Re-engineering of the Instrumentation Check Valve

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Abstract: The objective of this paper is to study and perform re-engineering of the check valve. In the present technological advancement and enhancement, check valves are used for variety of applications such as pumps, compressors, industrial processes like chemical and nuclear plants, petroleum and hydraulics etc. The check valve is a common piece of instrumentation fittings which allows only one directional flow. The main function of check valves is to prevent or minimize the development of reverse flow, as well as for preventing overflow. This function helps to protect systems from damage caused by reverse flow. This sort of function is essential for a variety of safety instruments. For Several types of applications, different types of check valves can be used which are having different characteristics. The check valve consists of merely six parts which ensures a required range of cracking pressure and other performance characteristics with smooth and safe operation.

Keywords: re-engineering, check valve, reverse flow, overflow, cracking pressure, performance characteristics

I. INTRODUCTION

Instrumentation valves and tube fittings are designed specifically for the many demanding applications such as chemical, petroleum, power generating, paper and various types of manufacturing industries. They, in combination provide a highly reliable, leak proof and torque free seal on all tubing connections. Check valves are common piece of instrumentation tube fittings which are also known as non-return or one-way valves. Check valves are designed to allow fluid to flow one way i.e. ability to pass fluid in solely one direction.

Fig. 1 Simple Check Valve

Check valves are often used with positive displacement machines such as pumps and compressors to prevent reverse flow in particular situation. These valves are often look like small cylinders attached to the pumps or compressors head on the inlet and outlet lines. Check valves are also used in many fluid systems such as those in chemical and power plants and in many other industrial processes. But for the fluctuating and cyclic loadings, check valves usually avoided.

The below, Fig 2 shows the pressure deactivated regeneration circuit, this circuit gives a fast advance and return from a lower volume pump when work is only done at the end of stroke. It is called a Regeneration Circuit since the rod end fluid is sent to the cap end during the fast approach. When the cylinder is advancing in regeneration mode the rod is the piston so extend force and speed is determined by rod diameter. On the retract stroke only the annulus area around the rod uses oil from the pump so speed is fast though force is low. Check Valve closes in the part of the cycle to stop pump flow from going to tank also. During this part of the cycle cylinder speed is half or less than it was regenerating but force capabilities are up to double. Pump flow goes around Unloading Valve through Bypass Check Valve and directly to the cylinder rod end. The cylinder starts retracting and cap end flow goes to tank through the directional control valve. Again the directional control valve sees up to twice pump flow and must be sized accordingly.

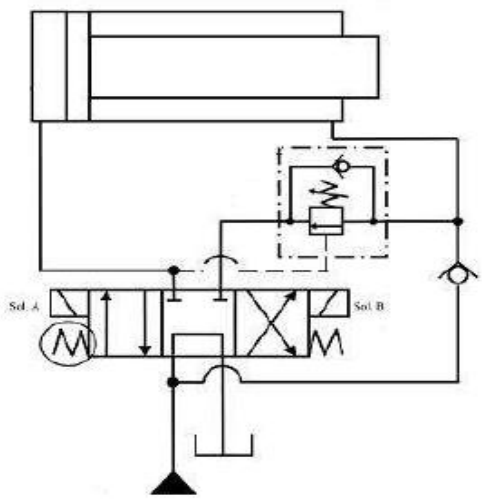

Fig. 2 Application of Check Valve in Regeneration Circuit

II. CHECK VALVE FUNCTIONAL EXPECTATIONS AND WORKING

The check valve should be sustainable, i.e. it should sustain high working pressure and environmental conditions. The check valve should have minimum number of parts and its size should be as small as possible. The design of valve should be simple, so that the complexity such as difficulty to operate under routine conditions, failure under shock loads, and difficulty of fixing when broken can be avoided.

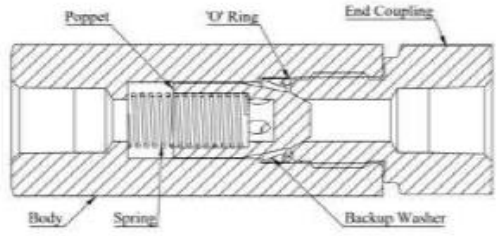

Fig. 3 Cross-Section of Check Valve

Check valve's construction is normally simple with only a few components such as the body, seat, poppet, and spring etc. Depending on design, there may be other items such as a stem, hinge pin, disc arm, spring, ball, elastomers, and bearings. Internal sealing of the check valve poppet and seat relies on fluid back-pressure. Metal sealing surfaces generally will allow some leakage while elastomers, such as Buna-N and Viton, provide bubble-tight shutoff (zero leakage). Because of this, elastomers should be considered for air/gas media, where chemically compatible, and low-pressure sealing. Because of their simple design, check valves generally operate without automation or human interaction and instead rely on the flow velocity of the fluid to open and close. This means they generally do not have a method of outside operation, like a handle or lever. According to the application and construction check valves are divided in various types as ball check valve, lift check valve, poppet check valve, butterfly check valve etc.

An important concept in check valves is the cracking pressure which is the minimum upstream pressure at which the valve will operate. Typically the check valve is designed for and can therefore be specified for a specific cracking pressure. Check valves are flow sensitive and rely on the line fluid to open and close.

Working of Check Valve:

Check valves commonly use a poppet and light spring to control flow as shown in the fig 4.

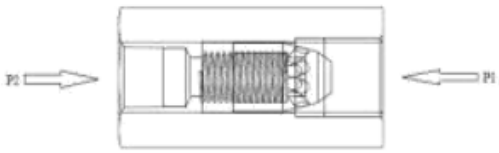

Fig. 4 Working mechanism of check valve

If P1A1 > P2A2 + spring force + friction, then the seal breaks and poppet pushed towards left and flow occurs, i.e. check valve opens.

But if P1A1 < P2A2 + spring force + friction, then the poppet would be pushed to the right, against the stop which forms the seal, prohibiting flow in the reverse direction, i.e. check valve closes.

III. REVIEW OF LITERATURE

Anthony Esposito from his book Fluid Power with Applications explained the function and modern application of check valve and its advantages over other types of valves. [1] William Orthwein and V.B. Bhandari from his books explains the design of various components with their analysis. These books also suggests the materials for the various components with their composition and material properties. [2][3]

K.S. Sriranjini, Abhishek H.V., Mandara Yograj, Dr. S. Nagaraja, explained design and analysis of check valve under static and thermal load conditions with material selection and geometric modelling of check valve. [4] The Daerospace Hydraulic Systems explains the working poppet check valve with mathematical relations having variables like pressure, area, spring force, friction, etc. evaluation of like spring force, friction, Pressure Rating, Regulation Range, Pressure Drop across the Valve, Temperature Rating, Valve Materials, Seals/Clearances, Leakage and Failure Modes. [5]

K.L. McElhaney shows the analysis of check valve performance characteristics based on valve design. It also tells that the performance of check valve depends on the check valve type and operating conditions. [6] S-LOK Tube Fittings journal and Parker Instrument Tube Fitting Installation Manual talks about the various applications of instrumentation tube fittings and their reliability and advantages over traditional method of pipe fittings. [7][8] DeZuric's APCO Check Valve Guide, Martin Lohse via Check Valves also proposed the characteristics of ideal check valve with reference of parameters like coefficient of valve, flow sensitivity, flow path, line size, open position, pressure drop etc. and it also talks about different types of check. [9][10]

Fevisa Check Valves explains about the different materials used for manufacturing check valves. Parker Hannifin Corporation Check Valve catalogue shows the performance curve of check valve i.e. Pressure vs. Flow parameters. [11][12] Val-Matic Design and Selection Criteria of Check Valve overviews the design considerations of various types of check valves. [13] Val-Matic Dynamic Characteristics of Check Valve talks about parameters like wave velocity, reverse velocity, pressure. It also talks about testing circuit of check valve. Flowserve Edward Valves explains application, installation, check valve flow performance, sizing of check valve. [14][15]

IV. IMPORTANT DESIGN CONSIDERATIONS

Designing check valves depends upon so many factors. These factors are analysed to get design inputs for the check valves. The list of such factors are mentioned below,

Flow Medium:

Identifying the fluid that will flow through the valve is the first and most important consideration. For the various types of fluids like fibrous, highly erosive, solid particle suspended, etc. different types of check valves can be used.

Flow Regulation:

Flow rate and velocity closely relates with the pressure drop. Increased flow rate or velocity may leads to lowering Cv of valve.

Sealing ability:

In general, there are two types of sealing materials - resilient or soft seat seals and metal-to-metal seat seals. Resilient seal provides a long lasting and leak proof seal.

Line Pressure vs. Valve Pressure Drop:

The valve pressure is subjected to full line pressure (upstream pressure) whereas the pressure drop ΔP is difference between the valve upstream and pressure exists that just downstream. Both pressure are equally important when selecting check valve. The line pressure determines the valve body rating whereas pressure drop determines valve trim or seat rating.

Pressure-Temperature Rating:

P-T is the maximum pressure which the valve can handle at a particular temperature and varies with valves materials of construction. Pressure handling capabilities declines with increase of temperature. Usually valves body can handle large pressure but material and design of valve seating cannot thus overall P-T rating is important.

Materials of Construction:

Selection of variety of materials of construction is generally based on their corrosion resistance to the line medium. Both metallic and non-metallic components must be considered. Concentration of material in fluid is very important. Most chemicals are easier to handle in dilute concentration. Temperature is an important factor in choice of materials because high temperature increase corrosion.

V. PRIME COMPONENTS OF THE CHECK VALVE

The check valve is a simple piece of instrumentation device, merely consists of six components which are as follows;

Spring:

A spring is a flexible elastic element used to exert a force or a torque and, at the same time, to store the energy. In other words we may say that the resilient member of valve. In check valve spring ensures the contact between poppet and ‘O’ ring when there is back flow.

Fig. 5 Spring of the Check Valve

Poppet:

A poppet is a valve component which covers an integral passage and is held in a space by a material flow pressure and spring. Poppet also ensures closed crossover and less wear of internal seal.

Fig. 6 Poppet of the Check Valve with a circular holes on surface

Threaded End Coupling:

Couplings are the mechanical devices which means to the act of joining two parts together. The most common application of it is joining of shafts of separately built unit. Threaded couplings are self-locking and it also provides protection against overloads.

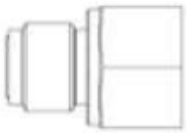

Fig. 7 Threaded End Coupling of the Check Valve

Threaded couplings have small overall dimensions which leads to compact design. The material used for thread are same as poppet. And ISO Metric Thread Designation of M16×1.5.

‘O’ Ring:

'O' Ring is the non-metal ring which forms the tight seal with the poppet.

Fig. 8 'O' Ring of the Check Valve

As it is metal to non-metal contact it forms resilient joints. When the inlet pressure raises above the cracking pressure the resilient seal breaks and material flows from inlet to outlet.

Backup Washer:

Backup washer is placed just behind the 'O' Ring. As the contact between the poppet and 'O' ring is not precise i.e. irregular shaped and slightly oversized backup washer is used to prevent leakage.

Fig. 9 Back up washer of the Check Valve

The material used for backup washer is Derlin.

Body:

Body is the outermost part of the valve. Body has internal threads which are similar to the threaded end coupling.

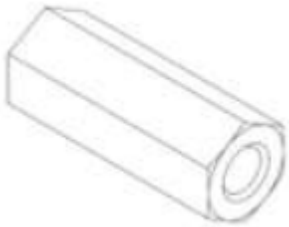

Fig. 10 Threaded End Coupling of the Check Valve

The hoses are connected to the body of the check valve. Body should sustain very high pressure as the maximum pressure exerted on the body. The material used for body is similar as threaded end coupling i.e. A 276 SS 316.

VI. RE-ENGINEERING OF FEW COMPONENTS OF CHECK VALVE

Spring:

In the check valve, spring should sustain high working pressure without failure. The check valves are generally subjected to static loading or very infrequently fluctuating loading but mostly subjected to severe service conditions. Some commonly used spring materials are Hard-drawn wire, Oil-tempered wire, Chrome Vanadium, Music wire, advanced alloy spring materials. As spring is subjected to severe service and according to the flow characteristics, Alloy A 276 SS 316 material which is subjected to high temperature heat temperature after spring forming followed by stress relaxation is preferred which ensures more safe operation.

In most of the situations spring fails due to direct shear due to applied loads or shear stress due to torsion, so according to application, by considering the factors like material properties, loading conditions, spring index (for spring used in valves; 4-14), Wahl factor (for curvature effect), the spring with required shear stress, rate of spring and deflection can be designed. From these values we can determine the other factors such as solid length, free height etc. diameter of spring should be lower than the inner diameter of seat. According to the above application, the open non-grounded spring may slip because of fluctuating loads, so the open grounded ends which The cross-section of the spring is circular as it shows more proof resilience with reasonable hardness over square or rectangular cross-section. As per the objectives, the size of check valve should be as small as possible, and the cylindrical space available between body and poppet the cylindrical helical spring with constant pitch is preferred over conical spring or barrel spring with variable pitch. The outer diameter of spring should be lower than the inner diameter of seat. According to the above application, the open non-grounded spring may slip because of fluctuating loads, so the open grounded ends which exactly fits in the slots provided in the body and poppet.

When the spring is subjected to the loading for number of various cycles, there should not be any change in the free height or solid length i.e. the spring should be reliable. And it is counted by the number of cycles for which spring sustains loading without any permanent deformation.

Poppet:

Poppet is one of the important component of the check valve which provides the passage to the material flow.

Poppet should form a resilient seal with the 'O' ring.

The material used for poppet is high end alloy as it is directly subjected to the high working pressure. Poppet is a hollow part which provides slots to the spring so that there will not be any slip of the spring. For the poppet subjected to sever service, alloy material is preferred, A 276 SS 316 can provide best results. For the safe operation permissible shear stress of material should be greater than force on poppet per area subjected.

The outer surface of poppet is chamfered at 60^{o} so that there won't be any direct impact of the flow when valve

is in open position and this chamfered edge also forms metal to metal seal with the help of spring force when in closed position.

The poppet must provide sufficient openings/passages to flow material, so that there won't be any pressure difference at the output flow line. Generally 4-6 holes with sufficient diameter were provided on the surface.

'O' Ring:

'O' ring is the circular non-metal ring with an inner diameter roughly equals to the outer chamfered diameter of the poppet which forms the resilient seal i.e. it ensures leak proof joint. The material used for the

'O' ring is Viton which is preferred for various flow material.

When the inlet pressure raises above the spring force, friction force and reverse pressure the poppet moved from its place i.e. seal breaks and valve opens.

As the 'O' ring is mounted on the slant edge of poppet, the complete leak proof joint is achieved with the help of backup washer.

VII. CONCLUSION

The check valves are the most important part of the instrumentation tube fittings. They have to be designed carefully to cope with precise working requirements. The paper presents the thoughts on re-engineering of the check valve which ensures the safe and precise operation of the valve. Spring plays main role in specific cracking pressure and it is also more prone to failure, due to shear by applied compression loading which can be overcome by using high end spring alloy material with high temperature heat treatment. The paper also comments on the rest two components, poppet and 'O' ring, with the various angles and openings on poppet and formation of seals with various metal to metal and metal to non-metal contact between poppet, 'O' ring and seat with-out large pressure drop. The paper also explains the various detailed operation, function and applications of check valve with the design considerations and various materials used for the check valves.

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