Design and Flow Coefficient Analysis of Globe Valve as Control Valve Using MATLAB

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Abstract:- Valves regulate the flow of pressure and fluid in a process or system. The glove valve has excellent throttle function and can be used for flow adjustment. A quick understanding of the flow of different trim types of glove valves and their impact on flow characteristics. Using MATLAB, we realized the characteristic curves of the pressure difference between the inlet and the outlet and the flow rate. We investigated the characteristic curves of hydropower for different trim types. In addition, we examined the flow through a linear, equal percentage of valves. Equal percentage of valves expand more area in the valve lift than linear valves that linearly expand the open area. Finally, a comparative study of glove valves between linear and equal percentages of trim is done.

Keywords:- MATLAB, Globe Valve, Equal Percentage, Trim.

I. INTRODUCTION

Control valves can be defined as mechanical devices that control the supply of fluid and pressure within a system or process. Control valves regulate the fluid flow and pressure of a process or process by performing various operations such as component overpressure. Many valve designs and types need to perform one or more of the above functions. As a result, many valve types and designs are reliably adapted for a variety of industrial applications.

Control valves are an important part of the automatic control of modern systems and are based on the precise allocation and adjustment of flowing liquids. The control valve acts as a variable resistor in the pipeline. It provides a pressure drop by adjusting the turbulence in a liquid or gas process. In laminar discharge, the modified valve resistance or resistance causes a pressure drop. This pressure drop process is often referred to as throttle. Control valves are the most important element of a liquid processing system because they regulate the flow of liquid. A globe valve is described as a linear motion valve represented by a sphere with long face-to-face dimensions corresponding to a smooth, round flow path. There are many advantages of globe valves. Therefore, it is widespread. Shutoff valves are particularly adaptable and can be used in a variety of services. The same valve can be used in dozens of different applications as long as the pressure and temperature limits are not exceeded. This versatility can reduce spare parts inventory and maintenance training. Linear motion, in this case, transfers the forces generated by the actuator or actuator system to the control elements. Therefore, minimal energy is lost to the control elements. Rotary valves, on the other hand, lose some of the transmitted energy and accuracy

due to the dead zone associated with the mapping from linear motion to rotary motion. For this reason, globe valves are suitable for high performance and are used in applications where such performance is essential. The main advantage of using a lift control valve is that it can withstand extreme processes. They operate at excessively high-pressure depths and are designed to achieve working pressure differences of thousands of pounds. A steady flow of incompressible fluids of Newtonian fluids is also assumed here.

Parts of Typical Globe Valve are:
- Body is the main pressure-containing structure, and it
- contains all of the valves' internal parts.
- Bonnet provides leak-proof closure for the valve body.
- Disc is the closure member of the valve.
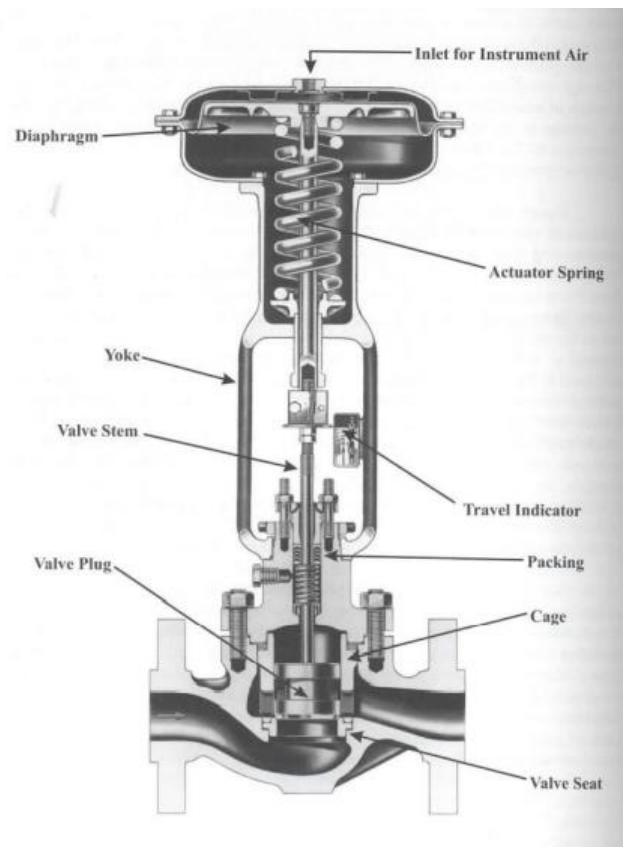- Stem serves as a connector originating from the actuator.

Fig 1: Typical globe valve [1]

II. SIGNIFICANCE OF VALVE DESIGN

In recent years, valve manufactories worldwide concentrated their awareness on designing high-performance globe valve techniques to overpower the issues caused by the conventional globe. Valve types represent the mechanical attributes and geometry (Ex/ gate, ball, globe valves). Valve Control is an important part of valve design, and the types are examined below:

A. Equal Percentage (most typically used valve control)
- Used in operations where large modifications in pressure drop are predicted
- Used in operations where the valve allows a small percentage of the total pressure drop
- Used in temperature and pressure control loops

B. Linear
- Used in liquid level or flow loops
- Used in scenarios where one can find fairly stable pressure drop across the valve is predicted to stay, steady-state systems)

C. Quick Opening
- Used for frequent on-off service
- Used for operations where "immediately" large flow is required (i.e., safety systems or Cooling water systems)
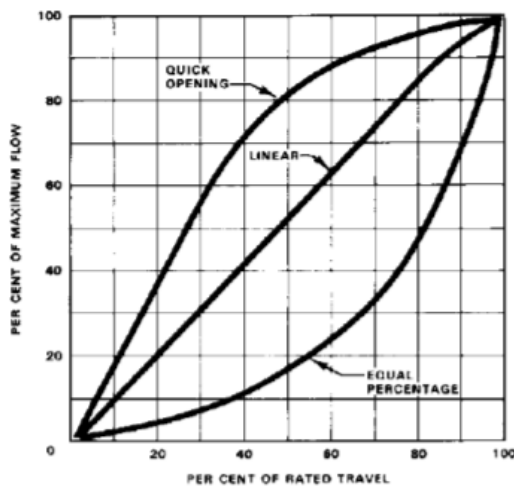

Fig 2: Valve characteristics curves [5]

III. FLOW COEFFICIENT CV

The flow coefficient is a measure of efficiency that allows fluid flow. Describes the relationship between pressure drop across valves, orifices, or other assemblies and associated flow rates.

The flow coefficient can be expressed as

$$Cv = F * \sqrt{\frac{SG}{\Delta P}}$$

Where;
Cv = Flow capacity rating or flow coefficient of the valve.
F = US gallons per minute -Rate of flow.
SG = Specific gravity of fluid e.g. Water = 1.
ΔP = Pressure drop across valve (psi).

More realistically, the flow coefficient Cv is the amount of water at 60 ° F flowing across the valve per minute with a pressure drop of 1 psi. The standard way to distinguish between valve capacity and sizing valves for common applications, which is widely accepted in the industry, is to utilize the flow coefficient shown.

IV. LITERATURE SURVEY

[1] Qin Yang, Zhiguo Zhang presents the author's work on shut-off valve modeling and simulation. Flow strategies with shut-off valves are difficult and have non-linear properties due to the structure and hydraulic activity associated with shut-off valves. In this article, we ran a 3D numerical simulation to monitor valve flow coefficient measurements, including flow design and flow fluctuations, when shutoff valves with different flow rates and uniform inlet velocities were used in the valve system.

[2] Alexandre Joel Chorin provides a finite difference approach for transforming the designed Navier-Stokes equations for incompressible fluids. This method uses primitive variables. H. Acceleration and force, equally suitable for 2D and 3D situations.

[3] Benjamin Saybolt presented a simple numerical method for deciphering the Navier-Stokes equation. It includes basic components such as houndstooth discretization, implicit viscosity steps, prediction steps, and visualization of solutions over time.

[4] JW Hutchison; This publication was produced under the supervision of the Final Control Elements Committee of the ISA Process Measurement and Control Department. This manual is intended to help engineers become familiar with control valve design and application elements and help equipment engineers select the optimal valve body, actuators, and application accessories.

[5] Arkelyan Erik, in a given article, examines the Navier-Stokes problem, a hyperbolic wave pattern that focuses on wave propagation. Starting with a linear wave solution, we present a nonlinear wave problem. Later, we will use partial differential equations to derive a numerical solution. He also developed a MATLAB program to solve and simulate wave propagation.
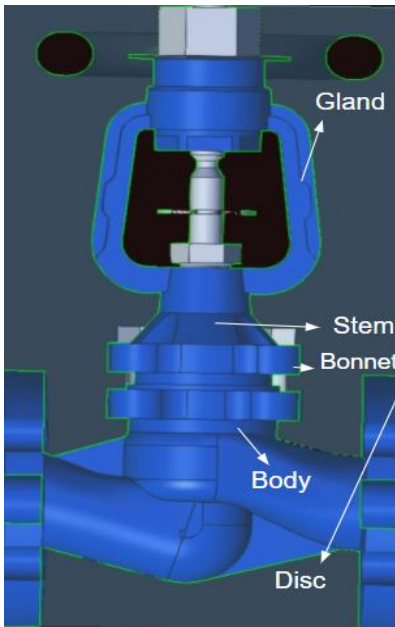
V. PROBLEM DEFINITION

Fig 3: Globe valve Nomenclature

The figure shows the sketch and nomenclature of a globe valve (globe valve DN20 model) investigated in this study.

- The cases are modeled & analyzed in this article by using MATLAB.
- The experimentally obtained graphical results via MATLAB are obtained and compared with the already theoretically verified graphical results.

Finally, we compare linear and equal percentage trim type Globe valves flow characteristics.

VI. SOLID MODELLING OF GLOBE VALVE

We would design the DN 20 globe valve with the help of MATLAB Code and compare the theoretically verified graph of the respective valve to validate the MATLAB code, the solid model of the globe valve has been developed in order to help in the visualization of the valve when developing the MATLAB code.
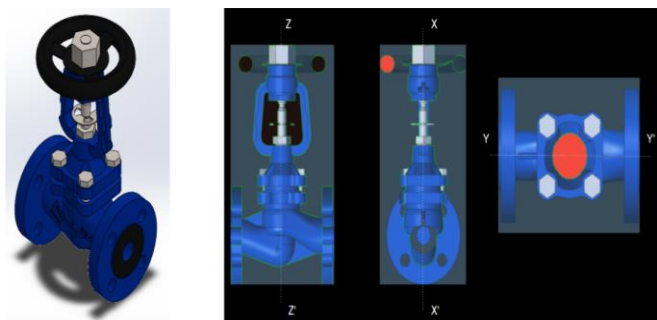

Fig 4: Isometric and Sectional Views of Globe Valve Assembly
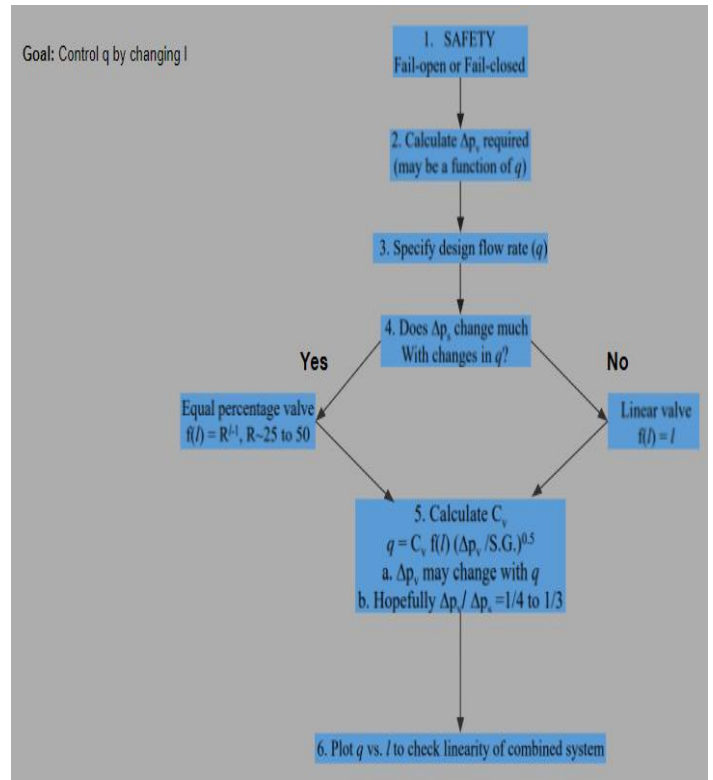
VII. METHODOLOGY

Fig 5: Valve Design Logic Diagram

The DN 20 globe valve is the first CAD modelled to give us a visual understanding of the valve and then coded onto MATLAB.

First, the pressure difference is calculated, which helps specify the design flow rate and obtain the graph via the flow characteristics.

VIII. DESIGN ACTUAL EXAMPLE

A. Characteristic Curve

For example, for linear and equal percent control, the total pressure of the lift valve produced by the pump is 200 bar and the flow coefficient of the valve is 2. The pressure difference between the inlet and outlet of the lift valve and the flow rate characteristics The MATLAB method is as follows.

```
clear all; close all; clc    % clear variables, close plots, clear screen
%% Lift functions for two different valve trim types
f_lin = @(x) x;              % linear valve trim
f_ep  = @(x) 20.^(x-1);      % equal percentage valve trim
lift = linspace(0,1);        % 100 equally spaced points between 0 and 1
figure(1)                    % create new figure
title('Valve Performance - Not Installed')
subplot(2,1,1)               % 2,1 subplot with 1st window
plot(lift,f_lin(lift),'b-')  % plot linear valve
hold on                      % use "hold on" to not erase additional items
plot(lift,f_ep(lift),'r--')  % plot equal percentage valve
ylabel('f(l)')
legend('Linear Valve Trim','Equal Percentage Valve Trim')
g_s = 1.1;                   % specific gravity of fluid
q = @(x,f,Cv,DPv) Cv * f(x) * sqrt(DPv/g_s);  % flow through a valve
%% Intrinsic valve performance
% no process equipment - all pressure drop is across valve
DPt = 200; % Total pressure generated by pump (constant)
Cv = 2;    % Valve Cv
flow_lin = q(lift,f_lin,Cv,DPt); % flow through linear valve
flow_ep  = q(lift,f_ep,Cv,DPt);  % flow through equal percentage valve
subplot(2,1,2)               % 2,1 subplot with 2nd window
plot(lift,flow_lin,'b-')     % plot linear valve response
hold on
plot(lift,flow_ep,'r--')     % plot equal percentage valve response
ylabel('Flow')
legend('Linear Valve Trim','Equal Percentage Valve Trim')
xlabel('Fractional Valve Lift')
%% Installed valve performance
% pressure drop across valve and process equipment
% pressure drop across other equipment
c1 = 2;
DPe = @(q) c1 * q.^2;
% combined valve and process equipment flow with 100 bar pressure drop
qi = @(x,f,Cv) sqrt((Cv.*f(x)).^2.*DPt ./ (g_s + (Cv.*f(x)).^2 .* c1));
% Process equipment + Valve performance
flow_lin = qi(lift,f_lin,Cv);  % flow through linear valve
flow_ep  = qi(lift,f_ep,Cv);   % flow through equal percentage valve
figure(2)
title('Valve Performance - Installed')
subplot(3,1,1)
plot(lift,flow_lin,'b-')
hold on
plot(lift,flow_ep,'r--')
plot([0 1],[0 9.4],'k-','LineWidth',2)
legend('Linear Valve','Equal Percentage Valve','Desired Profile')
ylabel('Flow')
subplot(3,1,2)
plot(lift,DPt-DPe(flow_lin),'k:','LineWidth',3)
hold on
plot(lift,DPe(flow_lin),'g:','LineWidth',3)
legend('Linear Valve','Process Equipment')
ylabel('\Delta P')
subplot(3,1,3)
plot(lift,DPt-DPe(flow_ep),'k:','LineWidth',3)
hold on
plot(lift,DPe(flow_ep),'g:','LineWidth',3)
legend('Equal Percentage Valve','Process Equipment')
ylabel('\Delta P')
xlabel('Lift')
```
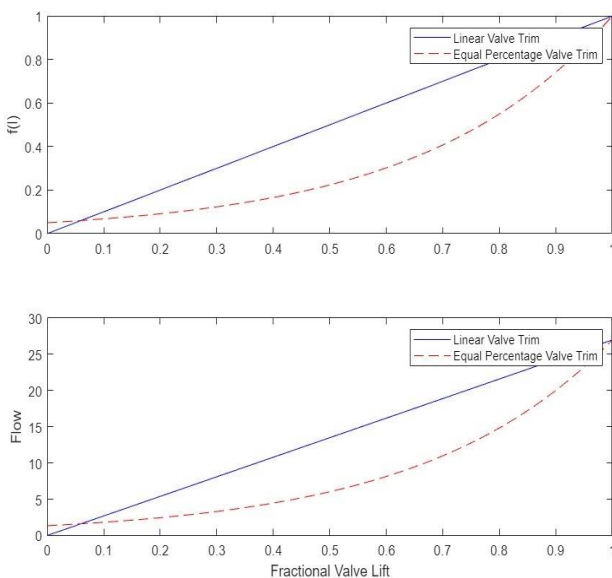
Fig 6: MATLAB Code

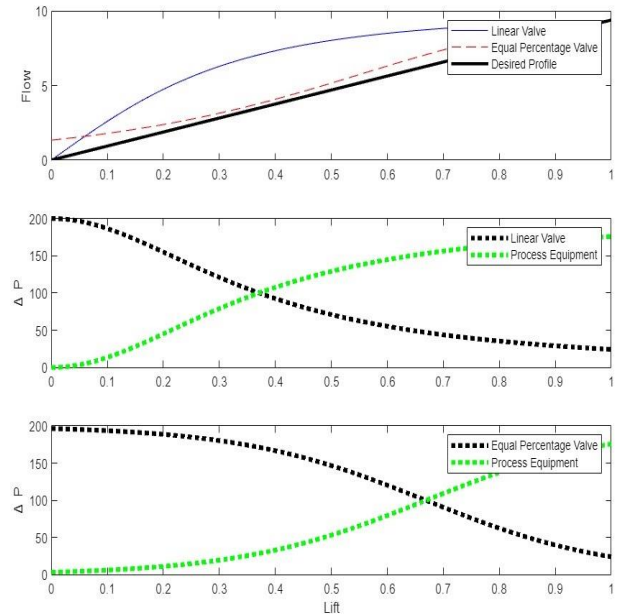Fig 7: The globe valve's flow rate characteristic curve

Fig 8: The characteristic curve of hydraulic force

B. Simulation Verification- Theoretically Verified Graphs (Flow Characteristics of Different Trim Types)

- *Equal Percentage*

The equal percentage is the feature most generally used in process control. The release occurring just before the transition is made directly proportional to the difference inflow per unit of valve stroke. While the valve's flow characteristic may be an equivalent percentage, most control loops will create an installed characteristic approaching linear when the overall system pressure drop is largely comparable to that across the valve.
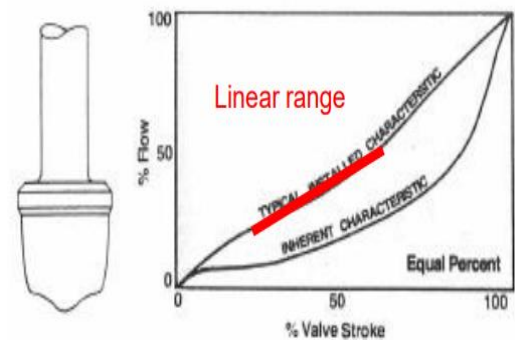

Fig 9: The equal percentage trim type flow rate characteristic curve [1]

- *Linear*

Due to its inherent linearity, the flow difference per unit of valve lift is equal regardless of the position of the plug. Therefore, linear plugs are used in scenarios where valve pressure drop accounts for a significant portion of the overall system pressure drop.
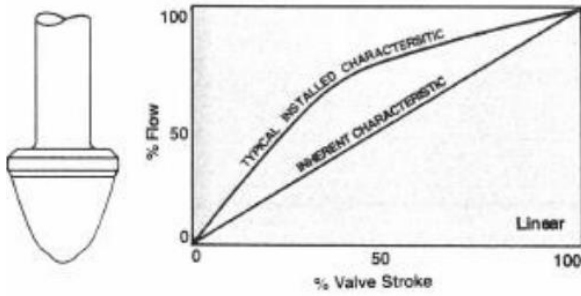
Fig 10: The linear trim type flow rate characteristic curve [1]

C. Cv is for an Equal Percentage Valve [1]

	Body Size (in)	Stem Position as a Percentage of Total Travel									
		10	20	30	40	50	60	70	80	90	100
Cv	1	0.79	1.25	1.80	2.53	3.63	5.28	7.59	10.7	12.7	13.2
	1.5	0.80	1.23	1.91	2.95	4.30	6.46	9.84	16.4	22.2	28.1
	2	1.65	2.61	4.30	6.62	11.1	20.7	32.8	44.7	50.0	53.8
	3	3.11	5.77	9.12	13.7	21.7	36.0	60.4	86.4	104	114
	4	4.90	8.19	13.5	20.1	31.2	52.6	96.7	140	170	190

Fig 11: Equal Percentage Globe Valve's representative Cv

The linear characteristic valve plug is shaped to directly proportional the flow rate to the valve lift (H) at a constant differential pressure. A linear valve accomplishes this by the valve lift and the orifice pass area having a linear relationship present between them.

These valves include a valve plug shaped so that per increment in valve lift raises the flow rate by a specific percentage of the earlier flow. Therefore, the relationship between valve lift and orifice size (flow rate) is not linear but logarithmic.

IX.   RESULTS AND DISCUSSION

The linear valve evenly changes the flow rate per unit stroke, regardless of the position of the plug. Therefore, linear plugs are used in scenarios where valve pressure drop accounts for a significant portion of the overall system pressure drop. A poppet valve with an equal percentage of valve cone will result in the same percentage of volumetric flow change with every constant increase in valve lift at all points on its characteristic curve. Equal percentages are the most commonly used characteristics of process control. When a constant pressure drop is maintained throughout the valve, the valve characteristics alone direct the flow, which is the inherent flow characteristic. However, when installing valves using pumps, pipes and fittings, heat exchangers, and other process equipment, the flow rate is controlled by the installed characteristics, such as the effectiveness of the valves and pipes.
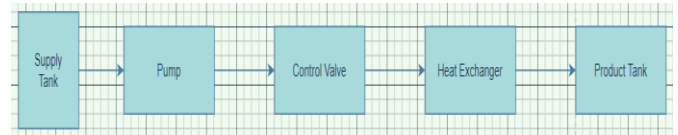

Fig 12: Installed valve block diagram

X.   CONCLUSION

Using MATLAB programming, it was easy to obtain flow characteristic curves for straight-through and equal percent poppet glove valves. Using MATLAB, we realized the hydraulic characteristic curve of the poppet control valve and obtained important parameter values. We used MATLAB to design a ball control valve and inserted parameter values into the modeling for experimental validation. This document provides a graphical method for designing structural parameters for gate control valves using MATLAB. The relationship between the position of the valve stem and the flow rate through the control valve is characterized solely by the flow rate characteristics of the valve or the valve characteristics. The unique curve graph shows the percentage of valve opening to the percentage of maximum flow coefficient (Cv). This can be determined by measuring the flow rate at different positions in the valve stroke with a constant differential pressure across the valve. The Cv value at each valve position is then calculated using the generalized form of the control valve Cv equation.

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