ACCURATE VALVE CONTROL WITH DeZURIK POWERRAC RACK AND PINION ACTUATOR

Modern DeZURIK PowerRac rack and pinion actuators with positioners provide valve control as accurate as traditional spring diaphragm actuators. The most important principle to remember is the positioner on top of the actuator must know exactly where the valve's flow control element (ball, plug or disc) is at all times. All connections between the flow control element and the positioner must be rigid and backlash free.

Control Valve Power Train Assembly

The control valve power-train assembly consists of a number of connections from the valve to the positioner. Accurate control valve performance depends on tight, hysteresis and stiction-free connections so that the positioner precisely reacts to any change in the position of the valve's flow control element. The connections include the shaft-to-ball/disc/plug; the shaft-to-gear; and the positioner-to-actuator.

Valve Shaft-to-Ball/Disc/Plug Connection

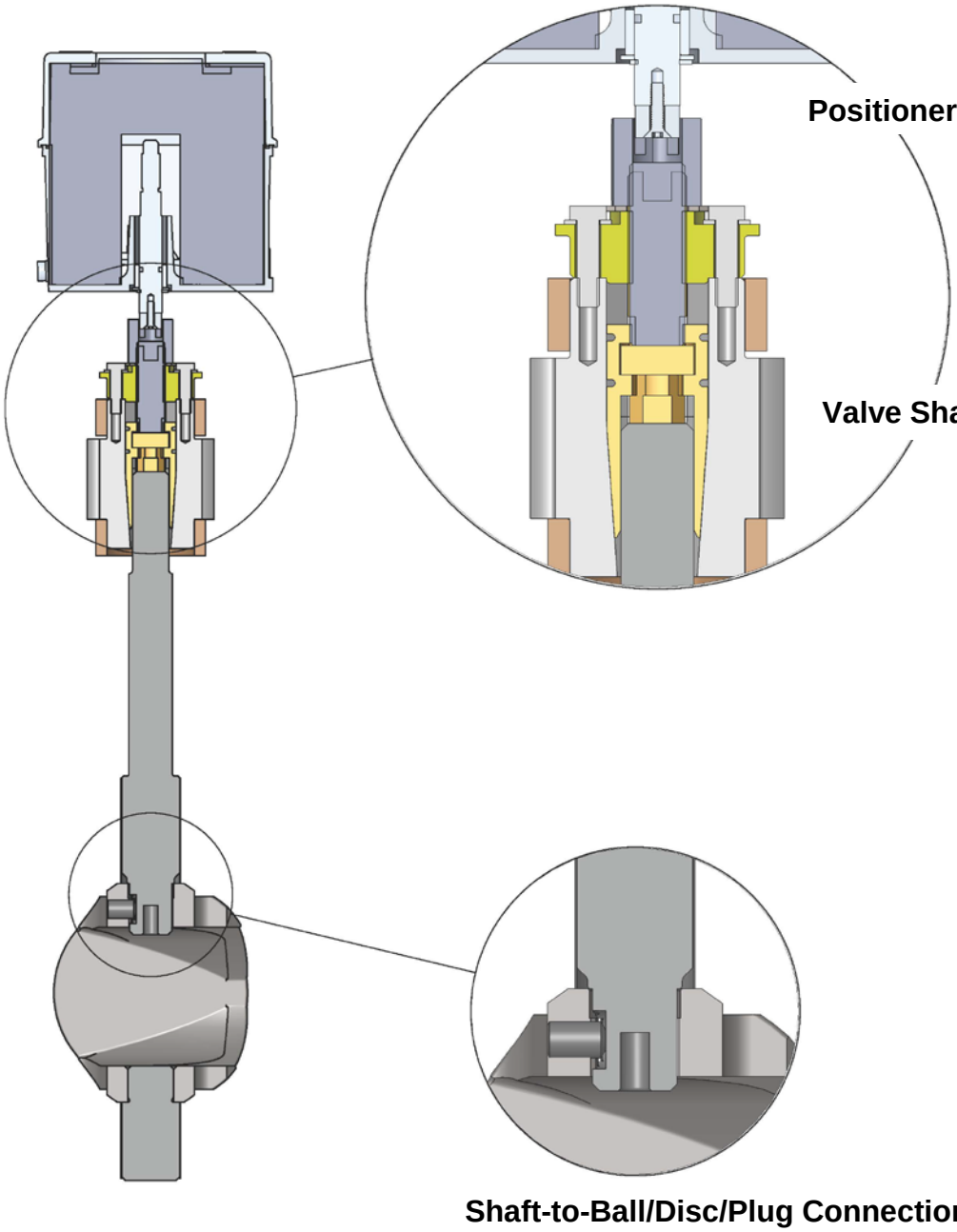
The first connection in this power train is the valve shaft-to-flow control member, which varies depending on the style of valve.

On DeZURIK V-Port Ball valves and Rotary Control valves, a splined connection with a lock screw gives a very strong, tight connection between the valve shaft and the ball/plug. A stainless-steel lock screw biases the spline against itself which effectively eliminates any backlash, but retains the inherent strength of the spline. The lock screw connection also facilitates the ability to take the connection apart if rebuild is ever required. An analysis of a splined connection part without a lock screw reveals that up to 1% backlash is possible due to normal manufacturing tolerances.

On High Performance Butterfly valves, there are several ways a dead-tight connection between the valve shaft and disc can be made. DeZURIK valves utilize a wedge-shaped tangential pin with a locking taper, or two pins mounted in compression, to provide a non-shear method of ensuring no lost motion between the shaft and disc, while providing a connection that can be disassembled if maintenance is required.

On Eccentric Plug valves, the plug and shaft are cast as one piece, ensuring no lost motion.

Control Valve Power Train Assembly



Positioner-To-Actuator Connection

Valve Shaft-To-Gear Connection

Shaft-to-Ball/Disc/Plug Connection

Valve Shaft-To-Gear Connection
The valve shaft-to-gear connection is next in power train assembly. This connection can be a simple slip-fit connection or a tight, clamped connection.

If it is a simple slip-fit connection, either a round shaft with key or a broached gear over a square or hex on the end of the valve shaft, then the positioner is tightly connected to the valve shaft itself, not the actuator gear. This is usually accomplished by locking a threaded stud into a tapped hole in the center of the top of the valve shaft, extending the stud through the gear, and connecting the positioner to the top of the stud. The positioner is driven off the valve shaft and not the gear, so any looseness or backlash due to the slip fit connection between the gear sector and valve shaft is out of the power train.

The second type of connection is a tight, clamped connection. PowerRac actuators utilize an adjustable square collet coupling to provide a backlash and hysteresis-free valve shaft-to-gear connection. This coupling is based on the principle of a drill collet. It consists of four heat-treated 17-4 stainless steel investment cast wedges that are tapered to 4 degrees. They mate with a matching four-degree taper inside the gear when the adjusting screw is rotated. Since a four-degree taper is a locking taper, the valve shaft-to-gear connection is permanently locked together and will not come loose until released by the adjusting screw. All components are in compression and therefore there are no parts to wear. Therefore, the valve shaft-to-gear connection is backlash and hysteresis free and the positioner can be driven off the top of the shaft-to-gear connection.

Positioner-To-Actuator Connection
The final connection between the positioner and the actuator is perhaps the most critical. Like the other connections, it must be totally backlash and hysteresis free. It is also critical that no undue side loads be exerted on the positioner input shaft bearings. Positioner manufacturers have done extensive testing and determined that any significant side load or play in this bearing adversely affects the overall control performance.

To eliminate this problem, DeZURIK uses a male square on the positioner shaft that self-aligns the positioner with a female square in the positioner drive coupling mounted on the actuator. The positioner drive coupling is accurately aligned with the center of the valve shaft. The positioner mounting bracket has enough freedom to allow this connection to align the positioner to the center of the actuator. With analog cam-type positioners where the cam exerts a spring load to the positioner input shaft, the spring load biases the shaft square in the coupling, eliminating any backlash from the connection. With digital positioners that do not have any spring load on the input shaft, two set screws create a tight connection in the positioner coupling to eliminate backlash.

Other Factors Affecting Accuracy
One common misconception of rack and pinion actuators is that backlash between the rack teeth and gear teeth will adversely affect control accuracy. If the positioner was driven off the rack this would be true, but since the pickup for the positioner is off the gear, the position of the rack is inconsequential. To demonstrate this, a valve with a PowerRac rack and pinion actuator and positioner were dynamically tested in a flow system. Then 0.15"

(1mm) was machined off the back surface of the rack to create backlash in the actuator. The valve was tested again, and there was no change in performance.

Rack and pinion actuators with their constant torque curve and ability to use higher supply pressures have much greater stiffness in any throttling range than spring diaphragm actuators. This produces a more cost-effective package because smaller actuators can be used and frequently pressure regulators are not needed. Installation and maintenance are also easier because of the smaller package size.

Other key areas of rack and pinion actuator design that are critical to accuracy are the rack and gear material, the finish on the back of the rack gear, the piston seal and the finish on the piston rod. To produce a long-lasting actuator, the rack and pinion should be made from strong materials. Cast ductile iron or heat treated, high carbon powder metal are two commonly used materials that have stood up well to shock loads and provide long service life in all types of applications. The finish on the back of the rack that mates with the rack bearing is critical for optimum control performance. The surface should be ground to a 32 micro inch finish or better to reduce the coefficient of friction between the two surfaces.

A high-quality cylinder assembly will assure a long, trouble-free life with good control accuracy. The smooth finish of a fiberglass cylinder provides for smooth, efficient operation and resists corrosion and pitting. PTFE piston seals instead of o-rings are crucial. O-rings tend to roll and performance begins degrading after as little as one thousand cycles. PTFE piston seals on the other hand provide low stiction performance for well over one million cycles. In fact, the seal stiction decreases as the actuator is cycled. The reliability of the piston seal is one major advantage of cylinder actuators over spring diaphragm actuators. When a diaphragm fails, the failure is catastrophic because the valve stops working immediately. When a piston seal begins to wear, it starts blowing by the seal and exhibits a gradual degradation of performance over an extended period of time that can be easily corrected during the next scheduled maintenance outage.

Performance Limitations of “Lunchbox” Style Rack & Pinion Actuators

What is commonly referred to as a lunchbox rack and pinion actuator is unable to perform at a level adequate for precise control. The following are key limitations to the lunchbox actuator: small gear (pinion) diameter; short rack stroke length; slip fit (clearance) connector from valve shaft to actuator gear; o-ring sealing piston to tube; rough cylinder finish; and positioner driven off actuator and not directly off valve shaft.

Conclusion

Precise control valve performance is obtained when the positioner exactly reacts to any movement of the valve ball/plug/disc. That level of control is achieved with tight mechanical connections between the ball/plug/disc and the positioner linkages. The DeZURIK control valve package with PowerRac rack and pinion style cylinder actuators provide the precise control required in today's process systems while maintaining the lower cost, smaller size and the greater reliability of double acting cylinder actuators.