(P728) Globe Valve Design Optimization & Trends

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Abstract:

In recent years, valve manufacturers across the world have focused their attention towards developing high performance globe valves design to outweigh the problems caused by the conventional globe. The valve manufacturers use FEA & CFD simulation tools to effectively optimize the design.

This paper briefly explains the typical problems faced in the industry with the conventional globe such as the difficult manual operation due to higher valve torque, stem bending issues in stainless steel material, packing performance deterioration by rotating stem design, galling problems at stem threads and at flange bolts and gland packing eyebolts at low temperature. It also dealt on the common control valve parameters which degrade performance like cavitation problems leading to erosion, reduced flow capacity, flow separation & recirculation, pressure drop across the valve & Noise levels.

The problems with conventional globe designs were addressed by developing the high performance globe valve. These are designed to achieve high sealing performance with lesser hand wheel effort by the introduction of new features like non-rotating stem globe design, in-suite seat arrangement (Integral body seat design) and seal-welding of threaded seat ring and guided disc arrangement. FEA and CFD tools are used to optimize the body-bonnet cover flange thickness, disc thickness and flow geometry.

1. Introduction:

Economic and environmental constraints dictate the need for the efficient performance of valves in stringent environments. Keeping this in mind, the globe & control valve designs were optimized using the latest software for FEA and CFD.

Standard globe valves are used in throttling applications where the flow rate is moderately regulated by manually adjusting the disc positions whereas in control valves the flow is very precisely controlled by the automatically operated actuators in the closed loop system. The control valves have inherent flow characteristics that define the relationship between the valve opening and flow rate under constant pressure conditions.
Globe valves over a period of usage face several typical problems in the site like deteriorated packing performance, seat leakage, difficulty in operating the valve & stem bending problems in stainless trims and binding of yoke-sleeve and stem threads due to the galling process etc. This paper explains in detail about the various problems faced in the site along with the solutions to overcome such issues and also it talks about the new globe features that enhance product performance. The cost focus was also given to reduce the valve weight in view of the global concerns on cost reduction. Weight reduction is done by optimizing the various parameters like cover flange thickness optimization using Finite element analysis (FEA).

2. Review of Globe valve: (Conventional type)

In recent years, the valve manufacturers across the world focused their attention towards developing high performance globe valve designs to outweigh the problems caused by the conventional globe.

2.1 Typical problems faced in the industry with conventional Globe:

- Higher valve torque due to the high thrust force acting on the disc.
- Difficult manual operation.
- Stem bending problems more prominent in stainless steel material.
- The high frictional forces at the stem threads & yoke sleeve collar faces leads to high torque and shortens valve life.
- Rotating stem design deteriorates the packing performance at fewer cycles.
- Improper selection of stem and yoke-sleeve material resulting in galling.
- Stem binding due to galling with the mating components.
- Gland packing leaks –not meeting fugitive emission requirements.
- Galling of flange bolts and gland packing eyebolts at low temperature.
- Threaded seat ring design leaks at high pressure applications.

3. Globe valve Optimization and its Trends:

The conventional globe designs were modified to address the above problems and also redesigned to meet the stringent requirements of the customer like achieving tight sealing performance with lesser operator force and fugitive emission requirements. Apart from redesign, these components were also
optimized for weight reduction by using FEA tool. The performances of the globe valve design are enhanced by the introduction of the following new features:

**Globe Valve New Design Features:**

- Non-rotating globe design arrangement significantly reduces the valve torque.
- The fugitive emission service requirements are met by eliminating the packing erosion caused by the stem rotation.
- In-suite seat arrangement (Integral body seat design) and seal-welding of threaded seat ring eliminates the leakage through the seat threads.
- Guided disc arrangement and selection of high strength stem material avoids the stem bending problem as well improves the sealing performance.
- Body-bonnet cover flange thickness and disc thickness optimization using ASME calculations and FEA simulation.
- Validation of theoretically determined flow coefficient (Cv) against the CFD simulation method.
- Introduction of needle roller/thrust ball bearing at the yoke-sleeve collar faces reduces the friction. Also the introduction of washers and application of proper lubricants at nut surfaces helps to reduce the galling of bolts.
- Selection of proper material of stem and yoke-sleeve avoids galling in the threads (ex. Al.Bronze with SS combination).
- The new taper seat angle reduces the seating thrust and hence the torque.
- Disc seat contact at the bottom for tight shut-off

### 3.1 Non-Rotating Stem Design:

The conventional rotating type globe designs have more difficulties in manually operating the valve due to higher valve torque. This problem is addressed by converting from rotating to non-rotating type stem design. This helps in reducing the valve torque by 15% to 25% when compared with that of the rotating stem design due to the elimination of packing frictional torque. The anti-rotating device across the stem flat prevents the stem rotation and allows only the guide support to linear travel through the slot guide provided in the bonnet. The fugitive emission requirements are easily met by preventing the stem rotation and also the packing life is enhanced by minimizing the packing erosion. Figure.1 and Figure.2 shows the arrangement of non-rotating stem design and the anti-rotating device.
3.2 Disc Seating Taper Angle:

Disc sealing force is the force which is exerted on the disc against the seating surface to have tight shut-off. The sealing force can be reduced by changing the taper seat angle from 30 to 20 degrees as the force component vector depends on the seating angle. The figure 3 depicts the disc taper angle.

\[ F = 3.14 \times D_s \times W \times P \times \sin (A+B) \]

Where
- \( F \) = Seating force
- \( D_s \) = Diameter of seat ring bore
- \( W \) = Width of the disc contact area.
- \( P \) = Fluid pressure
- \( A \) = Seat angle
- \( B \) = Friction angle.

In the above formula when “A” is changed from 30 to 20 degrees, the sine component reduces and hence the disc sealing force.
3.3 Body Guided Disc Type:

In this arrangement, the disc is very closely guided along the ribs provided in the body, during the valve opening and closing. This supporting rib reduces the alignment variations caused by the bending of the stem. Also it takes up the bending load that comes on the stem when the hand wheel is over-tightened and also it resists the side thrust exerted on the disc. This guiding arrangement provides effective sealing of the disc by the effective transmission of the hand wheel force to the disc. The figure.4 & 5 shows the body guided ribs.

3.4 In-Suite Seat Ring:

This design provides integral seat ring on the body itself by directly depositing the stellite over the base material. This enhances alignment control within closer limits between the seat and disc during the valve closure. This also ensures uniform contact of the disc over the seat surface and thereby reduces the
possible leakage path caused by non-uniform wear on the disc. This is generally used for large size valves where the sealing force is high.

Figure .6

3.5 Introduction of Thrust / Needle Roller bearing:

The thrust taking roller bearings are introduced on either side of the collar face of the yoke-sleeve of the gate valve to take up the axial thrust load. In the absence of the bearing, this load acts on the yoke-sleeve face and produces high frictional force, which is compensated by providing additional force on the hand wheel. The introduction of this bearing reduces frictional force developed between yoke-sleeve faces and hence easier the operation of hand wheel. The figure.5 shows the bearing on either of collar faces.

Figure.7

3.6 Aluminum Bronze Yoke-Sleeve materials:

A high frictional force is generated between the stainless steel stem and nodular cast iron yoke-sleeve acme threads due to the wear of soft SS stem by the harder yoke-sleeve material. This frictional force is reduced by the introduction of
aluminum bronze yoke-sleeve material, as it is a good self-lubricator and also has better anti-galling property. This reduction in force reduces the operator effort and hence makes the operation easier.

3.7 Design Optimization – using FEA

Finite element analysis is done on the pressure subjected components like body, bonnet & disc using FEA package. Structural analysis ensures that the stresses and deflection induced are within the allowable limits. The pressure loads are applied on the body and disc surfaces exposed to the line fluid and also bolting load is applied on the body & bonnet bolting spot face area. These gives the realistic picture of how the valve behaves under the pressure conditions. Fixed constraints are given on the end flanges of the body to stimulate that it is fixed on the pipe flanges. The Figure 8,9 &10 shows the FEA analysis on body, bonnet & disc.

The body stress plots shows that the maximum stress induced is 14000 psi, which is less than allowable stress of 20000 psi for stainless material. Similarly the disc stress and strain induced are within the allowable limits. The fringes of red color is the maximum value and blue is the minimum value induced.
3.8 Cover Flange Thickness Optimization – FEA

The Body-Bonnet flanged joint flange thickness is calculated by using the ASME SECTION VIII calculations. After the developments of CAD/CAE software, the valve industries started realizing that the ASME calculations were excessively conservative due to the more factor of safety on the mechanical strength which is inbuilt in the ASME approach of design by codes. The designs are validated using the ASME calculations and also by FEA. The FEA analysis gives the opportunity for optimizing the flange thickness further to meet the demands of the market on reducing the weights for cost reduction. The weight reduction along with the enhanced performance made the product always to be competitive in the market.

The ASME calculations and the FEA results are compared and analyzed for the optimized flange thickness. The FEA accurate interpretation of the results gives the designer a better opportunity for optimizations. In this analysis each single load can be detailed and the possibility to include the real and also non-linear bolts and gasket behavior get the loads. The real geometry can be taken into account including the uni-lateral contacts, material non-linearities and hub geometry.
The above comparison shows that the design by code and design by analysis predict that the ASME is excessively conservative and design by analysis can be applied to get an optimized design with consistent material, machining and cost saving. The above results shows that the flange thickness can be reduced by another 40-50% and this will lead to a significant weight reduction. The Body-Bonnet cover flange optimization in 8” cl 150 Globe valve results in 10% weight reduction. The figure 11-14 shows the body-bonnet assembly, stress and deflection plots.

![Figure.11](image1.png) ![Figure.12](image2.png)
4.0 Conclusion:

It has been shown that the means of improving the conventional globe performance by adopting the new features like Non-Rotating stem, Integral seat, Guided disc etc. These new features are incorporated in the design to improve the performance parameters like valve sealing leakage rate, valve torque, packing emission requirements and minimized hand wheel effort.

It has also been shown how FEA and CFD tools are used to effectively optimize the valve design. For instance, the body bonnet flange thickness optimization through design by code and design by FEA shows that the theoretical calculations results were very conservative compared to the FEA results. This approach leads to the significant weight reduction of the flange weight by 50%. Also FEA was done to validate the design by ensuring that the stress and strain levels are within the allowable limits.

5.0 References: