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Determination of Flow Coefficient of Different Valves

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Abstract: **Flow control valves are machine elements which are commonly used to control the flow of different liquids and gases based on the applications they are used for. This research paper covers three types of flow control valves namely, Ball valve, Gate valve and Butterfly valve and establishes comparisons between the results. The chief aim of it is to study the characteristics of these valves for a size as small as 1 inch. Such small valves can be used for irrigation facilities. The current available data only concerns with larger valves and hence this project specifies characteristics of these valves for the above mentioned sizes.**

Keywords- Ball valve, Butterfly Valve, Comparison of characteristics, Gate valve, Flow coefficient, Efficiency.

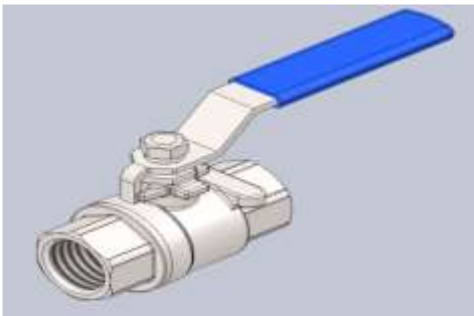
I. Introduction

Valves are essential type of fittings to any system as they regulate control and regulate fluid flow within that system. Flow-control valves, as the name suggests, control the rate of flow of a fluid through a hydraulic circuit. Flow-control valves accurately limit the fluid volume rate from fixed displacement pump to or from branch circuits. Their function is to provide velocity control of linear actuators, or speed control of rotary actuators. Typical application include regulating cutting tool speeds, spindle speeds, surface grinder speeds, and the travel rate of vertically supported loads moved upward and downward by forklifts, and dump lifts. Flow-control valves also allow one fixed displacement pump to supply two or more branched circuits, fluid at different flow rates on a priority basis.

The flow coefficient of a device is a relative measure of its efficiency at allowing fluid flow. It describes the relationship between the pressure drop across an orifice, valve or other assembly and the corresponding flow rate.

The flow coefficient of a valve is a relative measure of its efficiency at allowing fluid flow. It describes the relationship between the pressure across a valve or other assembly and the corresponding flow rate. The flow coefficient tells you how to properly size your valve so it has minimal effect on the hydraulic efficiency you've engineered into your system.

Ball valve: A ball valve is a form of quarter-turn valve which uses a hollow, perforated and pivoting ball (called a "floating ball") to control flow through it. It is open when the ball hole is in line with flow and closed when it is pivoted 90^0 by the valve handle.

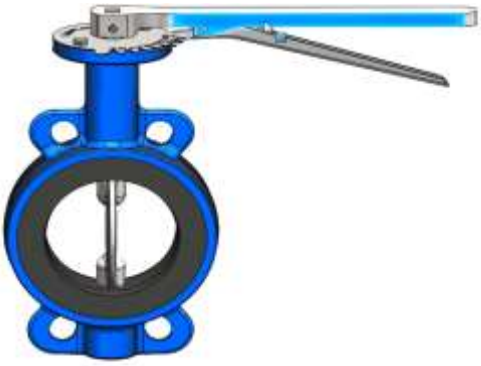


1. **Ball valve**

Gate Valve: A Gate Valve, or Sluice Valve, as it is sometimes known, is a valve that opens by lifting a round or rectangular gate/wedge out of the path of the fluid. The distinct feature of a gate valve is the sealing surfaces between the gate and seats are planar. The gate faces can form a wedge shape or they can be parallel.

2. **Gate Valve**

Butterfly Valve: Butterfly valve is very versatile component for use both as shut off and throttling valve in water system. Butterfly valve has simple mechanical assembly, and a small flow resistance in a fully open position, butterfly valves provide a relatively high flow capacity. They are the best suited for relatively low pressure flow. Generally, the fluid friction coefficient is low and also the build-up is usually minimum because of the Butterfly valve is operated with a quarter turn.



3. **Schematic of Butterfly Valve**

II. Literature Review

K punithrani et. al [1] In this study, a high-pressure, cryogenic ball valve that can achieve zero leakage was designed. To acquire the safety along with durability of cryogenic ball valve, we should consider the structural mechanics such as stress, deformation and dynamic vibration characteristics and identify those important aspects in the stage of preliminary design engineering. For the cryogenic ball valve, the assurance of structural integrity and operability are essential to meet not only normal, abnormal loading conditions but also functionality during a seismic event.

Dae-Woong kyun et. al[3] The objective of this paper to perform a stress analysis of the critical component of Gate Valve. The critical components in the Gate Valve are Body, Gate Stem and slab gate. This paper comprises Finite element analysis of Gate Valve. A model of each element of Gate Valve is developed in CATIA V5R17, and analyzed in ANSYS 11. Gate valve stress analysis is done by FEM using ANSYS 11 and validation is supported by stress analysis using classical theory of mechanics.

Piotr Duda [5] concluded that valves are formed from ball and seat in system. The balls must withstand the complex erosive-abrasive wear determined by corrosive environments, the effect of high temperature will also occur. Several experimental batches of balls with structural gradients are made using different extremely hard alloys.

Nermina Zaimović et.al [2] manufactured the butterfly valves in various shapes but a fitting performance comparison is not made up. For this reason, they carried out numerical analysis of some kind of butterfly valves for water supply and drainage pipeline using commercial CFD code FLUENT, and made a comparative study of these results. Also, the flow coefficient, the loss coefficient, and pressure distribution of valves according to valve opening rate were compared each other and the influence of these design variables on valve performance were checked.

III. Methodology

Mathematically the flow coefficient C v (or flow-capacity rating of valve) can be expressed as,

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

In more practical terms, the flow coefficient C v is the volume (in US gallons) of water at 60 °F that will flow per minute through a valve with a pressure drop of 1 psi across the valve.

The setup used is as shown in the figure below. The valve was mounted in between two pressure gauges that measure inlet and outlet fluid pressures respectively. The difference between both the heads was calculated. The time taken for a specific volume of fluid to discharge from the valve was recorded with the help of a surge tank and stop watch. This whole procedure was repeated for many different angles of opening (for ball and butterfly valve) and different number of turns (for gate valve). Having all these parameters, the flow coefficients were calculated.

These flow coefficients were different for different set of settings. These calculated flow coefficients were plotted against their corresponding angle of opening (in ball and butterfly valve) and number of turns (in gate valve). These graphs then helped concluding the experiment hence establishing comparisons between the three valves.

The results were then studied in detail so as to determine suitable applications for each valve.

4. **Setup used**

IV. Calculations

Q=A*R/t
where,
Q is the volume flow rate
A is the lateral area of the measuring tank
t is the time taken for the specific rise in the water level
R is the rise of water level in the measuring tube

h=x*12.6
where,

h is the difference in the pressure heads

x is the pressure difference in terms of cms of mercury

1) Result Table

Θ	h (m)	P (psi)	Q (gpm)	C_v
BALL VALVE				
10	3.8896	75.2651	0.5632	0.065
20	2.2302	43.1439	1.1294	0.1719
30	1.1844	22.9126	2.504	0.5231
40	0.9576	18.5251	2.9828	0.693
50	0.6678	12.9188	3.4398	0.957
60	0.4788	9.2625	3.935	1.2929
70	0.3906	7.5563	4.1932	1.5254
80	0.3528	6.825	4.3665	1.6714
90	0.315	6.0938	4.4151	1.7885
BUTTERFLY VALVE				
12.86	2.06	38.852	0.3964	0.0628
25.71	1.2096	23.4	0.7694	0.1591
38.57	0.5166	9.9938	2.2643	0.7163
51.43	0.2898	5.6063	3.17	1.3388
64.29	0.2268	4.3875	3.6024	1.7198
77.14	0.189	3.6563	3.9626	2.0723
90	0.1764	3.4125	4.0642	2.2
GATE VALVE				
N	SAME AS ABOVE			
2	0.7686	14.8688	3.4989	0.9074
4	0.2268	4.3875	4.2155	2.0125
6	0.1638	3.1688	4.4524	2.5012
8	0.126	2.4375	4.6619	2.986
10	0.063	1.2187	5.113	4.6316

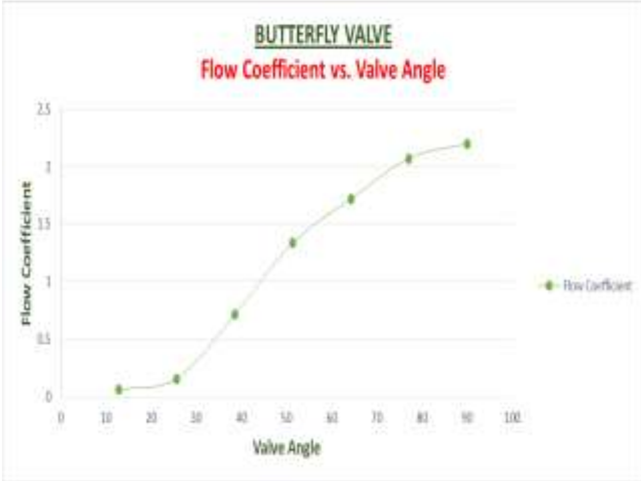
V. RESULTS

The following graphs show the results thus achieved:

The first graph shows the obtained flow coefficients of the ball valve of inner diameter 1 inch (or 25mm) plotted against the corresponding angles of valve opening:

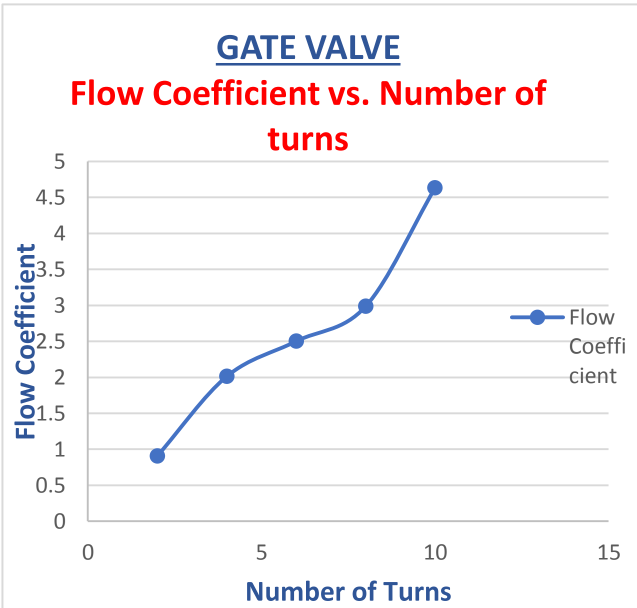
5. **Flow characteristics of Ball valve**

The second graph shows the obtained flow coefficient of butterfly valve of inner valve 1 inch (or 25mm) plotted against the corresponding angles of valve opening:



6. **Flow characteristics of Butterfly valve**

Similarly, the next graph shows the resultant flow coefficients of gate valve of inner diameter 1 inch (or 25mm) plotted against the corresponding number of turns of the valve:



7. **Characteristics of Gate Valve**

VI. CONCLUSION

As shown by the previous graphs, in case of quarter turn valves (Ball and Butterfly Valves) the flow coefficient shows a significant increase with increasing angles of opening upto 30° and then the increase becomes gradual. It stays gradual upto around an angle of 80° and then the increase becomes almost negligible upto an angle of 90°. Whereas, in case of gate valve, the flow coefficient increase is directly proportional to the increase in the number of turns.

This test rig can be fabricated in any teaching institute, thus increasing the industry-institute interaction. This is recommended because companies sometimes find it difficult to have a separate testing section. This need can be fulfilled by the institutes, thus increasing the revenue collection in the institutes. Also, the students will get exposure to the working environment in the industries.

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