Optimization of Flow Bore on Ball Valve Assembly by Using 7 New Quality Tools

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Abstract— In the field of competition, all companies should supply their goods and services with high quality, in shortest period with lower prices than its competitors in order to survive the competitive environment. A ball valve is a form of quarter-turn valve which uses a hollow, perforated and pivoting ball (called a "floating ball") to control flow through it. It is open when the ball's hole is in line with the flow and closed when it is pivoted 90-degrees by the valve handle. Reduced flow and excessive pressure drop are some of the common problems in ball valve. Angle backlash in the ball position is one of the causes for reduced flow and excessive pressure drop. This paper discusses on creating various alternatives for eliminating the angle backlash in the ball position, evaluating them and choosing the best alternative followed by CFD analysis of the ball valve before and after adjusting the backlash is made in ANSYS FLUENT and the results are compared.

Key words: CFD, ANSYS FLUENT

I. INTRODUCTION

A ball valve assembly contains a ball, valve body, spindle, handle, stop pin. The ball is placed inside the valve body and the spindle is placed over a slot provided on the ball. The handle attached to the spindle with the help of nut is used to rotate the ball through an angle of 90^0. Stop pin is used to ensures 90^0 rotation of the handle. Two end connectors are connected to the ball valve body to implement the assembly in the flow lines.

To analyze the angle backlash problem a ball valve with angle backlash is taken. After assembly, at the time of opening of the valve there is an angle backlash in the ball position. The assembled ball valve has an angle backlash in the ball position due to to the clearance fit between the spindle & handle and spindle & ball. As a result the specified requirement of flow bore diameter is not achieved This causes reduction in discharge rate, excessive pressure drop, and stress is induced at the protruding part of the ball inside the body.

The objective is to eliminate the angle backlash in the valve position in the ball valve assembly and to achieve the flow bore diameter of the ball valve assembly to minimize errors and to attain maximum efficiency. So brainstorming session is conducted and various alternatives are found and they are evaluated using 7 new Quality tools

II. QUALITY TOOLS APPROACH

First the root cause and the minor causes for the problem is found by drawing the relationship diagram. The various causes, effects and various alternatives are organised into their natural relationship by drawing affinity diagram. Finally all the alternatives are evaluated and they are given points by drawing matrix diagram. The alternative with more points is chosen as the best alternative

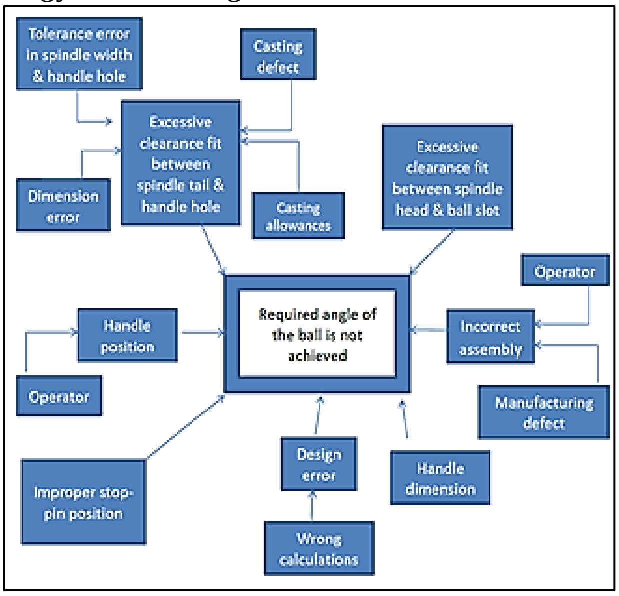

Fig. 1: Relationship Diagram

The main cause of the problem is the angle backlash in the ball position. Excessive clearance between the ball and spindle & Spindle and handle, improper assembly, improper tolerances, improper stop pin position, casting defects are some of the causes for the angle backlash.

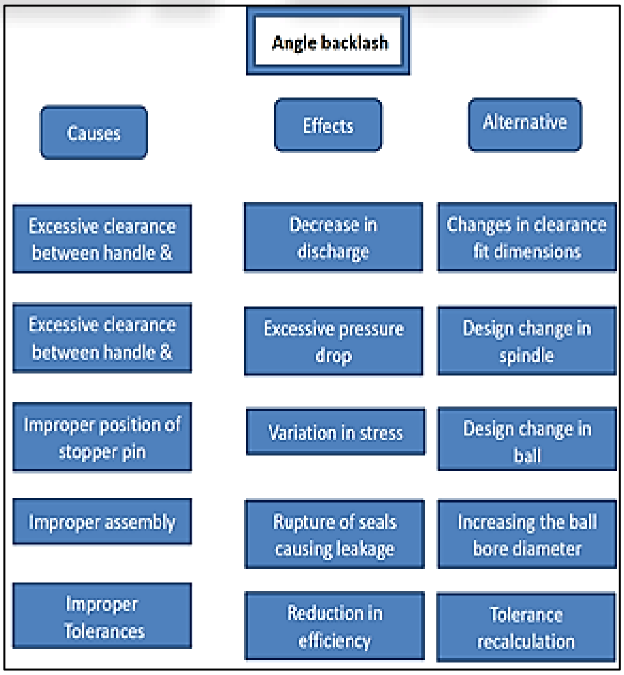

Fig. 2: Affinity Diagram

The various alternatives to solve the problem are clearance fit adjustment, design changes in spindle, handle and ball, increasing the ball bore diameter and tolerance recalculation etc. these alternatives are analysed by drawing the matrix diagram

- Relationship between problem statement
- Solution: ● -Strong (+7)
  ○ -Medium (+4)
  Δ -Weak (+2)

			ALTERNATIVES								
			CLEARANCE FIT		TOLERANCE RECALCULATION				DESIGN CHANGES	BORE DIAMETER	
			Spindle head width	Changing handle hole diameter	Ball bore diameter	Ball slot width	Spindle head & body width	Handle hole width & diameter	Design change in ball & spindle	Increasing ball bore diameter	Combining increased bore diameter & design changes
Problem statement	Overcome angle backlash	Increase discharge	○	○	○	○	Δ	○	○	●	●
		Minimize errors	●	●	●	○	○	○	Δ	Δ	Δ
		Reduce stress	●	●	○	●	○	○	○	○	○
		Reduce pressure drop	○	○	○	○	●	●	Δ	○	○

Fig. 3: Matrix Diagram

III. VARIOUS ALTERNATIVES

A. *Clearance Adjustments:*

- Spindle and Ball: Keeping the external member dimension as same we increase the internal member dimension with some tolerance changes.
  Sample dimensions: Spindle head width (internal member)
  Before changes - 0.193/0.195 in
  After changes - 0.194/0.196 in
- Spindle and handle: Keeping the diameter of the spindle body as same and changing the handle hole diameter.
  Sample dimensions: Handle hole diameter
  Before changes – 0.315/0.317 in
  After changes – 0.312/0.314 in

B. *Tolerance Recalculation:*

- Ball bore diameter:
  Centre lathe boring (Grade – 8) :
  Tolerance value – +/- 0.00072 in
  Horizontal boring (Grade - 9) :
  Tolerance value - +/- 0.0011 in
- Ball slot width:
  Slotting (Grade – 10) :
  Tolerance value - +/- 0.0018 in
- Spindle head width:
  Surface grinding (Grade – 6) :
  Tolerance value - +/- 0.00028 in
- Handle hole width:
  Fine honing (Grade – 6) :
  Tolerance value - +/- 0.00028 in
  High quality honing (Grade – 7):
  Tolerance value - +/- 0.00046 in
  Reaming (Grade – 8):
  Tolerance value - +/- 0.00072 in
- Handle hole diameter:
  Fine honing (Grade – 6):
  Tolerance value - +/- 0.00035 in
  High quality honing (Grade – 7):
  Tolerance value - +/- 0.00056 in
  Reaming (Grade – 8):
  Tolerance value - +/- 0.00088 in
- Spindle body width:
  Surface grinding-face (Grade – 6):
  Tolerance value - +/- 0.00028 in

C. *Other Alternatives:*

Other alternatives such as design changes in spindle, handle, ball and increasing the bore diameter of the ball does not yield the expected results. Hence they are not taken in to consideration for analysis.

IV. EXPERIMENTAL CALCULATION

A. *Nomenclature:*

Q	–	Discharge (m^3/s)
V	–	Flow velocity (m/s)
Δp	–	Pressure drop (pa)
Δh	–	Head loss (m)
G	–	Acceleration due to gravity (m/s^2)
C	–	Discharge coefficient
ℓ	–	Density (kg/m^3)
A	–	Cross sectional area (m^2)
D	–	Bore diameter (m)
Q_R	–	Discharge with angle backlash (m^3/s)
Q_F	–	Discharge after clearance adjustment (m^3/s)
Δp_R	–	Pressure drop with angle backlash (pa)
Δp_F	–	Pressure drop after clearance adjustment (pa)

B. *Calculation with Angle Backlash:*

Considering Water as a working medium and assume

- Head loss (Δh) = 10 m
- Density (ρ)=1000Kg/m^3
- Specific Gravity = 1
- Bore Diameter of ball Valve = 0.01 m
- Discharge Coefficient (C) = 4.7

1) *Velocity:*

$$V = c\sqrt{(2 \times g \times \Delta h)}$$
$$V = 4.7\sqrt{(2 \times 9.8 \times 10)}$$
$$V = 65.8\ m/s$$

2) *Discharge:*

$$Q_R = V \times A$$
$$Q_R = V \times \frac{\pi}{4} \times D^2$$
$$Q_R = 65.8 \times \frac{\pi}{4} \times 0.0095^2$$
$$Q_R = 0.00466\ m^3/s$$

3) *Pressure Drop:*

$$\Delta p_R = \left[\frac{Q_R}{c \times A}\right]^2 \times \frac{\rho}{2}$$
$$\Delta p_R = \left[\frac{0.00466}{4.7 \times \pi/4 \times 0.0095^2}\right]^2 \times \frac{1000}{2}$$
$$\Delta p_R = 97829.973\ pa$$
$$\Delta p_R = 97.\ 829\ kpa$$

C. *Calculation after Implementing Alternatives:*

1) *Velocity:*

$$V = c\sqrt{(2 \times g \times \Delta h)}$$
$$V = 4.7\sqrt{(2 \times 9.8 \times 10)}$$
$$V = 65.8\ m/s$$

2) Discharge:

$$Q_F = V \times A$$

$$Q_F = V \times \frac{\pi}{4} \times D^2$$

$$Q_F = 65.8 \times \frac{\pi}{4} \times 0.01^2$$

$$Q_F = 0.00516 \ \ m^3/s$$

3) Pressure Drop:

$$\Delta p_F = \left[\frac{Q_F}{c \times A}\right]^2 \times \frac{\rho}{2}$$

$$\Delta p_F = \left[\frac{0.00516}{4.7 \times \pi/4 \times 0.01^2}\right]^2 \times \frac{1000}{2}$$

$$\Delta p_F = 97699.857 \text{ pa}$$

$$\Delta p_F = 97.699 \text{ kpa}$$

Thus there is reduction in discharge due to angle backlash

$$Q_F > Q_R$$

Also the pressure drop is increased due to the angle backlash

$$\Delta p_F < \Delta p_R$$

It implies that the outlet pressure has decreased due to angle backlash which is not desired

V. CFD ANALYSIS

A. *Analysis with Angle Backlash:*

CFD analysis of the ball valve before and after clearance adjustment is made on ANSYS FLUENT 14.5

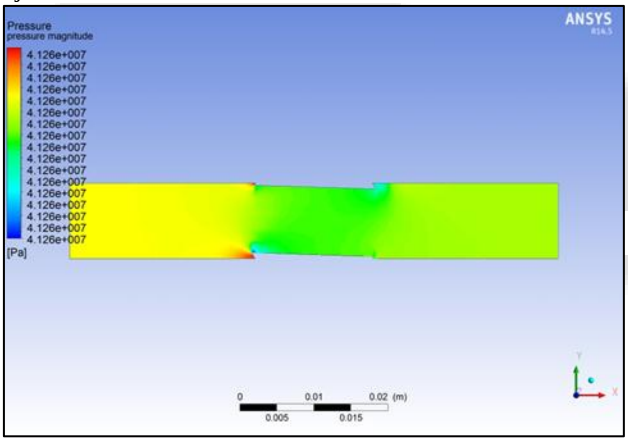

Fig. 5.1: Pressure Magnitude

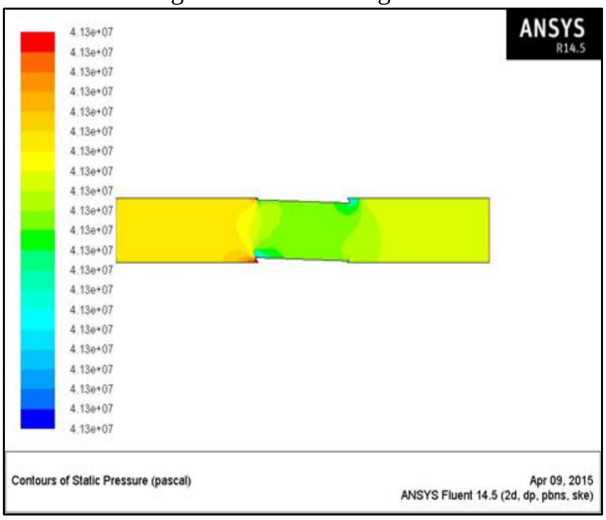

Fig. 5.2: Contours of Static Pressure

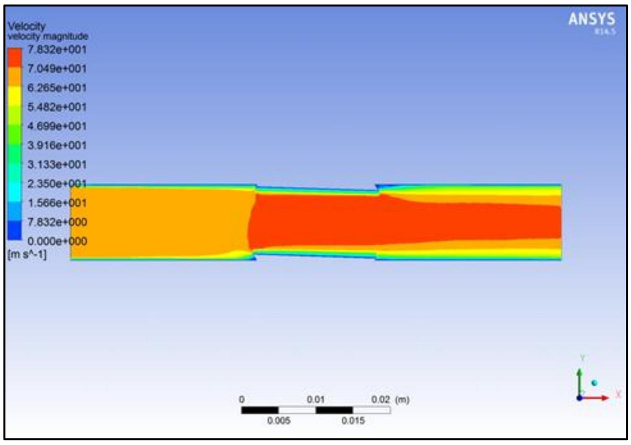

Fig. 5.3: Velocity Magnitude

B. *Analysis Implementing the Alternative:*

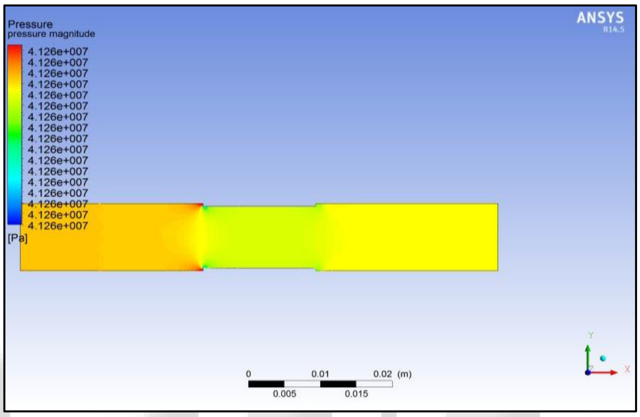

Fig. 5.4: Pressure Magnitude

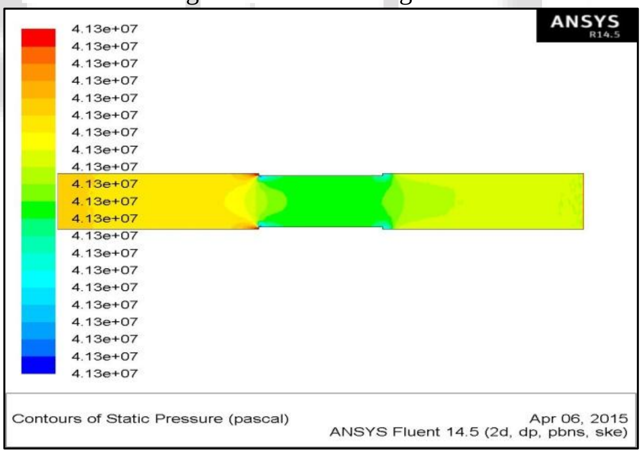

Fig. 5.5: Contours Of Static Pressure

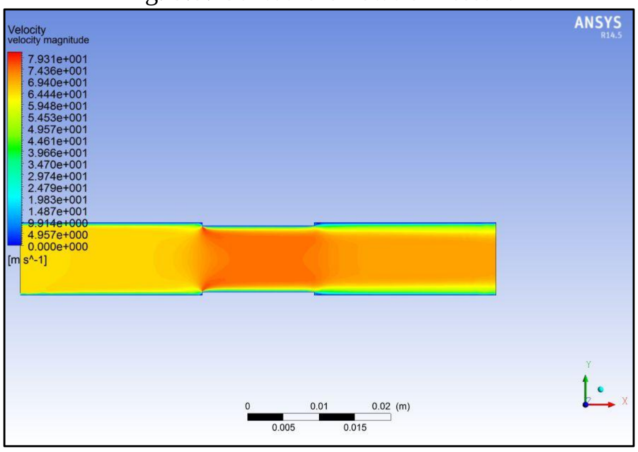

Fig. 5.6: Velocity Magnitude

VI. Conclusion

From the experimental calculation and analysis, the results produced show us that the Discharge has been increased and the pressure drop has decreased from the previous value after implementing the best alternative. Thus the clearance fit adjustment is the best chosen alternative that will eliminate the root cause of the problem.

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