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Design and CFD Analysis of Globe Valve

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Abstract— Stop valves are commonly used as fluid flow equipment in many of the engineering applications and Globe Valve Are Used as Regulating or Isolation Equipment in many pipe lines thus it is more important to know the flow characteristics of the valve. With the help of flow simulation and numeric technique, it becomes possible to observe the flows of valves, here we developed a method to obtain the plug design profile required to have desired flow. In this study CFD simulations will conducted to observe the flow patterns and to measure valve flow co-efficient when globe valve with different flow rate and constant pressure drop across the valve were used in a system. In industries it is essential to have accurate and perfect control on the flow of medium at various operations as per requirement for efficient output. This can be achieved by the accurate valve sizing and accurate plug design as per required flow characteristics.

Keywords— Globe valve, valve coefficient, CFD, Control valve, flow characteristics

INTRODUCTION

Definition of valve

A valve is a mechanical device that controls the flow of fluid and pressure within a system or else in Process. A valve controls system otherwise process fluid flow and pressure by performing any of the following functions. stopping and starting fluid flow, varying (throttling) the amount of fluid flow, controlling the direction of fluid flow, regulating downstream system or process pressure, relieving component or piping over pressure. They are important components of a piping system that conveys liquids, gases, vapours, slurries etc. different types of valves are available: gate, globe, plug, ball, butterfly, diaphragm, Qcnrv, check, pressure relief, control valves etc. Each of these types of valve has a number of models, each with different features and with functional capabilities. Some valves are self-actuated while others manually or with an actuator pneumatic or hydraulic is operated. Regardless of type, all valves have the following basic parts: the body, bonnet, trim parts, actuator, and packing.

Globe valve stands out among all due to fully closing and throttling purpose, short opening and less closing time due to shorter stroke of travel, etc. all these possible due to the provision of plug's geometry shape, which not only gives us accurate flow control but gives a chance to obtain various flow characteristics.

Globe valve has three inherent flow characteristics [2]

A) Linear characteristics
B) Equal percentage characteristics
C) Quick opening characteristics

Plug Design

Above mentioned characteristics of valve is heavily depend on plug's geometry. The shape of the plug is designed after consideration of pressure drop across it, flow rate, property of fluid used, etc. and after mathematical and fluid dynamic solution.

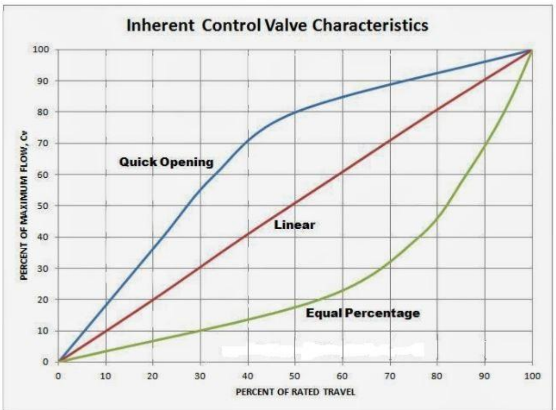


Figure 1: Flow characteristics

The relation between flow rates through valve as the stem of the valve travels from 0 to 100% full close to open condition. There are mainly two characteristics. Installed Characteristics and Inherent flow characteristics.

A) Inherent flow characteristics: Defines the theoretical relationship between valve opening and flow rate condition under constant pressure drop.

i) **Linear characteristics**: With lift of plug flow rate increases linearly so it's called linear characteristics.

ii) **Equal percentage:** These valves have desired plug design so each increment in stem travel lift increases flow rate linearly by certain percentage of the previous flow ,provide a precise throttling control of flow.[Figure 1]

iii) **Quick opening:** small opening of valve gives a large change in flow rate for a small valve lift from the closed position.

Co efficient of flow: The flow coefficient of a device is relative measure of its efficiency at allowing fluid flow. the flow coefficient Cv is the volume of water at 60° F that will flow per minute through a valve with a pressure drop of 1 psi across the valve.

$$\boldsymbol{C_v = Q\sqrt{\frac{SG}{\Delta P}}}$$

Here,

Q = Rate of flow (US gallons per minute)

SG = Specific gravity of the fluid

ΔP = Pressure drop across the valve

I. DEFINITION OF PROBLEM

Typical problems faced in the industry with present design Globe valves are; higher valve torque due to the high thrust force acting on the plug, difficult manual operation, stem bending problems is well known in stainless steel material, the high frictional forces at the threads of stem and yoke sleeve collar faces leads to high torque and shortens valve life, rotating stem design decay the packing performance at fewer cycles, improper selection of yoke sleeve and stem material resulting in galling, stem binding due to galling with the mating components, gland packing leaks not meeting fugitive emission requirements of valve galling of flange bolts and gland packing eyebolts at low temperature, threaded seat ring design leaks at high pressure**.** Problem discussed in this paper is difficulty in manual operation and controlling flow of fluid. Steps carried out to overcome the problem-Identification of problem, Problem statement, Solid modeling, Flow analysis using CFD software to find Cv, selection of appropriate model or trim from CFD results, Valve types are used to describe the mechanical characteristics and geometry (Ex/ gate, ball, globe valves). We will use valve control to refer to how the valve travel or stroke (openness) relates to the flow.

II. OBJECTIVE OF STUDY

In this work, problem presented is of modifying the existing plug and seat arrangement of the globe valve, such that it should control the flow of fluid up to maximum permissible lift ranging from 5 mm to 40 mm to obtain the optimum range of fluid flow. The current plug and seat arrangement of globe valve is according to quick opening characteristics. For small lift of plug gives large flow. The main objective of this work is to analyze the plug and seat arrangement using Computational Fluid Dynamics to obtain proper flow control of fluid in given range of lift of plug. The inputs given are inlet pressure of about 51 bar and total pressure drop across the valve is 2 bar.

III. SOLID MODELLING OF PLUG AND SEAT

To perform CFD analysis of any component, the solid model of the same is essential. A DN80 ASME class 300 globe valves with different internal trim parts and mainly three different types of plug design shape were modeled in Creo 3.0. Individual assembly was made for simplicity and desired flow analysis.

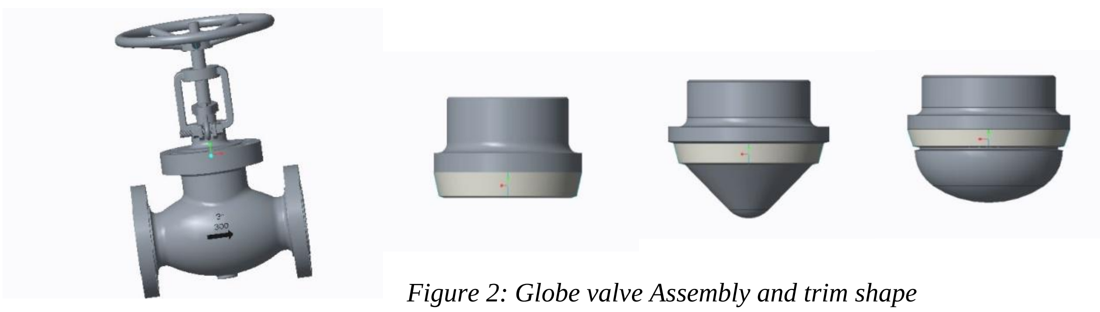


Figure 2: Globe valve Assembly and trim shape

IV. COMPUTATIONAL FLUID DYNAMICS

For doing the flow analysis on this model, there is a requirement of a CFD tools. It uses numerical methods and algorithms techniques to solve and analyze problems with fluid flow using the governing equations and the boundary conditions which is specified. For this work ANSYS Fluent was used to analyze the problem.

Methodology

The assembly files from CAD software Creo 3.0 was converted into IGES and imported into design modeler of CFD. The fluid domain created in it, took the shape of the entire void. The meshed volume of fluid domain is as shown in Figure 3. The gap between the trim surface and valve seat had a very fine mesh which was necessary to capture accurately the flow through that narrow region.

Boundary Element Method

The boundary element method as integral equations. It can be applied in wide areas of engineering and science including fluid mechanics, electromagnetic, acoustics, and fracture mechanics. The integral equation may be regarded as an exact solution of the governing partial differential equation. The boundary element method use the given boundary conditions to fit boundary values into the integral equation, rather than values throughout the area defined by a partial differential equation. Once it’s done, in the post-processing stage, the integral equation can be used again to calculate numerical solution directly at any desired point in the interior of the solution domain. The boundary element method is more efficient than other methods, including finite elements, in terms of computational resources for problems there is a small surface/volume ratio is taken. Conceptually it works by constructing a "mesh" over the modeled surface domain. However, for many problems boundary element methods are less efficient than volume discretisation methods. This, means that the storage requirements and computational time will tend to more according to the square of the problem size. By contrast, finite element matrices are typically banded and storage requirements for the system matrices grow quite linearly with the problem size wich are selected. Compression techniques can be used to boost these problems, though at the cost of added convolution and with a success-rate that depends heavily on the nature of the problem being solved and the geometry is involved.

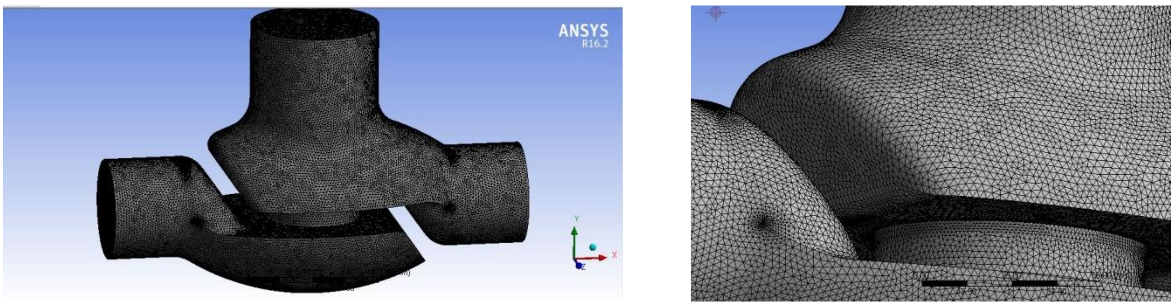


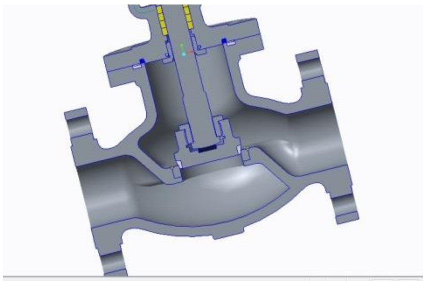
Figure 3: Fluid Domain Meshing

V. CFD FLOW ANALYSIS

In this section different solid Creo models and profiles of plug and seat are explained and these models then assembled in globe vale. These assemblies are then checked on CFD to calculate velocity for each 10 mm lift. From this velocity Cv (discharge) for each 10 mm lift is obtained. Total four trails are conducted for each different model. Total travel of plug is 40 mm.

Trial 1. For flat plug and seat diameter 76 mm

Solid Model of plug is shown in Fig.4
CFD: boundary conditions (common to all trials)
Inlet condition- 51 bar
Outlet condition-49 bar
Solution- outlet velocity
Q=Area × Velocity



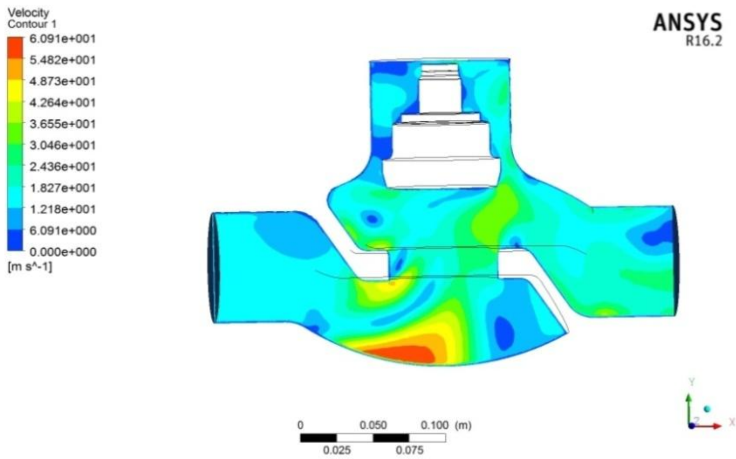


Figure 4: Trial-1 Flat Plug design

Figure 5: CFD result trial-1 velocity contour

SR NO	LIFT (mm)	OUTLET VELOCITY	DISCHARGE (Q)M^3/hr
1	10	3.2	52.2
2	20	14.98	244.5
3	30	16.79	274.1
4	47	18.32	299.0

Table 1: CFD result of trial-1

Trial 2. For round plug and seat diameter 76 mm

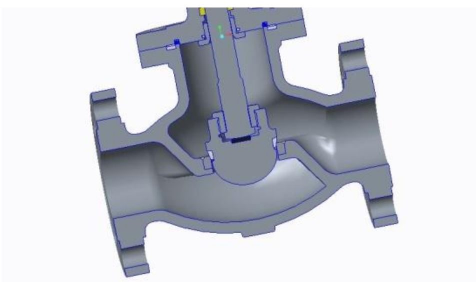


Figure 5: Trial-2 round Plug design

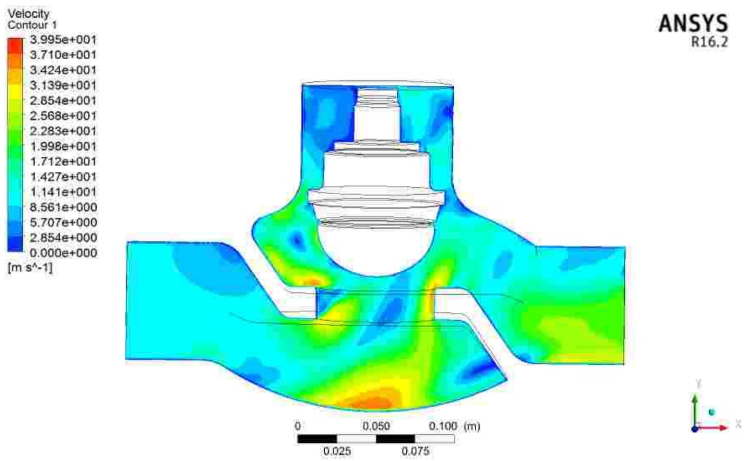


Figure 5: CFD result trial-2 velocity contour

SR NO	LIFT (mm)	OUTLET VELOCITY	DISCHARGE(Q)M^3/ hr
1	10	2.4347	39.74
2	20	3.03	49.46
3	30	6.11	99.73
4	47	17.99	293.65

Table 2: CFD result of trial-2

In Table 1 for each 10 mm lift outlet velocity and discharge is obtained. (Common to all trials)

Trial 3. For conical plug and seat diameter 76 mm

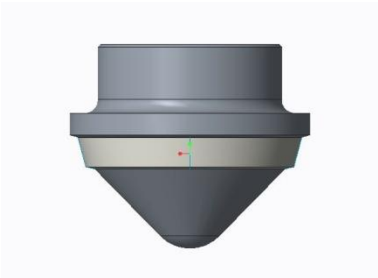


Figure 5: Trial-3 Conical Plug design

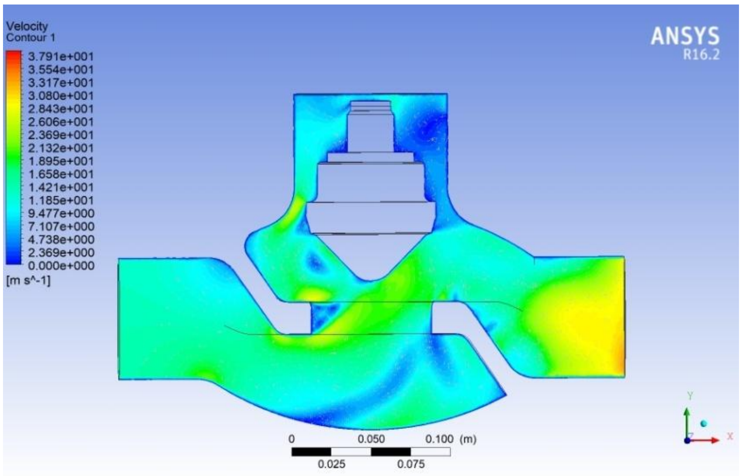


Figure 7: CFD result trial-3 velocity contour

SR NO	LIFT (mm)	OUTLET VELOCITY	DISCHARGE(Q)M^3/hr
1	10	2.009	32.79
2	20	6.5	106.10
3	30	12	195.88
4	47	18	293.81

Table 3: CFD result of trial-3

Fig.8 shows the comparison of different curves for each trial. It is graph plotted between lift and discharge.

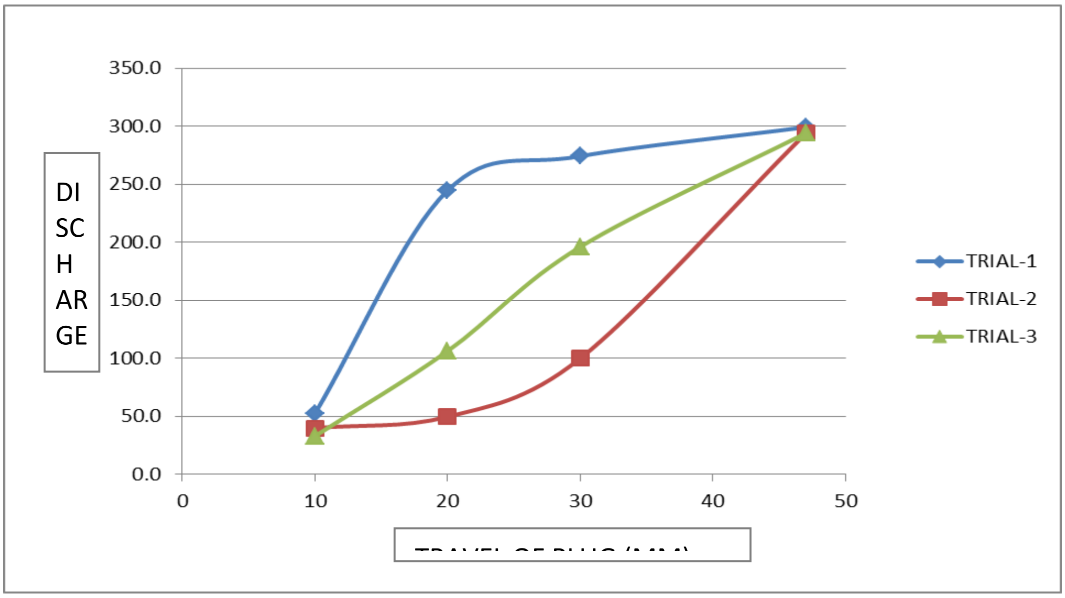


Figure 8: Discharge VS Lift Characteristic curve

VI. RESULTS AND DISCUSSION

Comparing the above generated curve figure-8 with flow characteristics curve figure-1

It is seen that for trial-1 during the lift of 10 mm to 47mm (full opening) discharge is vary from 52.2 m^3/hr to 299 m^3/hr, From 10 to 20 mm approx 50% of opening discharge is quickly increasing **for** trim shape 1. The curve for trim shape 1 shows an initial rapid increase in the flow for less percentage of valve openings. After 50% valve opening there is very slight change in the flow with increase in lift. Thus valves with this type of trims installed tend to show a fast opening characteristic. They find their use in On-off control applications. For trim shape 3, the rate of increase in flow rate is directly proportional to the opening of the valve. Hence it can be used Where linear valve characteristics are required. A typical application for such characteristics can be process where constant pressure drop is expected for different flow rates. From graph it is noted that valves with parabolic trim shapes -2 are slow opening valves i.e. they show a very less change in flow rates for initial increase in lift. Owing to this fact such trims can be used for low flow rate applications and where control output stability is of prime importance.

VII. CONCLUSION

CFD analysis is performed to analyze the effect of shapes of trim part (plug) and seat on the flow. From the analysis it is observed that for quick opening valve, trial 1 set can be used. For linear opening valve Trial 2 set can be used. For control valve, trial 3 set can be is proposed from which it seen that when lift varies from 10 mm to 20 mm, the discharge increases from 39.74 m^3 /hr to 49.46 m^3 /hr, hence it is concluded that the control of fluid obtained is approximately matches the equal percentage curve. In this work , flow co-efficient Cv one of the important factor for valve sizing was determined for varieties of trim shape using CFD tool. The discharge and flow co-efficient was calculated for different trim shape.

it also showed that trim shape with equal percentage characteristics have tendency of low flow rates at the start and overall has less discharge capacity for same lift as compared to valve with linear characteristics. This work also shows that CFD techniques can be implied for checking various valve flow characteristics performing a lot of virtual iterations thereby providing improvement in the accurate designing of valve trims for specific requirements.

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