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Fluid flow control through Flow Valves – A Review

Paul Gregory[1], Durkesh Karthik P[2], Gokul C [3], Sivasakthi Velan S[4] Dhiyanesswar R B[5]

[1]Department of Mechanical Engineering, PSG College of Technology, Coimbatore, INDIA
[2]Sales Consultant, Volkswagen Coimbatore, Ramani Cars Pvt. Limited, INDIA
[3]Asst. Production Engineer, Moldwell Products India Pvt Ltd, Coimbatore, INDIA
[4]QA/QC Engineer, Auto Shell Casts Private Limited-Unit II-Valve Assembly Division, Coimbatore, INDIA
[5]Student-Dept of Mechanical Engg, Sri Sairam Engineering College, Chennai, INDIA

***Abstract**: Flow valves play a vital role in any fluid flow system. Fluid flow valves either control the fluid pressure (regulation of flow) or the fluid flow (complete restriction of fluid). Fluid control systems are of core importance to send fluid wherever required, control its periodicity. The scope for improvement in such flow valves lies in the wide range of operating pressures, temperatures and the physical and chemical properties of handling fluid. Several innovations are emerging in flow valves and manufacturing of valve. This review article has a twofold objective. One is to throw light on various innovations in valve design and performance and other objective to discuss various manufacturing processes involved. Major types of valves such as ball, gate, butterfly, globe and other control valves have been discussed.*

1. Introduction

Flow valves are essential in any fluid flow system. The word '*valve*' derives its origin from the Latin word '*valva*', which means '*doorway*'. Valves are mechanical or electro-mechanical system that controls the fluid flow by restricting its passageway or by stopping the fluid flow in any particular direction. The main component of any valve is the actuator that operates to control the fluid. The actuator will be operated based on any of the power sources. Major functions that a valve needs to perform in fluid flow system can be listed as [1],

1. Throttling action on the fluid flow.
2. To initiate the fluid flow and also to terminate the fluid flow.
3. To alter the direction of fluid flow.
4. To relieve the fluid system from any over-pressure that would exists
5. To control the fluid pressure in the system (Regulation)

An important parameter in specifying a control valve is its flow coefficient. Flow factor (K_v) is a measure of the hydraulic performance of the valve. Flow factor can be defined as the flow rate of the fluid flowing at a temperature of 16^0C through the valve at a pressure difference of 1bar.

$$K_v = 0.865 \times Q \times \sqrt{\frac{SG}{\delta P}}$$

Where,

Q = Discharge of the fluid (m^3/hr)
SG= Specific Gravity of the fluid
δP = Pressure difference across the valve.

Valves can be classified according to the physical structure as well as mode of operation. Major types of valves include [2]:

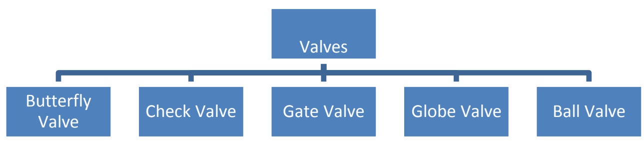

Figure 1 Types of Valves

Each and every type of valve can be noted for its own characteristics. The flow coefficient of the butterfly valve varies proportional to the angle of rotation of the disc in the valve [3], In a check valve, there is an increase of fluid velocity between the valve seat clearance [4], Gate valves are noted for its versatile applicability in refineries, petrochemical industries, etc [5]. Globe valves, being one of the oldest type of valve is noted for its better controllability and its range [6]. Ball valves can be noted for its durability and long lasting operating cycles. Advanced technology is used to manufacture ball valves [2].

2. Comparison of various flow valves

Various flow valves can be compared based on their flow characteristics and the performance. Fig. 2 – Fig.6 shows the common valves in use.

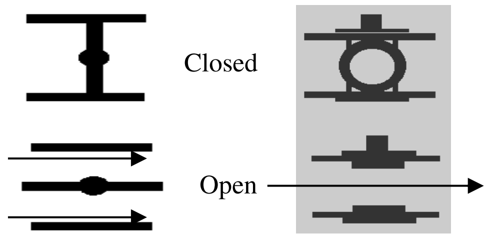

Figure 2 Butterfly Valve **Figure 3 Ball Valve**

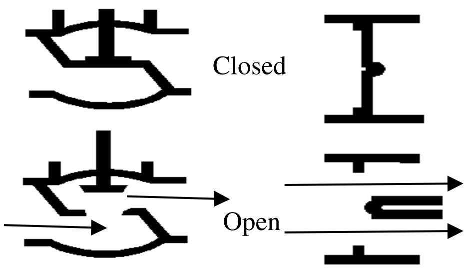

Figure 4 Globe Valve **Figure 5 Check Valve**

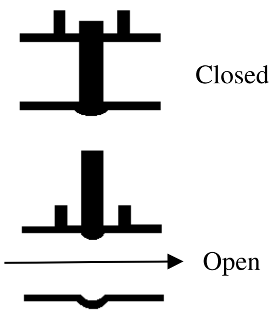

Figure 6 Gate Valve

Table 1. Comparison of performance of various valves

	Pressure Loss [2]	Weight [7]	Mode of operation [7]	Operating temperature range[7]
Butterfly Valve	Moderate	Light	Rotary Actuation	Narrower range
Ball Valve	Very Low	Heavy	Rotary Actuation	Narrower range
Globe Valve	Very High	Heavy	Linear Actuation	Wider Range
Check Valve	Moderate	Heavy	Parallel Linear	Wider Range
Gate Valve	Moderate	Heavy	Linear Actuation	Wider Range

Table 1 present a brief comparison of various parameters. Out of the comparison it can be seen that globe valve has a very high pressure loss in the valve. One advantage of using a check valves is that the very high operating speed will definitely prevent a water hammer to occur [2]. Also it is interesting to note that a gate valve cannot be used for faster action because of slower strokes in the valve. Globe valves also suffer from a disadvantage that it cannot be used for large system because of the power input to be given [2]. Globe valves require very large operating powers.

3. Flow Valve sizing

It is of core importance that the right sized valve is used for the purpose. Three main parameters remain important in valve sizing [8]. They are:

1. Pressure drop across the valve.
2. Flow rate
3. Flow factor (Coefficient of flow)

Selection procedure for valves is shown in Fig.7

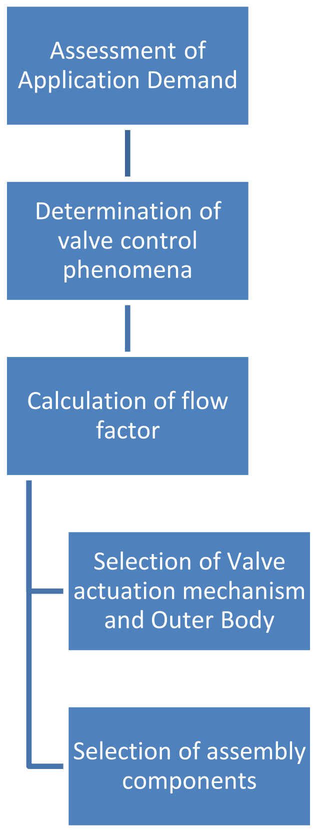

Figure 7 Selection of appropriate valve [2,9]

From the procedure it can be noted that flow factor is and important parameter determining the selection of valve. An approximate variation of valve size with varying flow factor (K_v) is shown in Fig.8. It can be seen that the valve size to be incorporated varies almost linearly with increasing flow factor (metric unit). This curve seems to be an important curve in selection of valves

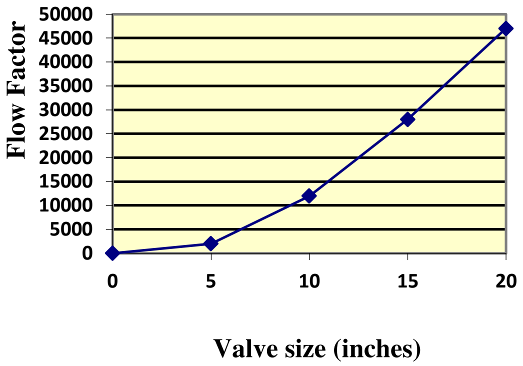

Figure 8 Variation of flow factor [2,10]

4. Troubleshooting in valves

Many problems do occur in valves. Problem can be induced due to physical activities or due to fluid flow. Generally physical factors that account for failures in valves can be as follows:

1. Any foreign particle that flows along with the fluid, which would collide with any part of the valve causing a damage or sudden failure.
2. Operating Temperature and Pressure that will cause damage to the valve. Valves are strictly restricted to a range of temperature and pressure and if operated at an unsuitable range will definitely fail.
3. Valve seals may get damage accounting for fluid loss. If the fluid being a toxic one will definitely affect the environment too, if leaked.
4. Valves have to be properly chosen for the type of fluid used. The valve material and the fluid must not be in conflict at any cost.
5. If proper maintenance is not followed up, then premature failure of valves may also take place.

In any industry, trouble shooting of valves generally follows the sequence as shown in Fig.9

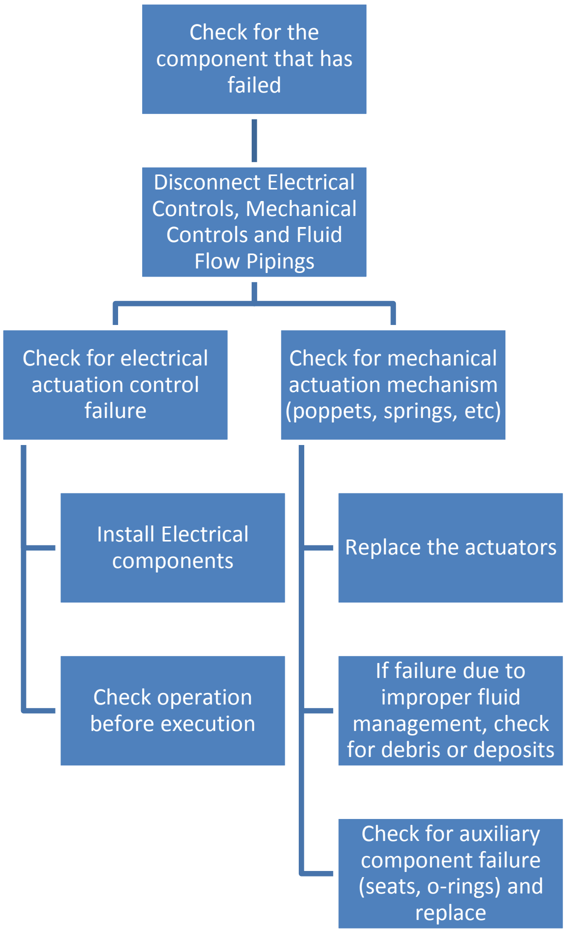

Figure 9 Variation of flow factor

A lot of valve problems do occur. They can be classified into the following as shown in Table 2

Table 2. Various valve problems

Category 01 – Improper Installation and fit
1. Valve adjustment is improper 2. Improper seating of poppets 3. Valve spring is improper 4. Orifice hole is not properly provided. 5. Faulty solenoid working **6.** Improper Control Linkages
Category 02 – Fluid Induced
1. Foreign body in fluid. 2. Viscosity of the fluid too high and unsuitable. 3. Improper temperature range of the fluid. 4. Sudden pressure spikes in the fluid
Category 03 – Physical Component Failure
1. Spool failure 2. Fluid leaks past the actuator motion 3. Plug Failures 4. Springs worn out and defective 5. Gasket Failures 6. Plungers scorched

In an analysis [11], various failures have been quantified. The analysis result is as shown in Fig.10.

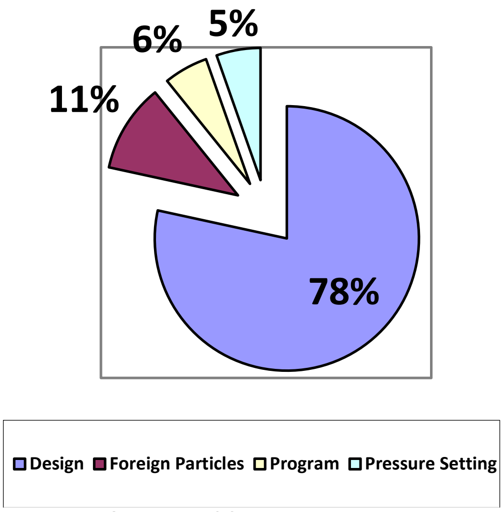

Figure 10 Causes of failure in a check valve

From Figure 9, it can be noted that the design of check valves accounts for majority of failures [11]. Foreign particles also accounts for some failures too.

Failures of valves are inevitable, yet preventive maintenance can be done to avoid premature failures. Several innovations are being developed to increase the performance and ease of control of valves. Innovations in valves are discussed in the next section.

5. Smart Valves

Technological advances have brought innovations in valve technologies. Smart valves indulge into electro-mechanical phenomena which can bring about self-adaptive features in valve operations. Smart valves possess the following features [12]:

1. Online Diagnostic Facility
2. Human Machine Interfaces (HMI)
3. Automatic Calibration system
4. In-built sensors

Smart Valves are noted for their safe instrumentation systems and automatic positioners that lessen the human effort for monitoring. Several diagnostic alarms are also in use. Smart valves can be an instrumentation devise too. Flow conditioning systems and averaging pressure systems can be a combined benefit in this smart valve.

Though series of electronic advances do take place a simple smart valve can be mechanically made by the following components.

1. Inlet Port
2. Outlet Port
3. Membrane
4. A fluid absorbing actuator

The actuator can be used to detect the fluid on the demand side and it will get swollen and it will restrict the fluid through ports. This can be a simple mechanical smart valve.

Various advantages that are achieved in electro-smart valve technology are:

1. Lesser human effort in monitoring
2. Precise monitoring
3. HMI Interaction
4. Emergency shutdown controls
5. Diagnostic alarms
6. Programmable valves
7. Preventive Maintenance
8. Self-adaptive (when programmed)

Though technologies are available to enhance the performance of fluid systems and to ease human activities, it is upto the user to apply in for the right purpose and application

6. Conclusion

This article has discussed the phenomenon of valve technology, the usage of valves and operating principles of important valves, and a comparison has also been made. Choice of valves for the appropriate application has also been discussed. Valve sizing procedures have been discussed. From the sizing procedure one would infer that flow factor and pressure drop are the chief components of the decision. Valves do fail and the trouble shooting of valves have been discussed. Electro-mechanical smart valve technology is an upcoming one in the industry. Features of smart valves stand outstanding compared to other valves.

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