MODIFICATION AND ANALYSIS OF GLOBE VALVE USING COMPUTATIONAL FLUID DYNAMICS

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Abstract: The aim of this paper is to determine and analyze the flow characteristic through CFD for Globe valve and to decrease losses inside the present valve and increase mass flow rate. To this aim, the flow path inside the valve is modeled and flow is analyzed to determine the flow characteristic which is quite accurate and reliable. The analysis results thus obtained could be used design the shape of the physical path of flow, which could improve the flow characteristic and optimize the valve design.

In the present study, CFD analysis of a specific SPIRAX-TROL fully opened globe Valve LE 31 DN 50 design has been carried out to understand its performance and reliability during the high pressure flow of steam. The control valve mass flow rate or Kv was experimentally measured and numerically predicted. The equal percentage (E) Globe valve was represented in the study. The numerical (simulation) study presented in this showed that the valve Kv and the inherent valve characteristic could be accurately predicted using symmetric flow model. In addition, the study demonstrates the usefulness of simplified CFD analysis for relatively complex 3-D flows. The analyses have been performed by applying the commercial computational fluid dynamics (CFD) code, CFX, to obtain the solution of the flow field through a globe valve.

***Keywords* - Computational Fluid Dynamics (CFD), Globe control valve, Mass flow rate, Pressure drop ratio**.

1. INTRODUCTION

Valve control the fluid flow and pressure in a system or a process. The selection of their types, design and material plays a vital role in the performance and reliability of any system. A number of researchers have experimented and analyzed valves for all its parts, fluid types, operating parameters, discharge coefficient and have improved the valve technology. Now, with the emergence of robust computational fluid dynamics (CFD) tools and

powerful computers, the analysis of valve performance, and thus the job of designing valves to suit a particular application can be done much faster. Control valves are used throughout in many process industries for controlling volumetric flow rates. One of the most common types of control valves is the single seat globe valve. It consists of three main components: body, trim, and actuator. The body of the valve houses the trim, which is made up of the plug and seat, and the actuator positions the plug. Past design strategies have relied heavily on experimental and to a lesser extent analytical techniques to analysis of valve. More recently, designers of fluid handling equipment have begun using Computational Fluid Dynamics ~ CFD! for product development and

optimization. In this work control valve design tools were developed which utilize the technology of CFD. In particular, simplified analyses are used that would be more useful for smaller companies having fewer R & D resources [1]. Globe valves are frequently used for control applications because of their suitability for throttling flow and the ease with which they can be given a specific 'characteristic', relating valve opening to flow. The typical globe valve is shown in Figure 1. An actuator coupled to the valve spindle would provide valve movement.

The major constituent parts of globe valves are:1) The body, 2) The bonnet, 3)The valve seat and valve plug, or trim, 4) The valve spindle (which connects to the actuator), 5) The sealing arrangement between the valve stem and the bonnet. Figure is a diagrammatic representation of a single seat two-port globe valve. The difference in upstream pressure (P1) and downstream (P2) of the valve, against which the valve must close, is known as the differential pressure (DP).

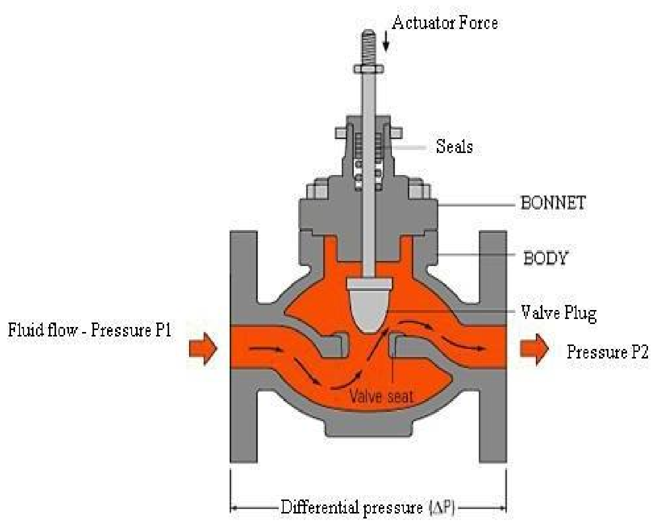


Fig. 1 Flow through two-port globe valve[6]

Overview of SPIRA-TROL globe control valve [7]

The Spira-Trol Globe Control valves are general purpose control valves that can be engineered to solve both complex and basic requirements. Its robust construction makes them long-lasting and easy to maintain, while its modular design makes it easy to specify, reducing spares inventory requirements. SPIRA-TROL is a range of two-port single seat globe valves with cage retained seats. When used in conjunction with a pneumatic actuator they provide characterized modulating or on/off control.

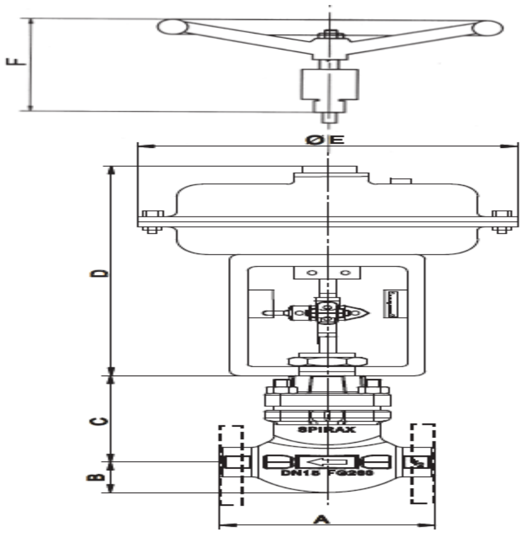


Fig.2 Overall dimensions of SPIRA-TROL valve with actuator [8]

VALVE SIZE	A	B	C
DN 50	230	80	132

Valves need to be measured on their capacity to pass fluid. To enable fair comparison, valves are sized on a capacity index or flow coefficient “Kv”.
Kv= Flow rate in m3/hr of water at a defined temperature, typically between 5oC and 40oC, that create pressure drop of one bar across a valve orifice. here, Kv value of SPIRAX-TROL globe Valve LE 31 DN 50 is 36, taken from Technical information sheet of Spirax Marshall Ltd.

2. SIMPLE SIZING ROUTINE FOR GLOBE VALVES IN STEAM SERVICE [6]

The flow and expansion of steam through a control valve is a complex process. There are a variety of very complex sizing formulae available, but a pragmatic approach, based on the 'best fit' of a mathematical curve to empirical results, is shown in following Equation. For globe valves throttling saturated steam .

$$\dot{m}_s = 12\,K_v\,P_1\sqrt{1-5.67\,(0.42-x)^2} \quad \text{Equation 1}$$

Where: ms = Mass flow rate (kg / h) Kv=Valve flow coefficient (m^3 / h bar) P1=Upstream pressure (bar)

x= Pressure drop ratio = (P1-P2)/P1 P2=Downstream pressure (bar)

Here, Kv for DN 50=36, P1=2.5bar, P2=1.5bar, x=0.4

$$\dot{m}_s = 12 \times 36 \times 2.5\sqrt{1-5.67\,(0.42-0.4)^2}$$

$$= 1078.77 \text{ kg/hr}$$

For further CFD analysis, this flow rate is used as a reference flow rate.

3. MODEL FOR FLUIDIZATION STUDY

a. Simulation Model of Present Valve.

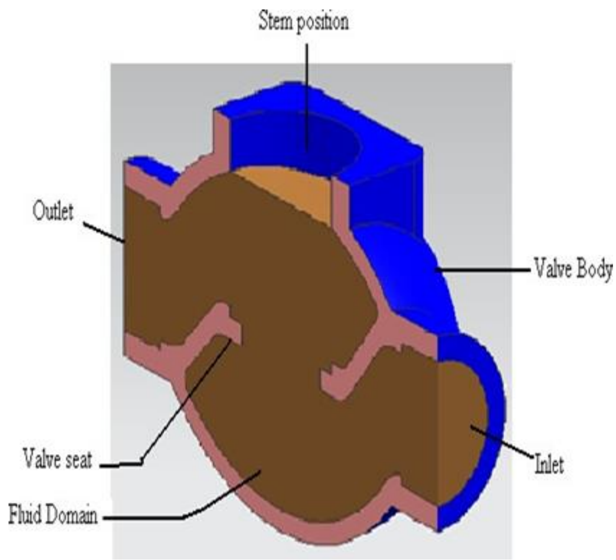


Fig.3 Symmetry section of 3-D DN50 valve body, with fluid domain

Fig.3 shows model geometry which is filled with fluid known as fluid domain.

B) Computational model:

Fig.4 shows symmetric Geometry with valve plug cavity and upper port for stem and plug is closed while preparing fluid domain, because we focused on fluid flow path which is used for ANSYS CFX analysis.

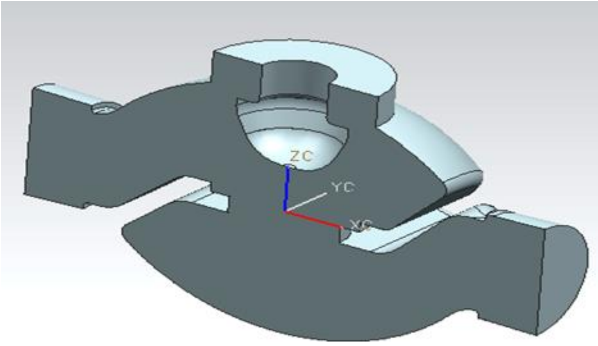


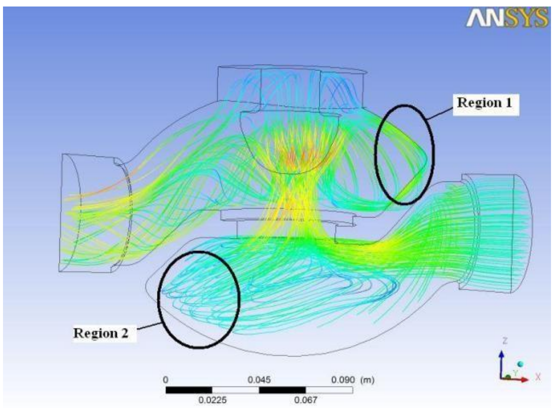
Fig.4. Geometry with valve plug cavitySteam Properties:

Saturation temp. =139.023 ^{0}c
Sp.Enthalpy of steam (hg) = 2.7326E06J/kg
Density of steam=1.9142kg/m^3
Sp.volume of steam (Vg) =0.5224m^3/kg
Sp.entropy of steam (Sg) =6939.49J/kg
Sp.Heat of Steam (Cp) =2227.03J/kgK

Note: All values are taken from a case study Packaged Plant Room System (PPRS) For Hot Water generation.

4. DOMAIN DEFINITION AND BOUNDARY CONDITION

The simulation of control valve was performed using ANSYS CFX 12. The k-epsilon Model was applied in order to simulate fluid flows. Domain consists of one fluid Steam-continuous fluid throughout the domain. Boundaries are defined as according to locations viz. Inlet, Outlet, Wall, and Symmetry.



I.CFD post: Result for Present SPIRA TROL fully opened Globe Valve -:

Table 1.Details of Boundary Conditions: Boundary Physics

Domain	Boudary – in	
Default Domain	Type	INLET
	Location	IN
	Settings	
	Flow Direction	Normal to Boundar Condition
	Flow Regime	Subsonic
	Heat Transfer	Total Temperature
	Total Temperature	139.023 [C]
	Mass And Momentum	Mass Flow Rate
	Mass Flow Rate	2.9966e-01 [kg s^-1]
	Turbulence	Medium Intensity and Eddy ViscosityRatio
	Boundary - out	
	Type	OUTLET
	Location	OUT
	Settings	
	Flow Regime	Subsonic
	Mass And Momentum	Average Static Pressure
	Pressure Profile Blend	5.0000e-02
	Relative Pressure	1.5000e+00 [bar]
	Pressure Averaging	Average Over Whole Outlet
	Boundary WAL	
	Type	WALL
	Location	WALL
	Settings	
	Heat Transfer	Adiabatic
	Mass And Momentum	No Slip Wall
	Wall Roughness	Rough Wall
	Roughness value	25micron
	Boundary-Symmetry	
	Type	Symmetry
	Location	Symmetry

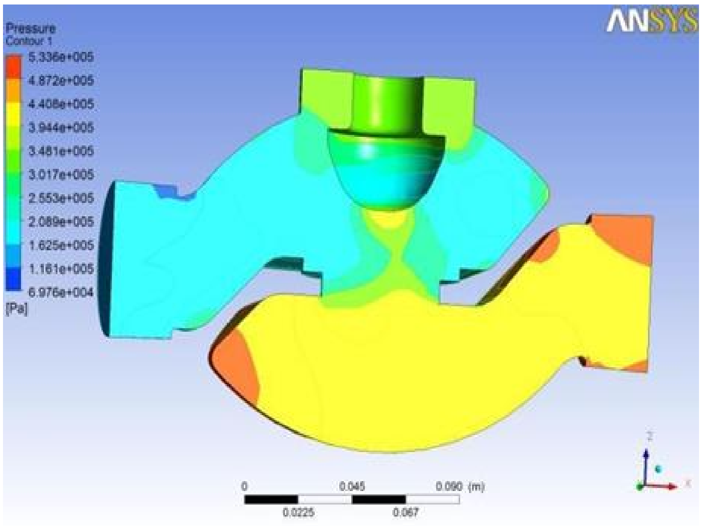


Fig.5 Pressure contour for present valve

In this CFD POST for Present SPIRA TROL DN 50 globe control valve, for all boundary conditions which are mentioned in table 1,gives INLET Pressure P1=4.8849bar.in FUNCTION CALCULATOR. We can calculate (PD) Pressure drop as (P1-P2) i.e.

4.8849-1.5 =3.384 bar.Kv=36.Using this PD we got Mass flow rate by Eqn.1 So, mass flow rate become 1600 kg/hr.

Fig.6 Showing Eddies at Region 1 and Region 2 in present valve.

The present fully opened globe valve Fig.6 shows unwanted eddies in two region viz. Region 1 which at above the valve seat and Region 2 which is at below the valve seat. By modifying flow domain and hence present valve body which minimizes the eddies in the flow region we can increases the mass flow rate through the same DN50 control valve as shown in next topic.

5. MODIFIED MODEL OF SPIRA-TROL DN50 GLOBE CONTROL VALVE.

Fig.7 shows complete Geometry as same with INLET, OUTLET, AND VALVE SEAT Diameter i.e. DN 50.but, some modification of flow domain.

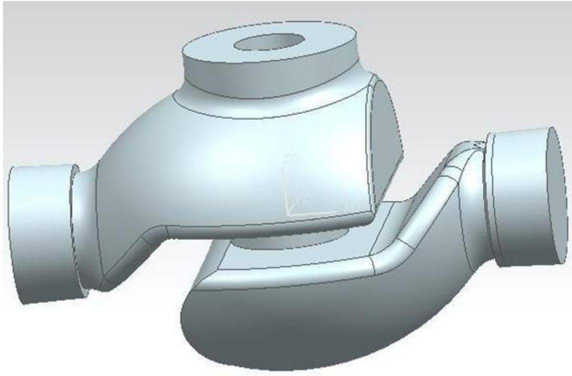


Fig.7 Complete Geometry with modification.

Fig.7 shows modified DN 50 Valve body where Flow of fluid open to valve seat from inlet of valve which minimizes eddies at Region 2 due to aerodynamic nature of flow and flow open the outlet zone after valve seat which minimizes eddies at Region 1.

Computational model:

Fig.8 indicates the modified symmetric Geometry with meshing which is used for ANSYS CFX analysis

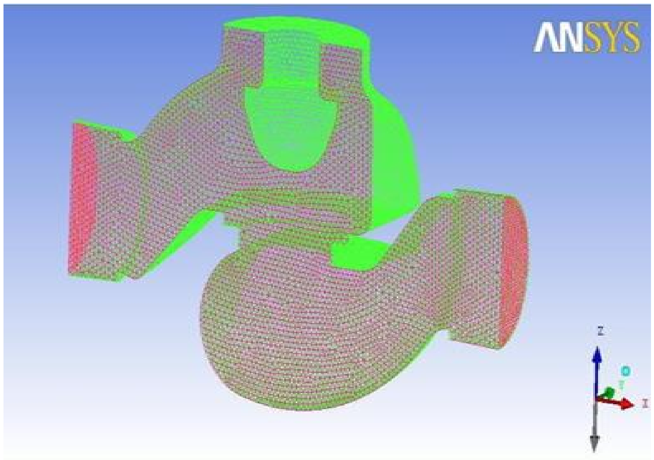


Fig.8 Modified Geometry with meshing

As in this Modification II) Steam Properties and III) Domain definition and Boundary Condition are taken as same which are used in Present Control valve. This is helpful to compare in CFD POST results, computed mass flow rate between both valves.

6. RESULT AND DISCUSSION

CFD post: Results for Modified SPIRA TROL Globe Control Valve:

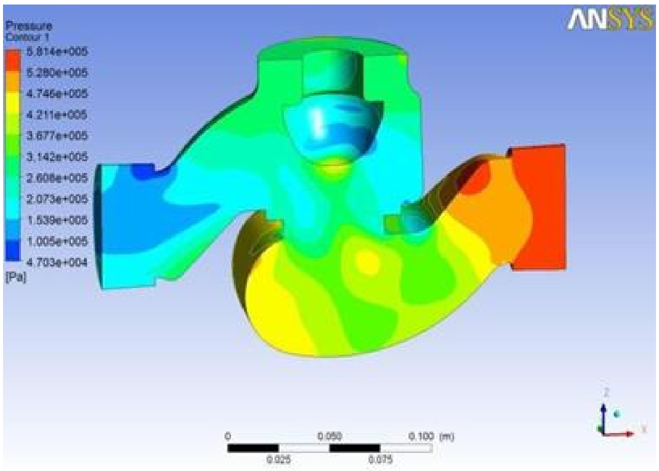


Fig.9 Pressure contour of Modified Valve

In this CFD POST for Modified SPIRA TROL DN 50 globe control valve, for all boundary conditions which are mentioned in table1, gives INLET Pressure P1=5.4060 bar in FUNCTION CALCULATOR. We can calculate (PD) Pressure drop as (P1-P2) i.e. 5.4060-1.5 = 3.906 bar with Kv=36. Using this PD we got Mass flow rate by Eqn.1 is 1620 kg/hr.

7. CONCLUSION:

The Result of this analysis is modified valve gives 20Kg/hr maximum mass flow rate through same DN50 compared to present DN50 valve. With modification it satisfies customer increasing demand and save his money. The money that customer lost to satisfy slight increase in the demand of mass flow of steam for Steam system Heat exchanger or any other application this reason lead to shift choice of valve from DN50 to DN 80 and finally increases in flange size, increase in inlet pipe size, out let pipe size ,weight and overall cost of process.

8.References

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