ORIGINAL ARTICLE

CHARACTERIZATION OF QUICK OPENING CONTROL VALVE FOR PROCESS FLUID THROTTLING APPLICATIONS

K.Vidyasagar[1], G.Venkata Hari Prasad[2],
K. Sudharani[3], K.Vijay Chandra[4]

[1] Professor, VNR Vignana Jyothi Institute of Engineering & Technology, Vidyasagar_k@vnrvjiet.in
[2] Professor, CMR College of Engineering & Technology, drgvenkataharipriprasad@cmrcet.ac.in
[3] Assoc. Professor, VNR Vignana Jyothi Institute of Engineering & Technology, Sudharani_k@vnrvjiet.in
[4] Asst. Professor, VNR Vignana Jyothi Institute of Engineering & Technology, Vijaychandra_k@vnrvjiet.in

ABSTRACT **Background:** Control valve is the significant component in closed loop process control applications. The loop performance is impacted by the control valve. The ideal characteristics will differ from installed characteristics. The valve should exhibit the Ideal characteristics with no external load influences. This paper considered quick opening trim valves. The valves are ¾ inch size operating with quick opening trims. The fluid throttling through the control valve is recorded with varying suction head pressure. The fluid flow rate at 100 percent open is estimated as2.201 for quick opening control valve. With varying input signal to the actuating element of the control valve, the inflow rate, outflow rate, upstream and downstream pressures, valve capacity (CV) are computed, and the differential pressure developed across the control valve is characterized. Fluid velocity is also estimated across the control valve. With the results achieved quick opening control valves, these valves are reliable for tight shutoff applications.

Key words: Control valve, ideal characteristics, Fluid flow rate, Upstream pressure, downstream pressure, valve capacity, fluid flow velocity.

Address for correspondence: Professor, VNR Vignana Jyothi Institute of Engineering & Technology, Vidyasagar_k@vnrvjiet.in

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INTRODUCTION

In Process applications, to regulate the fluid flow, for throttling the process fluid and to cease the fluid flow a mechanical control valve is imperative. Typical Valve is shown in Fig.1. Is designed using pipe data-Pro 14.0 ASMEB16.10 flanged valves. The fluid enters through the upstream port and leaves through the downstream port. The valve plug seated into the valve seat is labeled as 100 percent closed.

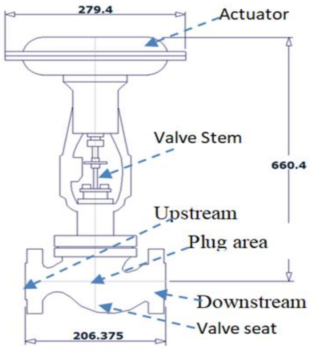

Fig1.1. Typical Control Valve

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The Actuating signal is applied at the bottom side of the actuating element (diaphragm) since the valve is normally closed valve. With increasing actuating signal ranging between 3Psi to 15 Psi, the valve stem is travel from fully closed to fully open.

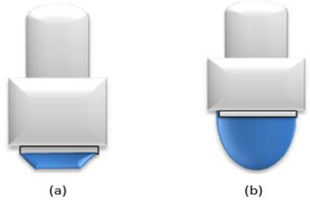

Fig.1.2(a) Quick Opening Valve PLUG
Fig.1.2(b) Linear Valve plug

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The plug is attached to the Valve stem which will lift the plug to allow the fluid to throttle through the valve body. The performance and characteristics of the control valve are influenced by the shape of the valve plug.

Control valve flow characteristic curve is determined by the amount of valve stem travel to the corresponding flow of fluid through the valve. The valve is testing on bench i.e in testing laboratory; exhibiting characteristics are labeled as Ideal or flow lift or inherent characteristics of a control valve. The valve opening percentage against maximum flow coefficient represents the inherent characteristics of a control valve. The flow coefficient (Cv) is estimated with varying stem position. Quick opening type of valve plugs are deliberated during experimental process.

With quick opening valve, small valve stem travel results maximum amount of fluid is throttling through the Valve body. To produce rapid maximum flow, specifically for emergency shut off applications quick opening control valve is a good choice. In process applications, the total pressure drop is much influenced by the control valve, and then linear valve plug is a good choice. The Valve plug may produce constant pressure drop across the control valve. The response of the control valve is consistent only under constant deferential pressure. The valve coefficient and volumetric flow rate of the fluid is estimated with varying stem positions.

VALVE PARAMETER ANALYSIS

Quick opening control valves isconsidered. The pipe cross sectional area and fluid flow cross sectional area of control valve is imperative to determine 100 percent opening of a control valve.

Area of cross section of a pipe or upstream port of a control valve $A_{UP} = (\pi /4)\, d^2$ Eq1

Area of cross section of a control valve for fluid flow $A_{CV} = (\pi /4)\, d_{cv}^2$ Eq2

The percentage of valve opening is represented as

$CV_o = A_{CV} / A_{UP} = (d_{cv} / d)^2 \times 100$ Eq3

The process fluid moves in a control valve through reduced area, so the flow of fluid is contracted. The minimum cross sectional area of a control valve is considered i.vena contracta. The upstream and downstream of this vena contracta will differ the flow process. The flow process changes at center line are very small, hence the flow changes at elevation are neglected. The flow passage area of the control valve is significant because the flow velocity is dependent with flow passage area of the control valve. The relationship is inversely proportional. The flow velocity will increase inversely proportional to the fluid passage area of the control valve. The fluid flow velocity is estimated across the control valve.

The Fluid Pressure is dropped to minimum level at the point of restriction and at which the velocity of the fluid is increased to a maximum level. The process fluid at downstream of Vena contracta is not same at several pipe diameter from the downstream. The Velocity and pressure of the fluid can be recovered when the upstream pipe diameter is same as the downstream diameter. Significant drop in pressure across the restriction of process fluid flow, results specific amount of heat energy is loss and subsequently internal energy is loss. More restriction results more loss of both internal and heat energy. This loss is directly proportional to square of the velocity of fluid flowing through the constrictive area of a control valve. This can be represented in eq.4.

$H = C \times \rho V^2 /2$
Eq.4

Where ‘C’ is head loss coefficient.
The head loss is considered very small when the Control valve is 100 Percent open. When valve is fully open than the actual fluid flow, the head loss is imperative.
The head loss coefficient is estimated using Eq. 5
$C = h_l (2g / V^2)$ Eq.5

Where h_l = height of the control valve from the reservoir.
The Coefficient of the control valve is represented as
$C_v = A_2$ Square root of $(2/ \rho_{water} \times K_I)$
Eq.6
The density of water ρ_{fluid} = Specific gravity (G) $\times \rho_{water}$ Eq.7
The volumetric flow rate Q= C_v * Square root of (P1-P2/ G) Eq.8

The head loss coefficients for ball and globe valves are taken from the pipe data- pro flow loss coefficient table.
For fully open ball valve, the head loss coefficient is =0.05
For fully open globe valve, the head loss coefficient is =10

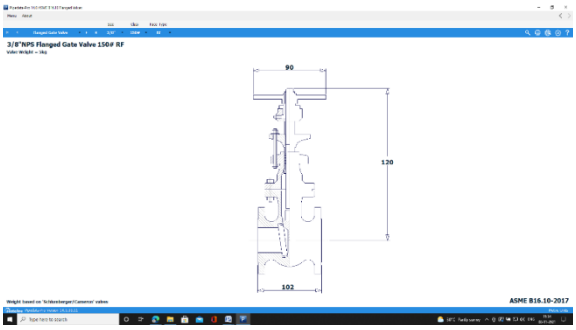

Fig.3.1. ¾ inches flanged gate valve ASME B16.10

Wedge shaped valve plug is specifically used for ON-OFF applications. This plug will lift from fully open to fully closed using valve stem. Applying for continuous ON-OFF operations may limit the efficiency of valve plug and valve seat. The plug size of double flanged gate valve is The ratio of Process fluid density and water density which is neglected in this paper. Because the process fluid is water. The pressure loss is estimated with varying flow rate values using Eq.9

ΔP = (Specific gravity of process fluid ×square of the Actual Flow rate)/ Square of flow coefficient Eq.10

The flow coefficient (Cv) represents number of gallons of water flowing through the control valve in a minute under pressure drop of 1PSI.

1 PSI pressure drop = 2.31 feet water head.

With a pipe diameter i.e upstream and downstream port of the control valve diameter is 20 mm; the fluid flow velocity is estimated using valve coefficient C_V and the flow coefficient K_V is also estimated using Eq.14

K_V= Volumetric Flow rate (Q) ×. Square root of (Density of fluid/ Density of water (1000) ×ΔP)] Eq.11

From the Standard charts Precisely Cv= 0.86497767 ×Kv Eq.12

The Pressure differential across the control valve is estimated using known KV value

$$\Delta P = \frac{D \times Q^2}{1000 \times K_v^2} \qquad \text{Eq.13}$$

The pressure 'P' is calculated
P= Fluid Head in meters (H) × Density of fluid × g / 100000 Eq.14

The Total Pressure loss is estimated using Eq.15
Total Pressure loss in PSI= H fluid × SG × 2.311 Eq.15

Experimental Results and Analysis

Table 4.1. Quick opening control valve

Valve % open	Inflow rate (GPM)	Outflow rate (GPM)	Upstream Pressure (P1)PSI	Downstream pressure (P2) PSI	Differential Pressure	Sqrt of Delta	Estimated Flow rate(GPM)
100	3.434	2.201	2.27	1.85	0.6416	0.8009	780
75	3.43	2.1	2.13	1.75	0.6122	0.7824	780
50	3.39	2.059	2.272	1.91	0.5976	0.773	770
25	2.2894	1.84	4.26	3.97	0.5363	0.7323	520

Table 4.2. Flow velocity and Head loss Vs Percentage of valve opening

Valve open %	Upstream Flow rate	Downstream Flowrate	velocity V1	velocity V2	Head loss coefficient (C)	Head loss (H)	Valve coefficient (CV)	Flow Coefficient (KV)
100	3.434	2.201	7.778	7.7883	0.04278	1.2949	2.201	2.544
75	3.434	2.1	7.778	7.4309	0.04484	1.2406	2.1	2.428
50	3.39	2.05	7.6783	7.254	0.04593	1.2084	2.059	2.38
25	2.2894	1.84	5.1855	6.5109	0.05118	1.0848	1.84	2.1274

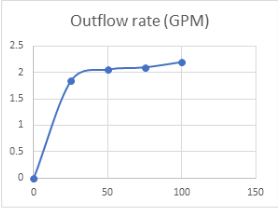

Fig.4.1. Outflow rate Vs Valve Open

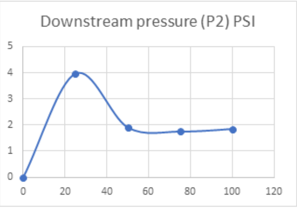

Fig. 4.2.Downstream pressure Vs Valve Open

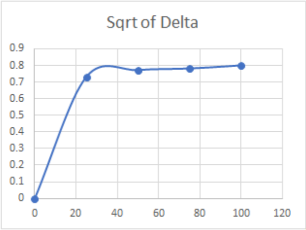

Fig.4.3.Differential pressure Vs %Valve opening

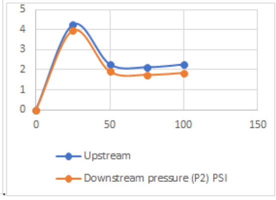

Fig.4.4. Pressure change Vs %Valve Opening

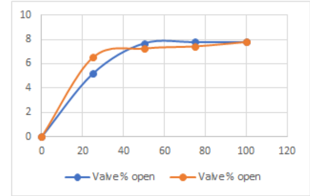

Fig. 4.5. Velocity change Vs%Valve open

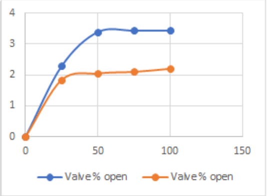

Fig.4.6. Change of flow rate Vs % Valve open

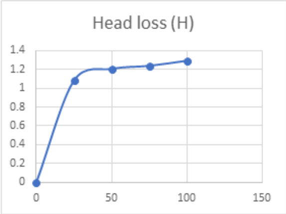

Fig.4.7. Head losss Vs % of valve open

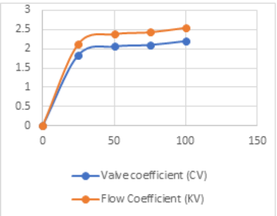

Fig.4.8.valve coefficent Vs % of valve open

The maximum fluid flow through the control valve is observed at 2.201 GPM with 100 percent valve open at which the differential pressure is 0.6416Psi. The outflow rate is significantly increased to a maximum value with 100 % valve open. For small opening of the control valve i.e., 25% open, the outflow is observed as 1.84 GPM. The outflow rate is quickly reached to 90 percent of the final value with 25 percent valve open. And a small incremental change is observed between 50 % to 100 % open of the control valve. This quick reaction is best suited for emergency shutdown applications. The downstream pressure is increased to a maximum value i.e 3.97 PSI for small opening of the control valve. The downstream pressure is abruptly dropped to a minimum value i.e., 1.75 PSI for 75 percent valve open. This is the lowest pressure recorded at which the velocity of the fluid flow is 7.4309 m/s. this pressure is the venacontracta pressure. The vapor pressure of water is 0.4602152 PSI. The lowest pressure at which the velocity is high is the venacontracta pressure is recorded at 1.75 PSI. So, if the venacontracta pressure is greater than the vapor pressure the plug and the valve seat is encountered with flashing and the control valve is operating under ideal conditions. The pressure difference across the control valve i.e.,the differential pressure is raised to a maximum value with 25 percent valve open and the slope of the response is constant for wide open of the control valve. The downstream pressure is maximum for small open of the control valve, i.e., 3.97 PSI and it shows negligible change between 50 to 100 percent open of the control valve. The change of velocity between 50 to 100 percent is negligible value. This valve exhibits initial velocity is at maximum valve when the valve is suddenly open for fully closed to 25 percent open and it is maintaining small change for fully open the valve plug. The valve flow coefficient value is following the valve coefficient value. The head loss is at maximum value i.e 1.2949 at 100 percent plug open position. An incremental change in head loss is observed between 50 to 100 percent of the control valve.

Conclusions

The Quick opening plug type valve characteristics are studied with varying load conditions. The Valve is normally open type control valve. By varying the input pressure signal to the actuating element insteps of 3 PSI the percent of valve opening is estimated. The pressure differential and the change of velocity from upstream to downstream ports with varying load conditions are tested. The plug exhibits an initial quick response when it is operating from fully closed to 25% of valve open. The valve discharge flowrate reaches to 90 percent of the final valve with small input change. This type of valve is best suited for emergency shutdown applications. The head loss is also significantly a small valve between 0 to 75% of valve open.

References

1. Swapnil R. Yevale, K. S. Gharge,” A Review on CFD Analysis of Control Valves”, GRD Journal for Engineering, Vol.3(7): pp 66-69, june 2018.

2. Shixian Wu, Heqing LiuID1, Yongping Chen,” Comparative analysis of regulating characteristics between air-ring flow regulating valve and center butterfly valve”, PLOS ONE, May 19, 2021.

3. Singh. D, Charlton. M, Asim. T, Mishra. R,” Design for additive manufacturing and its effect on the performance characteristics of a control valve trim”, International journal of condition monitoring and diagnostic Engineering management, Vol. 22(2), pp 59-67, 2019.

4. Dr. Ibrahem Farhan, Salman Alrefo,” Design of Industrial Electro-Hydraulic Valves, New Approach”, Int. Journal of Engineering Research and Application, Vol.6(9): pp 58-63,September 2016.

5. Jana Jablonska1, MiladaKozubkova, “Evaluation of the Characteristics of the Control Valves”, MATEC Web of Conferences 328, 03011 (2020)

6. Zhiqiang Xu,Wanli Li, XiangyongLiu, and Zhixin Chen,” Dynamic characteristics of coupling model of valve-controlled cylinder parallel accumulator”, Mechanics & Industry VOL. 20. (306), pp 1-17, 2019.

7. Leonid G. Kozlov, Leonid K. Polishchuk, Oleh V. Piontkevych, Mykola P. Korinenko , Roman M. Horbatiuk , Paweł Komada , SandugashOrazalieva , Olga Ussatova,” Experimental research characteristics of counterbalance valve for hydraulic drive control system of mobile machine”, PrzeglądElektrotechniczny,pp 104-109, 2019.

8. Wei Ma, Fei Ma and Rong Guo,” Experimental research on the dynamic instability characteristic of a pressure relief valve”, Theoretical and Experimental Advances of Complex Fluid Flow in Mechanical Engineering - Research Article,Vol.11(3):pp1-13,2019.

9. Jana Jablonska, Milada Kozubkova,” Flow characteristics of control valve for different strokes”, EPJ Web of Conferences,PP 1-5,2016.

10. Jianxi Yu, Pei Liu, Zheng Li,” Hybrid Modelling of a High-Pressure Control Valve of a Steam Turbine at Off-Design Modes Using First-Principal Mechanism and Operational Data”, Chemical Engineering Transactions, Vol.76: pp 589-594,2019.

11. Yuqi Wang, Xinhui Liu, Jinshi Chen, YafangHan,Siyuan Liu, and Dongyang Huo,” Investigation on the Characteristics of a Combination Microflow Control Valve”, Hindawi Mathematical Problems in Engineering Vol. 2021: pp1-13, April 2021.

12. Li Liang Member, Liu Jiannan, and Wan Huaqing,” Parameter estimation for linear control valve with hysteresis”, IEEE Transactions on automation science and engineering: PP1-7, May 2016.

13. Wei Dongpo, Zhao Hongxia, “Research on Flow Characteristics of Throttle Valve Based on Fluent”, Journal of Physics: Conference Series, 1676: PP 1-8,2021.