White Paper

The Case for Tangential Wedge Pins in Quarter-Turn Valves

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Introduction

There are many possible ways to attach the closure member of a quarter-turn valve to the valve's actuating shaft. This connection sees loads primarily based on the actuating torque requirements. Other tensile or compression loads from the fluid pressure, temperature, and flow are relatively small by comparison and for the purposes of this paper may be ignored.

This connection must transmit high torque loads which are often fluctuating from turbulent fluid flow and change rotation direction with each opening and closing stroke. This connection must also be tight and free of hysteresis as these valves are often used in throttling and even in on-off service must repeatedly position the closure member accurately into the seat.

Figure 1 depicts several of the most common shaft-to-disc connection methods. These are:

A	Square or rectangular key
B	Round Key
C	Flat Key
D	Kennedy Keys
E	Centered Straight Pin
F	Centered Roll Pin
G	Centered Taper Pin
H	Centered Rivet Pin
I	Tangential Straight Pin
J	Tangential Taper Pin
K	Tangential Wedge Pin

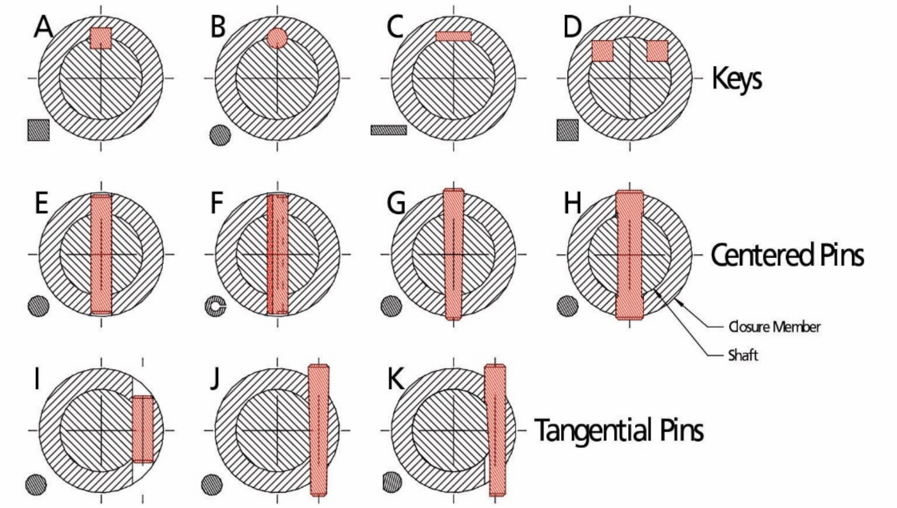


FIGURE 1. Typical Quarter-Turn Valve Shaft to Closure Member Connection Types

Analysis

The first four keyed connections (<u>A through D</u>) are not typically used because the installation and removal of the key is often impossible in many valve designs. Even when the design is such that this connection can be used there is an amount of hysteresis in the connection unless the keys are tapered, interference, or shrink fitted. In either case, a hysteresis free connection is not well suited to mass production techniques, is not an interchangeable design or is not easily repaired in the field. Therefore, these connections are not popular in quarter-turn valves.

The next two straight centered pin connections (E and F) also have some major drawbacks. First there is an amount of hysteresis when using the typical mass production machining fit dimensions. Use of precision fit dimension tolerances, interference, or shrink fit techniques here is also costly and not well suited for mass production and economy as well as parts interchangeability. Use of distorted locking, spiral rolled and "C" form spring type pins reduce the hysteresis initially but tend to loosen in service because of the highly reversing torque requirements. Next, the hole through the center of the shaft removes a large amount of the shaft's cross-sectional area and causes stress concentration factors in the valve shaft of values greater than 2.1 to as much as 4.6 for most optimal pin diameters of about 20% to 40% of the shaft diameter.

This reduces the strength of the shaft significantly and the size of the pin must be balanced with the shaft diameter based on the relative strengths of the shaft, the closure member, and the pin materials to optimize the joint strength. As a result, these first six connections are not often used of quarter-turn valves.

The next two straight centered pin connections (G and H) are often used as they are tight fitting (little or no hysteresis) and are suitable for mass production. Like the E and F centered pin connections, these joints are susceptible to high shaft stress concentration factors and the relative size of the pin to the shaft should be optimized based on the relative strengths of the three materials (shaft, closure member, and pin).

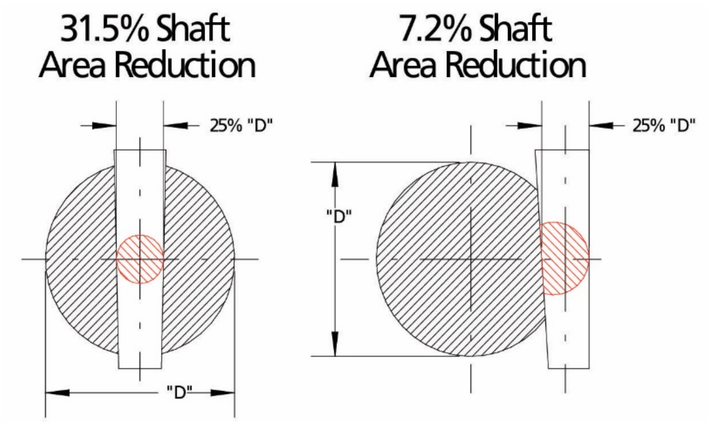
The taper pin of the type G connection makes this assembly non-interchangeable as the shaft and closure member must be match taper reamed for the taper pin. Therefore the shaft, closure member, and taper pin(s) must all be replaced or repaired together and considered a single, matched set rather than three separate components. The tapered pin is often held in place with a secondary pin, set screw, nut or threaded fastener which keeps it from loosening in service.

The centered rivet pin of the type H connection is formed with the pin hole in the shaft being slightly larger than the diameter of the pin and the pin hole in the closure member being slightly greater than the pin hole in the shaft. When assembled in the valve body the entire valve assembly is placed in a press and the pin is loaded and is deformed. As the pin is loaded axially in the press above the yield point of the pin it increases in diameter to fill the pin holes in both the shaft and closure member. This connection is tight, does not have any hysteresis, and suitable for mass production. The drawback to this structure is that it cannot be disassembled without destroying the pin. Also reassembly requires the use of a large pin press. As with all centered pin connections (E through H), this connection reduces the strength of the shaft significantly and the size of the pin must be balanced with the shaft diameter based on the relative strengths of the shaft, the closure member, and the pin materials to optimize the joint strength. Also, if coupled with brittle shaft or closure member materials (e. g. cast iron) it is easy to induce fractures.

The connections I through K employ pins that are located tangentially to the shaft. This connection removes less than half of the shaft material necessary for a centered pin and tremendously reduces the stress concentration factors. Although this arrangement creates stress concentrations in the shaft and closure member, the magnitude of the concentration is much lower. In this case, stress concentration factors in the shaft are only about 1.35 to 2.1 for pin diameters from 20% to as high as 58% of the shaft diameter. This means that the joint strength is increased, the pin to shaft diameter ratio is not as critical and stronger (larger) pins can be used without reducing the shaft strength.

The type I, straight tangential pin, connection does still have issues with hysteresis and mass production like the other straight pin designs but the types J and K (tangential taper pin and tangential taper wedge pin are tight fitting connections.

The reason tangential wedge pins cause much lower shaft stress concentration factors than centered taper pins can be easily seen by comparing the amount of shaft area lost in both the installations. As displayed in Figure 2 the taper pin installation reduces the shaft cross-sectional area by 31.5% while the tangential wedge pin only reduces the cross-sectional area by 7.2%. Additionally, the diameter of the wedge pin can be increased for greater contact area with the shaft without changing the shaft cross-sectional area.



Design Selection

In the design of any product it is normal that there are many juxtaposed requirements or traits that can make selection of a specific element unclear. When confronted with such a task it is best to select the 5 most important design qualities and rate all of the designs for each of these on a three level ranking system (e.g. good, moderate, poor or good, better, best). In this case we selected the following 5 design characteristics for rating each connection type

A. Suitability for high production techniques
B. No or low joint hysteresis
C. Part interchangeability
D. Low stress concentration factors
E. Ease of field repair

The following table shows how we rated each design against each of these characteristics.

Type	Description	Suitability for High Production	Low Hysteresis	Parts Inter-changeability	Low Stress Concentration Factors	Ease of Field Repair
A	Square / rectangular key	Good	Moderate	Good	Moderate	Good
B	Round key	Good	Moderate	Good	Moderate	Good
C	Flat key	Good	Moderate	Good	Moderate	Good
D	Kennedy keys	Moderate	Moderate	Good	Moderate	Good
E	Centered straight pin	Good	Moderate	Good	Poor	Good
F	Centered roll pin	Good	Poor	Good	Poor	Good
G	Centered taper pin	Poor	Good	Poor	Poor	Moderate
H	Centered rivet pin	Good	Good	Good	Poor	Poor
I	Tangential straight pin	Good	Poor	Good	Good	Good
J	Tangential taper pin	Poor	Good	Poor	Good	Moderate
K	Tangential wedge pin	Good	Good	Good	Good	Good

Conclusion

The tangential wedge scored the highest in all of the characteristics selected as being the most important to the design of this critical valve joint. Val-Matic uses this connection as the preferred method for its quarter-turn valves.