Dimensional Analysis of the Stop Valve of a Steam Turbine Governing System

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Abstract - *One of the most challenging tasks after installation of steam turbine is its maintenance. The safety of the steam turbine lies in preventing it from the leakage of steam and regulating it according to the type of load acting and the speed at which the rotor rotates. The governing system is employed which contains a control valve, stop valve and a governing console. The design parameters are to be taken into consideration to ensure the safe design of the stop valve. The stop valve is used as a part of governing system in the steam turbine to prevent the leakage of the steam. In this paper, the total lift considering the pre lift and the main lift along with the material to be machined in disc during protocol dimension adjustment are calculated.*

Key Words: **Steam turbine, governing system, control valve, stop valve, governing console, total lift, main lift, pre lift.**

1. INTRODUCTION

A steam turbine is a mechanical device that converts thermal energy in pressurized steam into useful mechanical work. The original steam engine which largely powered the industrial revolution in the UK was based on reciprocating pistons. Now, this has been almost totally replaced by the steam turbine because it has a higher thermodynamic efficiency and a lower power-to-weight ratio and it is also ideal for very large power configurations used in power stations. The steam turbine derives much of its better thermodynamic efficiency because of the use of multiple stages in the expansion of the steam. This results in a closer approach to the ideal reversible process. These machines are widely used for the generation of electricity in a number of different cycles, such as Rankine cycle ,Reheat cycle, Regenerative cycle, Combined cycle, The steam turbine may consist of several stages. Each stage can be described by analyzing the expansion of steam from a higher pressure to a lower pressure. The steam may be wet, dry saturated or superheated [1].

1.1 Steam Turbine Principle

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

2. Governing System

Governing System of Steam Turbines driving generators, blowers, compressors and pumps etc., play an important role in Steam Turbines operation. The reliability and availability of the equipment depends on the type of Governing System selection. For Continuous availability of these equipments, special attention is to be paid in respect of their maintenance by carrying out scheduled overhauling of main equipment and Governing System in particular[2]. The main purpose of the Governing System is to maintain:

1. Constant speed at variable loads.
2. Constant speed at varying steam inlet parameters.
3. Constant speed at varying extractions and exhaust steam parameters/conditions.

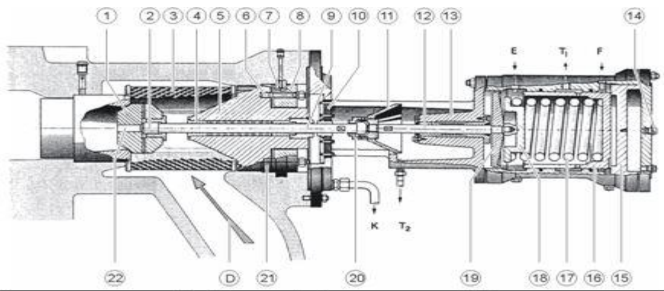
2.1 Parts in Governing System

The following parts constitute the assembly of the entire governing system, they are:

1. Control Valve Assembly
2. Stop Valve Assembly
3. Governing Console

2.2 Stop Valve Assembly

The emergency stop valve is the main shut-off element between the steam network and the turbine. It interrupts the steam flow to the turbine within the shortest of times. This is particularly important in the event of a malfunction. For steam turbines, being able to shut off the steam supply quickly and reliably is required. This is normally accomplished by stop valves which are usually installed in the inlet piping to the steam turbine or on the turbine shell. The valves are designed to be leak tight otherwise any steam leakage may keep the turbine turning at low speed after shutdown or causing an over speed because the valve did not close completely after a shutdown or trip [3].



Labeling of the parts of the Stop Valve Assembly	
1 Valve cone	12 Piston spindle K Leaking steam
2 Pre-stroke cone	13 Control block T1 Drain oil
3 Steam strainer	14 Pressure gauge port T2 Leaking oil
4 Guide bush	15 Test piston
5 Valve cover	16 Piston
6 Stud bolt	17 Compression spring
7 Segment ring	18 Spring plate
8 Disk D Steam inlet	19 Piston plate
9 Valve spindle E Emergency stop oil	20 Spindle lock
10 Thermal protection F Starting oil	21 Seal ring
11 Oil trap H Test oil	22 Hole

Fig -1: Assembly and details of the stop valve assembly

2.3 Structure of Stop Valve

The emergency stop valve consists of a steam part and oil part; both are connected to one another by an intermediate piece. The control block flanges onto the side of the turbine's inflow part. The steam part is sealed off to the outside by a valve cover (5). It is pulled against a seal ring (21) by stud bolts (6). It lies on a segment ring (7) and also on the inflow part. As soon as steam pressure acts on the valve cover, the seal ring is vigorously pressed against the outer case and is expanded. The steam forces acting on the valve cover are mainly transmitted directly to the inflow part of the turbine. In the valve cover, the valve spindle (9) is guided in two guide bushes (4). The steam end of the valve spindle on the steam side consists of a valve cone and it is connected in a frictional connection with the main cone .The other end of the valve spindle is connected via a spindle lock (20) to the piston spindle (12). The spindle lock additionally has oil trap (11) which collects oil leaking from the oil section and discharges it into the leaking oil line .The valve spindle bush is sealed effectively by the guide and labyrinth bushes. The guide bush on the steam side additionally features a sealing edge. When the emergency stop valve is open, the steam force acting in the direction of the oil part presses the valve cone with a sealing face intended for this purpose against this sealing edge. Leaking steam that escapes through the labyrinth bushes when the emergency stop valve is open is therefore ruled out . At the same time, the valve cone is prevented from rotating while the valve is open. Steam that leaks when the valve is closed is discharged in the area of the guide bush on the oil side into a leaking steam line 'K'. The oil part that is bolted onto the control block is the active part of the emergency stop valve. It is a piston that consists of two parts. One part is plate-shaped and is permanently connected to the piston spindle. The other part is bell-shaped and moves in the rounding cylinder. A compression spring (17), which moves on the one hand in the interior base of the bell-shaped part, and which on the other hand is supported via a spring plate (18) on the piston spindle, establishes the frictional connection between the two parts of the piston. Both parts are pressed against each other when emergency stop oil (starting oil F) flows behind the bell-shaped piston and moves it against the plate [4].

2.4. (A) Operating principle: Oil section

The emergency stop valve is opened hydraulically and is closed by spring force [5]. It is opened with the aid of the starting unit. To this end, emergency stop oil (starting oil F) is first routed to behind the piston. Overcoming the spring force, the piston moves in the direction of the piston plate and presses against it, forming a seal. Controlled accordingly by the starting unit, the Trip oil pressure E now builds up before the piston plate. While the pressure before the piston plate rises, the oil pressure after the piston slowly decreases again through solenoid valve. The piston plate and the piston jointly move to the end position before the test piston (12), thus opening the valve. On triggering of emergency stop, the trip oil pressure drops in circuit and thus will not be able to keep the spring in compressed position the spring release its stored energy hence piston plate become pressure less. The valve is abruptly closed by the compression spring. The remaining emergency stop oil flows into the spring area and further into the drain line T1, insofar as it does not already flow back into the inlet line. During this operation, the piston remains in the outer end position.

2.4. (B) Operating principle: Steam section

While the pressure before the piston plate rises, the oil pressure after the piston slowly decreases again through solenoid valve. Due movement of piston spindle along with the piston plate(disc) valve spindle is pulled up by pre lift value in valve cone assembly causing opening of steam passage(pos 22) for balancing of steam pressure in both side of the valve cone. Once the pressure is stabilized in both side of the valve cone the oil pressure is now able to open the valve cone against the high pressure of steam [6]. Further jointly movement of piston plate and piston to the end position of assembly open the stop valve completely. Drop in the trip oil pressure below 3kg/sq. Cm is not sufficient to keep the spring in its compressed position and the sudden release of stored energy in spring closes the stop valve in fraction of seconds.

2.5 Procedure for Stop Valve Assembly

Collect stop valve cylinder, intermediate piece & bottom flange from stores/ machine shop. Clean and remove sand patches from cylinder. Assemble all the parts and carryout hydraulic pressure test of stop valve cylinder at $16kg/cm^2$ for duration of 30 minutes. Dissemble all the parts and thoroughly clean cylinder. Inspect and measure the bore sizes of cylinder. Obtain the piston & tester piston size of stop valve as per fit and tolerance. Ensure the freeness of tester piston in the cylinder. Assemble the tester piston in the cylinder and cover it by bottom flange and tight the flange using stud and nuts. Ensure freeness of piston in cylinder and check color matching between stop valve cylinder and the main piston, if necessary. Place compression spring inside the piston. Cover the spring using spring seat. Place the disc and piston spindle assembly. Assemble intermediate piece and prepare for leak proof joint. Send the stop valve assembly for functional testing.

2.6 Assembly of Stop Valve in Top casing of the turbine

Firstly, inspection of the stop valves side bores and the other dimensions in the top casing. Secondly, obtain the assembly size of valve seat, segmental ring and valve cover as per fit and tolerances. Then, obtain the bushes size for valve cover and ensure that the bushes are inspected and finally cleared after material certification, special operation as nitriding, chromium carbide coating by plasma spraying, stress relieving, etc. Check the freeness and interference of bushes and assemble it, also check the freeness of valve spindle. Ensure that the lapping of stop valve seat with stop valve cone is in assembled condition also ensuring the lapping of valve spindle with valve cone and threaded ring. Record the pre-lift and maintain it as per drawing. Mount the intermediate piece and carry out stop valve protocol. Send the disc/square nut for machining as per protocol dimension adjustment. Assembling is done according to the above said parts.

2.7 Assembly Check Points of Stop Valve

1. Ensure thorough cleaning and deburring of all parts (cleaning to be done preferably by kerosene or cleaning agent)
2. Color matching between stop valve spindle to valve cone.
3. Color matching between valve spindle to threaded ring.
4. Color matching between shrink fit bush face to threaded ring.
5. Color matching between valve cone to its seating portion in top casing/ valve seat assembled in top casing.
6. Ensure freeness of piston and tester piston in cylinder.
7. After maintaining pre lift in valve cone assembly, ensure plate welding between valve cone & threaded ring.

2.8 Stop Valve Protocol

The main reason for stop valve protocol dimension adjustment is:

a. To maintain Pre lift ,main lift & float To avoid any damage of stop valve spindle during opening or closing of stop valve
b. To avoid any damage of piston spindle during operation of stop valve
c. To avoid damage of valve cone & valve seat during tripping of stop valve.

Pre lift is a linear free movement of stop valve spindle between valve cone & threaded nut for easy opening of stop valve with application of lower trip oil pressure compared to the high pressure of steam.

Main lift is the movement of valve cone assembly along with valve spindle to facilitate entry of steam inside the control valve (steam turbine) when the stop valve remains open.

Thus the total lift is calculated using the pre and the main lift.

2.9 Calculations of Stop Valve Protocol

To calculate the stop valve protocol we need to know the pressure and the temperature of the steam used. These values correspond to the power developed by the steam turbine.

Unit capacity (MW)	Steam Pressure (bar)	Steam Temp. /Reheat Temp. (°C)	Boiler Capacity (tone/hr)	Efficiency at generator terminals (%)
125	127	538/538	420-435	35.50-37.50
250	176	565/565	820	38.95
250	306	600/565	788	40.05
350	169	566/566	1157	39.80
500	246	538/538	1770	40.00
600	246	538/566	1900	40.30
700	246	538/538	2500	40.30

Fig -2: Steam Condition and Thermal Efficiency

The following calculations are done considering the values corresponding to a steam turbine producing 125 MW of power [7].

Steam Temperature Main / Reheat Steam	Variant 1 540°C / 540°C	Variant 2 566°C / 566°C	Variant 3 600°C / 600°C
Rotor (50Hz or 60Hz)	low alloyed	low alloyed or high alloyed	high alloyed
Inner Casing	low alloyed	low alloyed	high alloyed
Outer Casing	globular cast iron	globular cast iron	globular cast iron
Valve Casings	low alloyed or high alloyed	low alloyed or high alloyed	high alloyed

Fig -3: Materials used for the type of casing and the relation between the steam temperature and its variants

The different types of materials used for the different sets of temperature variations is also taken into the consideration while designing the stop valve for the durability with the ease in availability and the low cost of the material [8].

The following are the abbreviations of the terms used in the calculation of total height (H1) and the material to be machined (X).

F/O - Full open dimension

F/C - Full close dimension (c)

D/T- Free movement of disc

a - Dimension from cylinder top face to piston top face

H1 – Total lift

H2 - Pre lift

H3 - Main lift

Float - Difference between full open dimension & disc free movement dimension

X - Material to be machined in disc during protocol dimension adjustment

Formulae - H1 = H2 + H3 + (FLOAT)/2
X = H1+C-a

Stop Valve Protocol for w.o. no-1-0-193-044-00 [9]

F/O=143.80 mm

D/T= 137.80 mm

F/C = 62.70 mm

H2 = 7.70mm

'a' dimension =132.10 mm

Float = 6.00 mm

H3 = (D/T)-(F/C + H2) =137.80-(62.70+7.70) =67.40mm
H1 = H2+H3+ (FLOAT)/2

= 67.40+7.70+3.00 mm

= 78.10 mm

X = H1+C-a= 78.10+62.70-132.10 = 8.70mm

Disc initial thickness=45.20mm

Disc final thickness =disc initial thickness-X

=45.20-8.70

=36.50 mm

Thus the total lift is 78.10 mm and the material to be machined in disc during protocol dimension adjustment is 8.70 mm.

3. CONCLUSIONS

Thus the functioning of the stop valve takes place in a proper way at variable loads. In addition to it, minimum clearances provided to the piston and cylinder are strictly followed to meet the requirements of the output. The failure of stop valve is vanquished by the proper design parameters while conducting the functionality test. The safe design is produced to prevent the leakage of steam for the safety of the workers.

ACKNOWLEDGEMENT

This research was supported by BHEL, Ramachandrapuram Hyderabad, Telangana. We are also grateful to Eswar Prasad (BHEL) for assistance and Nagarjuna Kumma (VLITS) who moderated this paper and in that line improved the manuscript significantly.

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