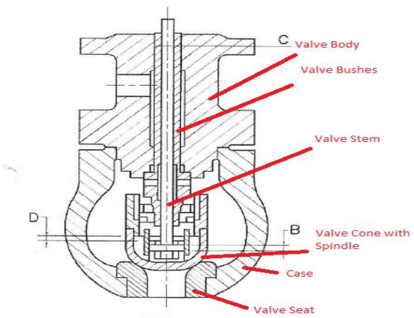


Fig. 14 Control Valve components and damages

Above shown essential components were damaged normally during the continuous operation of turbo-generation and course time. As per Original Equipment Manufacturer guide lines the above components were inpected and replaced.

HPT Control Valve Seat Damages

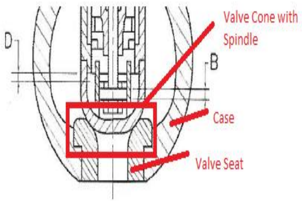


Fig. 15 Control Valve Seats damages and replacement

Above Shown HPT Valve seats were replaced with new Valve Seats as supplied by Original Equipment Manufacturer. Valve Seat damage includes Dent marks, Line marks, Uneven sufaces blow holes, pitting and erosion etc., These causes no tigt seal in between Valve Cone Spindle and Valve Seat. It leads to steam passges (without controlling) into th steam turbine, which is very danger.

XII. HPT LOWER HALF CONTROL VALVE SEATS REPLACEMENT

HPT Lower half Control Valves – Construction

As shown in Fig. 8 HP Turbine Control Valves Location – Bottom half Control Valves (2 no’s) are connected with the bottom half casing with two connections on both left and right sides. Control valve seats are assembled prior and remaining assembly was done as per Shown Fig. 14 Control Valve components and damages. Hence, Control Valve seats are not possible to take out and replace easily as these components are working since more than 5 years.

Solution for Removing Control Valve Seats

After attempting several methods to remove control valves seats, it is clear that Valve seats are not coming out and having narrow space to work over it. Also, which is clear that can’t carry the whole (Bottom half assembly is linked with several components) to outside workshop. In this case, suggested to remove Control Valve seats by On-site Machining equipment. This equipment is used on-site to machine the Control Valve seat as per required dimensions and surface finish.

On-site Machining Equipment for Control Valve Seats

Fig. 16 On-Site Machining Equipment

On-site Machining is performed when the unit is under Shutdown. Portable machines are used to carryout machine shop operations without removing the plant installed machinery. Expert technicians perform machining operations to achieve desired dimensional accuracy and surface finish.

Steps to Perform Control Valve Seats Replacement

1. Record Reference Dimensions,
2. Remove Control Valve Tack Welds,
3. Machine or Remove Control Valve Seats,
4. Casing bore Cleaning and NDT Performing,
5. Perform Co-axiality Check,
6. Preparing New Control Valve Seats, and
7. Assembling New Control Valve Seats & Tack weld.

1. Record Reference Dimensions

Record reference dimension in between Valve seat collar and Case. So that the Control Valve Assembly can be performed as before. For this Normal measuring tools are used. They are depth Vernier and Vernier Calipers.

2. Remove Control Valve Tack Welds

Control Valve Seats were tack welded with case and Valve seats. Tack welds generally allowed on four corners of the Valve Seat, So that Valve Seat sticks strongly during turbo-generator in operation. These tack welds were removed by using grinding tools. This step is concluded when there is separation in between two parts, they are Valve Seat and Case.

3. Machine or Remove Control Valve Seats

Above Shown Fig. 16 shows Control Valve Seats are removed by performing On-site Machining. Here, Skilled Machinists were used to maintain concentricity of the case. Also required to supervise closely the activity while machining, So that Machining activity is performed within required level in accuracy. During Machining activity, avoided Ovality and dimensional errors. After Machining the case is found without Valve Seat and having suitable dimensions to assemble new Valve seats. To Measure the Valve Seat assembly inside and outside diameters, They are: Inside and Outside Micrometers:

4. Casing bore Cleaning and NDT Performing

Clean case bore and ensure without having any machining chips, uneven surface and check for surface smoothness. After that perform Non-destructive tests as per given below depending on the requirement criteria:

- Liquid Dye-Penetrant Test
- Magnetic Particle Inspection Test
- Ultrasonic Test
- 5. Perform Co-axiality Check:

Fig. 17 Fixture for performing Co-axiality

Above Shown Co-axiality fixture is fabricated and used to correct Co-axiality. The fixture is assembled on the case. This method concludes the co-axiality and accordingly machining is performed. Finally, concluded the center line of the is in-line with Case. Hence Co-axiality is completed.

6. Preparing New Control Valve Seats

New Control Valve Seats are received from warehouse. These are measured with instruments. Further calculated the dimensions and compared each other. Valve Seat Machining on Outer Diameter is performed to get required size.

7 Assembling New Control Valve Seats & Tack weld

Control Valve Seat assembly requires Interference 0.05 mm to 0.10 mm. Hence dimensional value is checked and compared with required values. Accordingly, Once achieving the required values, Control Valves Seats are assembled n Case.

Fig. 18 Control valve seat assembly

After completion of Control Valve Seats, Wait for some time to get atmospheric temperature, so that Valve Seat Collar can rest properly on the case and to get its proper position. After having atmospheric temperature at Valve seat, Measure reference dimensions and check for proper position of Valve seat. Then perform tack weld in between Valve Seat and Case. After that NDT tests (as mentioned above) like Dye-penetrant test can be performed.

Lapping and Blue Contact Check

Lapping in between Control Valve Cone and Valve Seat is performed to get very good contact surface in Valve cone and Valve seat. If required, Leakage test is performed to get closer contact in between both the surfaces. Finally, the Surface contact is ensured by Blue Contact check. This test concludes and provides contact surface. This test is passed when contact surface is up to 90%. Practically, Blue Contact is maintained complete the contacting area.

XIII FLOW REGIONS AND PATTERNS

Majorly four regions are identified in terms of valve opening and pressure ratio, they are A, B, C and E by considering pressure distributions, pressure oscillation frequency and amplitude.

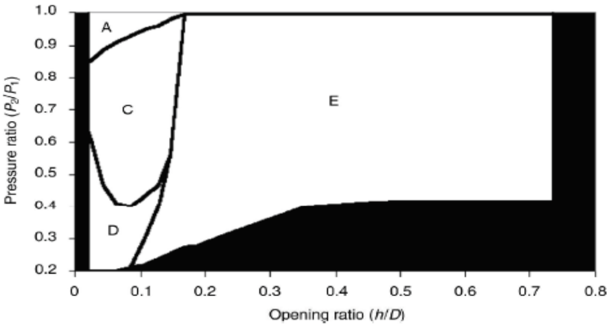


Fig. 19 Flow regions

In above Fig. 19 FlowC regions shows regions A, D and E pressure distribution occurs. Pressure oscillates with a high frequency and small amplitude. This is due to strong turbulence. In region C, there are several types of pressure distribution that keep changing to each other. A large amplitude of pressure oscillation occurs due to the changing flow pattern. All transition regions between C and other regions are included in region C. This region C is the most unstable region. The flow pattern is analytically determined using the measurement results of the static pressure distribution and pressure oscillation.

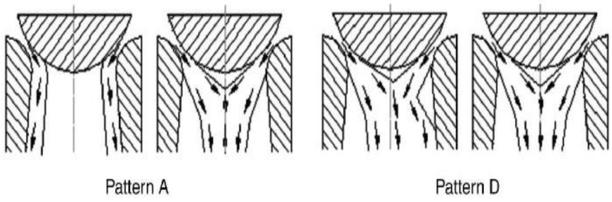


Fig. 20 Flow patterns A and D

From shown Fig. 20 Flow patterns A and D – Pattern A happens in region A, where there is a small opening and a high-pressure ratio. Pattern A is almost symmetric but not axisymmetric. Flow attaches to the valve seat in one cross-section, while it expands to the center in the other cross-section.

Pattern D happens in region D, where there is a small opening and a low-pressure ratio. It is almost axisymmetric free supersonic jet flow. After the valve throat, flow expands and joins together. The flow attaches to the valve seat in some places downstream.

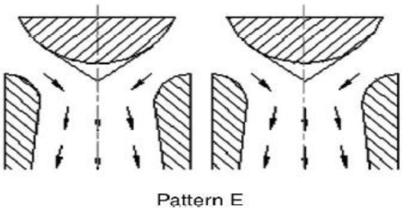


Fig. 21 Flow patterns E

Flow in region E is axisymmetric. Because of the high mass flowrate at large openings, flow fills or almost fills (with some separation at downstream seat side) the valve. Separation occurs in the center of the plug.

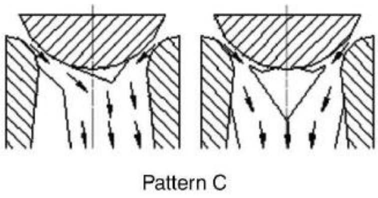


Fig. 22 Flow patterns C

Flow in region C is mostly unstable. In this region many failures occur. For pattern C, flow attaches to one side of the seat and separates from the other, joining together near the plug center in one cross-section. In the other cross-section, flow attaches to the seat sides and the two streams join further from the plug center. Part of the flow also attaches to the plug center. The 'hollow' region actually is full of flow shown in the other cross-section and a vortex. This is a very unstable flow pattern. It can change to three other patterns: C_0, C_1, and C'.

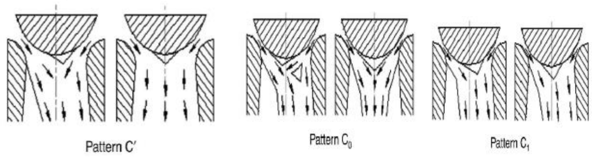


Fig. 23 Flow patterns C', C_0, C_1

At a small valve opening (when h/D<0.065), the flow pattern keeps changing between C_0, C_1, and sometimes C. At a somewhat larger opening, it keeps changing between C and C1. At opening ratios larger than about 0.102 h/D, the flow pattern oscillates between patterns C and C'. As the transient regions between patterns C and C'. As the transient regions between different regions are also included in region C, at the boundary of the region, some intermediate flow patterns happen.

XIV FLOW ASYMMETRY

An asymmetric pressure distribution can cause forces, resulting in plug vibration. Thus time-averaged pressure differences between opposite pressure sensors are calculated. In Fig. 10, Aveseat ΔP means time-averaged $(|P_1 - P_3|) + |P_2 - P_4|)_{seat}/2$. Here P_1, P_2, P_3 and P4 are measured static pressures from sensors 1,2,3 and 4 respectively as shown below.

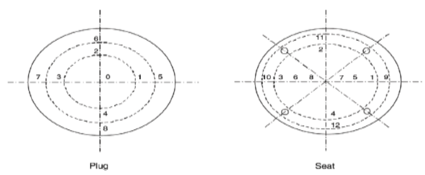


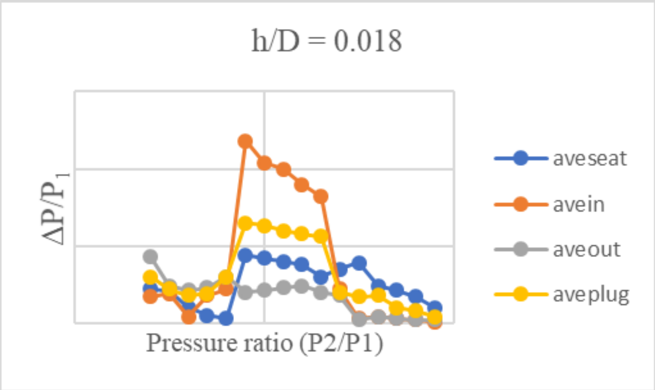
Fig. 24 Static sensor labels

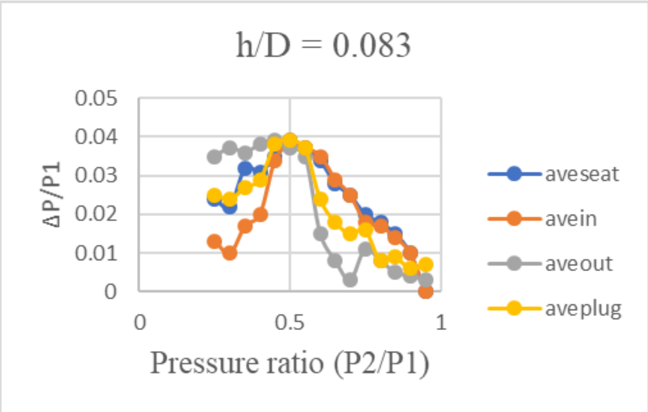
Avein ΔP means time-averaged $(|P_1 - P_3|) + |P_2 - P_4|)_{plug}/2$.
Avein ΔP means time-averaged $(|P_5 - P_7|) + |P_6 - P_8|)_{plug}/2$.
Where, P_1, P_2, P_3, P_4, P_5, P_6, P_7 and P_8 are measured static pressures from sensors 1, 2, 3, 4, 5,6, 7 and 8 respectively in the plug.
Aveplug ΔP means (Aveout ΔP + Avein ΔP). The pressure difference is non-dimensionalized by the inlet chest pressure P_1. If the time-averaged pressure differences are larger

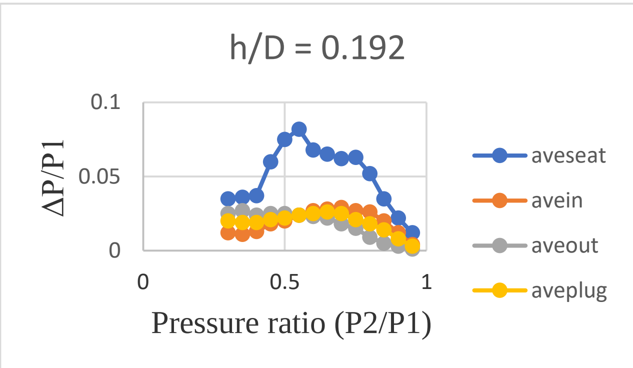
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 09, September-2019

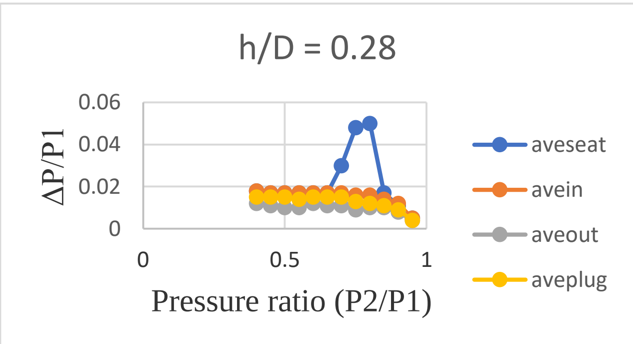
(greater than 0.02), the whole flow pattern can be considered as axisymmetric.

Graph 2 Pressure difference variation with pressure ratio at different valve openings





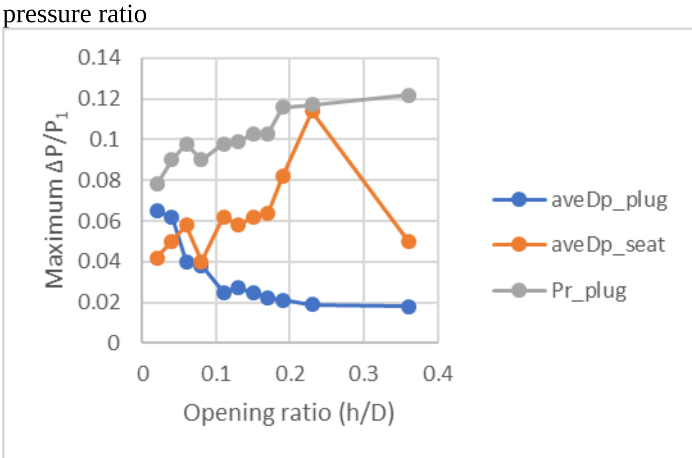




Pressure difference variation with pressure ratio at different valve openings are shown in graph 2. At small openings, the plug-side pressure difference has similar trends and similar amplitudes to the seat side. The peak value occurs at some place near the pressure ratio of 0.5 located in region C at most cases (at very small valve openings, such as h/D = 0.018, the peak pressure happens in region D). At an intermediate valve opening h/D = 0.192, the seat-side pressure difference is higher than that on the plug side. At large openings, which are located in region E, the plug-side pressure difference is very small at high pressure ratios, similar to all other openings. Then, as the pressure ratio is decreased, the plug-side pressure difference increases and reaches a constant value at a pressure ratio of about 0.7. At this opening, _ow diffuses in the seat passage after the throat. At pressure ratios between 0.65 and 0.85, asymmetric _ow happens in the passage after the throat, making the seat-side pressure difference much larger.

The maximum average pressure difference across the plug surface, aveDp_plug, its corresponding pressure ratio, Pr_plug, and maximum average pressure difference across the seat surface, aveDp_seat, are shown in Graph. 5.3 Maximum pressure difference and corresponding pressure ratio. As the valve plug travels to the fully open position, the maximum pressure difference in the plug side decreases. The seat-side pressure difference increases and reaches its peak value at about 0.23 h/D opening and then decreases. Because the pressure difference in the plug side causes hydraulic forces on the plug, for a venturi valve, smaller openings mean more possibility of valve failure when upstream pressure is constant. Compared with Fig. 8, the pressure curve shows that the maximum pressure difference happens in the lower part of region C in most cases except for very small openings such as h/D = 0.02. For very small openings, the maximum pressure difference happens in region D.

Graph 3 Maximum pressure difference and corresponding pressure ratio



XV CONCLUSION

M/s. BHEL Supplied LMW 210 MW turbo-generator Control Valves are dis-assembled, Cleaned and dimensions were checked. After that all dimensions were analyzed and accordingly as per equipment manufacturer provided guidelines, these were assembled back. Hence dimensional analysis on HP turbine Control Valves completed.

HP turbine bottom half control valves are found with steam passing may be chances to have valve seats contact area is not uniform due to foreign particles passing through the Valve seats. Expected these foreign particles may entered from the boiler welded chips or due to low quality of steam. Hence observed Steam passing through the control valves without opening.

As per planned shutdown, HP turbine control valve seats were inspected and found that valve seats had non-uniform contact area with dent marks. For this, Valve seats were replaced with new Valve Seats. This activity majorly involves Valve seats removal, Cleaning and assembly of valve seats. Thermodynamic analysis of control valve, assumptions and specifications. Experimental results on control valve mass flow rate. Flow regions and patterns. Flow asymmetry graphical representation

From above Valve seats findings and performing Valve seats replacement activity, Concluded the below:

- Foreign particles or chips or weld particles are passing through the boiler, Further these particles are entering into HP turbine through emergency stop valve and Control valves. Hence recommended that No particle is allowed inside the HP turbine.
- Operate turbo-generator as per the guide lines provided by original equipment manufacturer and accordingly maintain operating condition should be as recommended.
- Do not operate turbo-generator on more than allowed Overloading.
- It is recommended to check steam quality in the boiler. And make sure steam quality should be as per within the guidelines provided by original equipment manufacturer.
- Take proper precautions when boiler shutdown like blinding on pipelines to avoid foreign particles passing into the HP turbine.
- Conduct Baroscopic inspection on steam pipelines to ensure that No foreign particles present in the steam pipelines.
- It is recommended that do not operate turbo-generator when valves passing is higher, It leads to un-controlled speed. Further which damages the turbo-generator components.

XVI REFERENCES

[1] A handbook on the steam engine, with especial reference to small and medium-sized engines, for the use of engine makers, mechanical draughtsman, engineering students, and users of steam power (1902).

[2] http://archive.org/details/handbookonsteame00haeduoft

[3] Thermal engineering by R.K. RAJPUT.

[4] K. Sravanthi, M. Susmitha," MECHANICAL RUN TEST ON STEAM TURBINE", Volume: 03 Issue: 12 | Dec -2016 International Research Journal of Engineering and Technology (IRJET).

[5] Turbine Governing System: Types of Governing System Power Plant operation NPTI Publication BHEL manual CEGB Manual on power plant operation Power Plant.

[6] Maintenance and Overhaul of Steam Turbines, International Association of Engineering Insurers 38th Annual Conference – Moscow 2005.

[7] Turbine Governing System: Types of Governing System Power Plant operation NPTI Publication BHEL manual CEGB Manual on power plant operation Power Plant.

[8] Steam Turbines, Hubert Collins, First Edition, Second Impression.

[9] Steam Turbines, Hubert Collins, First Edition, Second Impression.

[10] Power Plant Engineering by Arora and Domkundwar, First Edition.