Conical, Floating Piston Isolation Valve

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ABSTRACT

These pages provide the details of a recently patented valve design titled the "Conical Seat Valve". This valve concept consists of a solid piston floating in amedium to controll flowstream. The piston is designed to be axially and radially balanced within the flow stream whether the valve is in the open or closed positions. The only force imparted onto the piston is that which the operator chooses to input on to it. The advantages to this concept are the elimination of conventional actuators which are replaced by one or two simple solenoid valves; elimination of valve actuator adjustments; consistant seating force no matter the pressure drop across the valve; elimination of the valve stem and stem seals; and elimination of most flow induced thrust forces. Additionally, the valve consists of five parts with simple seals incorporated into well protected designs. This simple design allows configuration for extremely high pressures and the use of soft or harder metal seats.

Keywords: valve, balanced, actuatorless, high pressure

1 THE PROBLEM

Although the patent is titled "Conical Seat Valve" and the conical shape of the seat is a prominent feature of the valve, , especially when the concept was first developed, the key feature of the valve is the balanced floating piston that acts as both the valve plug and the actuator. The origin of this design initiated based upon the need for large extremely high pressure valves to replace the ball valves currently used as supply valves tank pressurants in rocket testing. The current valves are 12,000 psi, 8" ball valve which flow 890 lbm/sec of gas through them during testing

The ball valves currently in use have been problemmatic during operation with very short lives and expensive rebuilds and redesigns that are often required. As supplied, the valves only operate two or three cycles before failure and can not be opened with a pressure drop across them. A recent redesign has extended their life span to over twenty cycles, but they still cannot be opened with a pressure drop across them; equalization is required before opening.

Instead of looking to "improve" the current valve, the thought was to determine what was causing the failures and design that out of the valve. By assessing this, it was determined that the forces acting on the ball by the seat retainers was extremely high and the interanl pressure acting on the valve stem to eject it was also extremely high. Failures were occuring in the trunnion and in the seat itself due to the excessive force being applied by the seat retainer, which used both springs and the internal pressure of the valve to generate a very high load on the seat retainer to hold the seat onto the ball. Because of this force, a large diameter stem is required to transmit the force of a very large actuator to the ball to get it to turn. As a result, the large diameter stem is also trying to be ejected by the internal pressure of the valve, which requires a thrust takeout feature that allows turning. Rolling bearings were not desired due to damaging effects upon failure they'd have on expensive equipment, and lubrication use was limited because the work is being conducted in a very high pressure oxygen environment. These issues lead to a design that initially featured bronze sliding thrust bearings, which led to subsequent revisions, that ended up with Torlon thrust bearings. This process can be equated to trying to turn the wheels on your car while the disc brake is applied. The Torlon disc actually wears much like the pads on the disc brakes but with a much shorter life.

2 THE CONCEPT ORIGIN

In trying to eliminate or control the forces acting on the ball and stem, the the seat retainer that pressed the seat to the ball using springs plus the additional force of the pressure drop across the valve was first approached. This design, a version found in most ball valves, causes the seating force to vary greatly depending on the pressure across the valve. This is also common in other valve designs, such as globe valves. Looking at the design, it was determined that the force generated by the valves internal pressure could be removed by adding an additional set of seals, and the pressure could be used to actually work against the springs if desired to lift the seat completely off the ball, allowing for free rotation. Upon noticing that when both seats were lifted, flow would move around the ball before the ball was moved, it seemed that by increasing the retraction of the seat, or now the valve stroke, the ball could be eliminated. The ball was replaced with a fixed seat, moving the wear item over to the non-moving part and designing channels to route the flow around the seat and out the other side of the valve.

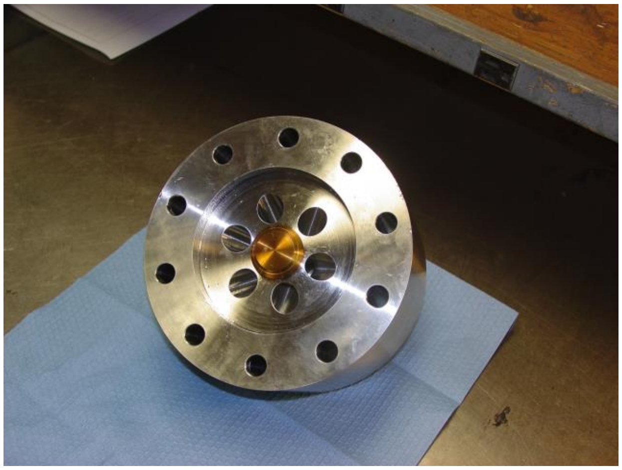

Figure 1: Original Head with flow passages

An additional chamber was added to eliminate the spring and power the valve in both the open and closed directions. The motive force for the piston could be either an external souce or the working fluid inside the valve itself. Finally, a final chamber was added to balance the force of the downstream pressure. This last innovation allowed all forces to be balanced on the floating piston no matter what position the valve is in or what the pressure drop is across the valve. This means the valve always opens or closes with the exact same force as per the design.

Figure 2: Demonstrator Valve Disassembled

The simplest way to look at the valve is as a globe valve in which all of the flow passes through the center of the plug instead of just being diverted off to the side of the plug. In this case, the plug and the seat are reversed in that the seat is a solid disc, whereas on typical globe valves the seat is a ring and all of the flow passes through the seat. The piston is designed so that it is not influenced by the pressure drop or flow inside the valve.

3 ADVANTAGES AND FEATURES

This concept has many unique features and design advantages over conventional valve concepts. First, the flow path is always axially and radially symetric, eliminating almost all of the flow induced thrust loads, even during transition from closed to open. This minimizes the need for mounting restaints and a thrust take-out structure.

Next, the flow areas where the flow is required to change direction over the seat and through the connecting passages, are designed to at least 150% of the cross sectional flow area of the inlet and outlet pipes. The inlet, outlet, and piston passages should match the pipe, exactly as ball valves are designed to do. The 150% area is estimated to reduce the velocity in the turbulent regions and minimize flow losses. Modeling indicates that this design will have an approximate 15% improvement in flow over a similarly sized standard globe valve.

The next, and largest advantage, is the elimination of the valve stem and any conventional actuator. No matter how large or how high a pressure, the valve is designed for one or two small solenoid valves that will operate the valve completely. For very high pressure valves, stem seals and bending of the valve stem are two major issues that cause valve failure. Because of the design concept of this valve, there are essentially no bending forces that have to be addressed. Since there is no valve stem, there are no stem seals to leak or to protect from gettting dirty and scaring or binding the stem.

With the elimination of the valve stem, the need for a conventional valve bonnet is eliminated as well. Instead, the body of this valve is formed by two cylindrical parts which are squeezed together with a bushing between them. The elimination of the bonnet reduces the envelop and mass of the valve by an estimated 30%.

Additionally, the features of the parts are all simple circular features, so everything can be either turned on a lathe or drilled on a simple mill. This reduces fabrication time and cost.

Because of the large diameter seat, the amount of piston movement needed to achieve full flow is greatly reduced. Typical globe valves may have a plug assembly that has to travel over three inches in order to get sufficient flow area. With this innovatve concept, travel of only about ¾” will meet the design requirement of 150% cross sectional flow area through the seat opening. This short stroke allows for reduced valve actuation times while keeping the piston velocity much lower. An issue seen with large, rapid actuation valves is that the valve stem actually stretches when the actuator tries to slow the valve, right before it slams into the seat. With the reduced velocity and increased seat contact area, slowing may not be required. If slowing is required, it will be achieved through baffling the venting process of the opening chamber and therefore, no hard pulling or stretching is required. Additionally, contact will always be with the same amount of force no matter what the pressure drop is across the valve.

Another advantage to eliminating the connection to a valve stem is the elimination of the need for valve adjustments. Conventional valves require the stroke to be adjusted as the seat wears or is coined in. Because the piston floats in this valve, it will move forward until it is stopped on the seat. Seat wear or temperature changes will not affect either the force of the closure or the contact area with the seat.

Because the piston is balanced within the flow stream and so the force required to close the valve is always the same, the amount of gas required to operate the valve is reduced by over 90% of that required for a conventional pnuematically actuated valve. Large pnuematic actuators can cost over $50,000 and be several feet in diameter and length, adding to the envelop of the valve. Although the large reduction of gas required to operate the valve may be a small cost portion of the total cost, it may allow the valves to be operated with a gas source such as a K-Bottle or a compressor, and thus eliminates the need to run high pressure gas tubing to every valve in a system.

Overall, with the fewer parts, smaller size, robust component shapes and designs, shorter stroke, and consistant seating force, the valve is expected to demonstrate increased reliability and life over comparable conventional valve designs. The cost of fabrication should also be significantly less and should require less raw material. Because of the balanced design, the valve is also inherently bi-directional. The closing force is exactly the same, even if the higher pressure fluid is on the "downstream" side of the valve.

4 OPERATION

The functional operation of the valve is very simple. The entire body and pressure boundry is formed by three parts, the main body, the bushing, and the head. In the first concept, these are all held together by bolts or studs squeezing the three parts togther with the bushing in the middle and everything sealed with o-rings.

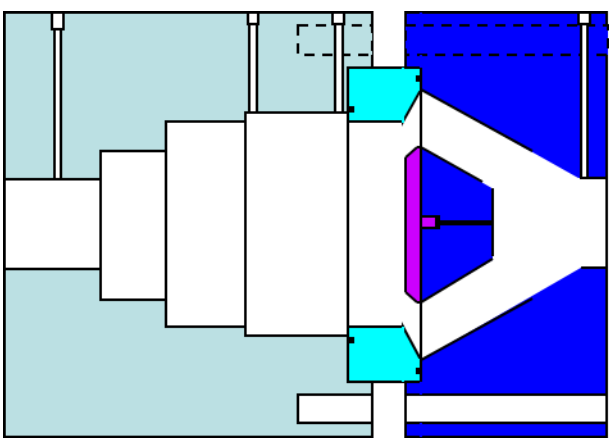

Figure 3: Pressure Boundries

The floating piston is positioned inside the body assembly and seals to the body assembly in four places with circular seals such as o-rings, or pressure energized seals, such as omni-seals. The piston and body shape combined with the four seals form three annular chambers on the outside of the piston.

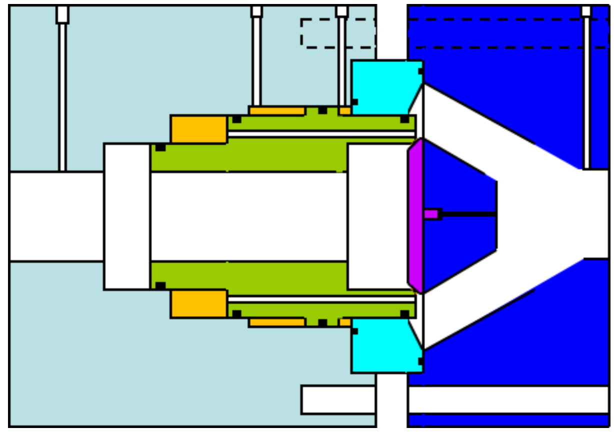

Figure 4: Chambers

The first chamber is connected to the downstream face of the piston through a series of holes drilled through the piston. This connection between the chamber and the downsteam face can be done externally through the body if desired, but in in Figure 4, it is through the piston. The annular area of the downstream face of the piston is exactly equal to the connected face area of the piston in the cavity. Because the two faces have the same area and see the same pressure, no force is generated to try to move the piston by either of these areas no matter what the pressure is inside the valve.

In similar engineering, the upstream face of the piston is equal in area to the expanding area of the flowpath inside the piston. So again, the pressure acting on both of these faces will be equal and thus the forces generated by these pressures will cancel each other out and not generate a motive force trying to move the piston.

The remaining two chambers are equal in size and connected to the outside of the valve body through a drill passage for each. These chambers are the operating chambers and provide the force to open and close the valve. The working fluid to operate the valve is up to the valve designer and user. The force required can be generated by any pressure gas by varying the outer diameter of the chamber. The working fluid can come from an external source or use pressure from the inside of the valve. The operation of the valve is simple; one chamber is pressurized and the other chamber is vented. The piston moves in the direction of the vented chamber until it is physically stopped by either the seat on closing or the main body surface on opening. The speed of the piston is easily controlled by controlling the rate at which the venting chamber bleeds off.

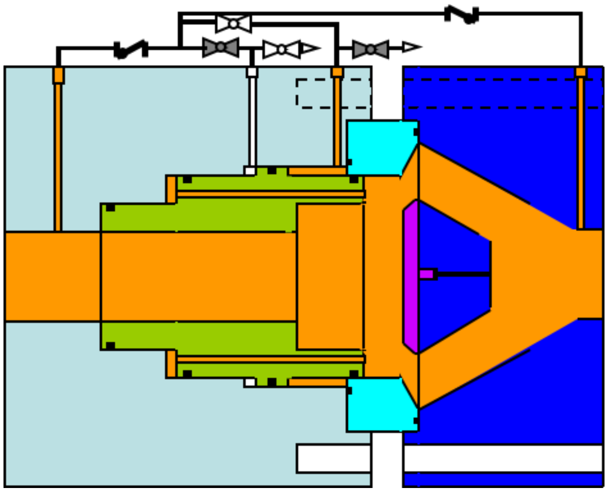

Figure 5: Open Configuration

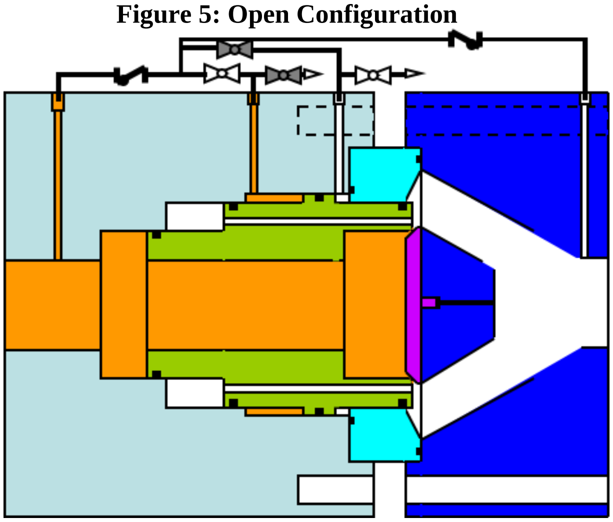

Figure 6: Closed Configuration

5 DISADVANTAGES OR CHALLENGES

The most significant challenge assocaited with this valve concept is that there is no obvious way to see the position of the piston in the valve..

Another challenge of this design is that the valve has to be removed from the line in order to be serviced. Many ball, globe, and gate valves permit the bonnet to be removed and the valve serviced while the body remains installed in the field. Designers generally design the wear parts in a way that they are accessible and replaceable in the field. That may not be possible with this valve concept, however, its fewer parts and predicted increased reliability may make that a minimal factor.

6 SUMMARY

The balanced, floating piston valve design has a wide range of potential applications of all sizes and pressure ranges. The extremely simple design and few parts makes the concept inherently reliable, simple to manufacture, and easy to work on. The valve concept works with soft or hard metal seats, and the closing force is easily adjustable so that any closing force desired can be created. The valve will consistantly close with exactly the same force as long as the driving medium is at the same pressure as designed. The fact that no adjustment is required in the design will ensure valve performance thoughout the life and operation.

The one moving part with incorporated simple seals in a well protected configuration, along with the short travel of the piston, should add to the life of the valve and reduce associated maintenance.

In addition, the reduction in commodities needed to operate the valve will reduce overall life cycle cost and enable designs that operate longer on smaller accumulators in the case of a loss of the operating medium or in power failures.