DIMENSIONING ACTUATORS FOR TRUNNION BALL VALVES

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Abstract. *Ball valves are used in various industrial equipment, often in severe regime determined by the properties of the working fluid, pressure in the system and / or operating temperature. Featured smaller hydrodynamic resistance and reduced installation space has the advantage of ensuring a sealing component fluids containing gas and, at the same time, ensures sealing in accidental fires. This article examines the stages of actuator trunnion ball valves sizing , size optimization of seats for ensuring the normal simultaneously seal and fire safety functions , plus eventual discharge into line overpressure valve body (important requirement for environmental protection).*

Keywords: *trunnion ball valves, dimensioning actuators*

1. INTRODUCTION

Trunnion ball valves are used in large dimensions, on the entire pressure range. In this constructive solution the ball is guided into the body or the base and into the top cover through the pivot drive. The seats are made out of metal and are able to slide in bores machined body (Fig.1). Sealing is done for the upstream seat by action of the system pressure [2],[3].

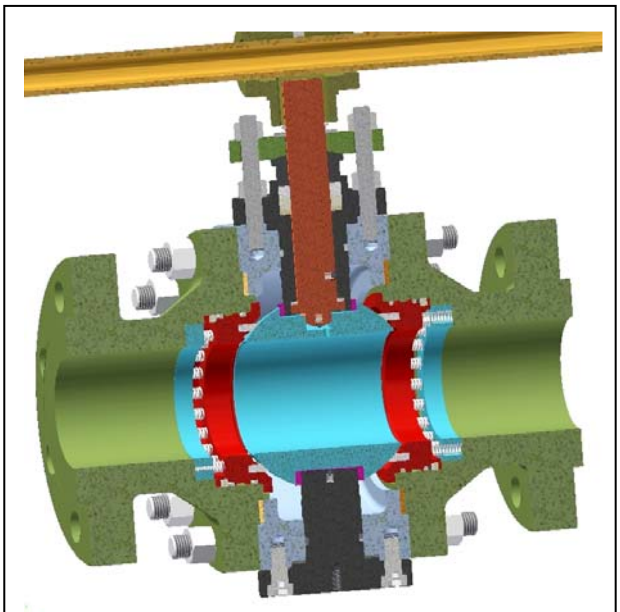

Figure 1. Trunnion ball valve solution

2. SEAT DIMENSIONNIG AND THE CALCULATION OF TORQUE MOMENT

2.1. Dimensioning seals according to the pressures upstream – downstream

For the dimensioning of the seat and the seal elements are considered all possible situations:

2.1.1. In the initial phase when pressure in the system is zero, the seats are pushed onto the ball by the elastic elements (helical cylindrical springs) (Figure 2).

For the pressing force to be more evenly distributed, a number of 10 ÷ 30 can be used and calculated with the following relation :

$$F_a = n_a \cdot F_i \qquad (1)$$

where n_a -represents the number of springs; F_i - the force developed by a spring that is mounted preloaded..

Sealing pressure in the initial phase will be:

$$p_{et_0} = \frac{F_a}{\frac{\pi}{4}\cdot\left(D_{ee}^2 - D_{ei}^2\right)} \qquad (2)$$

where: D_{ee} - outside diameter of nonmetallic sealing ring [mm]; D_{ei} - the inner diameter of the nonmetallic sealing ring [mm]

The springs are calculated from the condition that the air pressure test (4 ... 6 bars) ensures valve sealing (zero leaks).

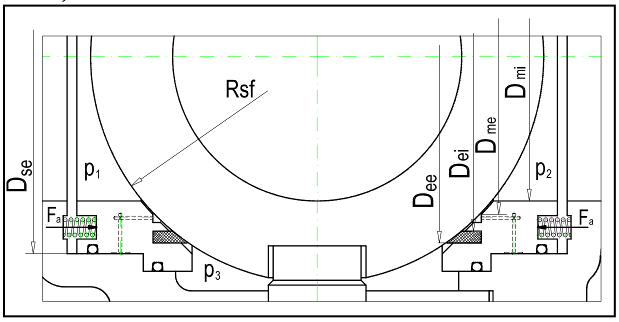

Figure 2. Seat dimension

2.1.2. If the pressure upstream of the seat and the pressure in the body are equal to nominal pressure $p_1 = p_3 = p_n$, the thrust exerted by the fluid on the seat is minimal:

$$\Delta F_{p_{min}} = \frac{\pi}{4}\cdot\left(D_{ee}^2 - D_{ei}^2\right)\cdot p_n \qquad (3)$$

$$F_{e_{min}} = F_a + \Delta F_{p_{min}} \qquad (4)$$

The fluid pressure from the seat will be:

$$p_{et_{\min}} = \frac{F_{e_{\min}}}{\frac{\pi}{4}\left(D_{ee}^2 - D_{ei}^2\right)} = p_n + p_{et_0} \tag{5}$$

2.1.3. If the upstream pressure is equal to the pressure of the working fluid $p_1 = p_n$, and the pressure p_2 in the valve body is zero, maximum pressure difference between upstream and body will determine the maximum pressure sealing. Dimensioning will be done so as not to crush the nonmetallic rings:

$$F_{e_{\max}} = F_a + \Delta F_{p_{\max}} \tag{6}$$

$$\Delta F_{p_{\max}} = \frac{\pi}{4} \cdot \left(D_{se}^2 - D_{ei}^2 \right) \cdot p_n \tag{7}$$

In this case, the fluid pressure from the seat will be

$$p_{et_{\max}} = \frac{F_{e\max}}{\frac{\pi}{4}\left(D_{se}^2 - D_{ei}^2\right)} \le p_{str} \tag{8}$$

2.1.4. In case an overpressure $p_{sc}=p_3$ (possible due to local heating, accidental fire etc) appears in the body, it is indicated that it is discharged into line, by overcoming the oppression forces of the seat on the sphere. Dimensioning will take care of discharging the overpressure when it exceeds a certain value (eg 1MPa).

If the upstream pressure is equal to the pressure of the working fluid ($p_1 = p_n$), and the downstream pressure is zero ($p_2 = 0$), the force caused by the body overpressure will be:

$$\Delta F_{s_{\min}} = \frac{\pi}{4} \cdot \left(D_{se}^2 - D_{ee}^2 \right) \cdot p_{sc} \tag{9}$$

Since the sealing pressureof the downstream seat is minimal ($p_{et} = p_{et0}$), the discharge will be done downstream, by overcoming the resistive force of the springs mounted behind the seat:

$$\Delta F_{s_{\min}} \ge F_{rez_{\min}} = F_a \tag{10}$$

The minimum overpressure in the body at which the discharge will be produced:

$$p_{sc_{\min}} = \frac{F_a}{\frac{\pi}{4} \cdot \left(D_{se}^2 - D_{ee}^2 \right)} = \Delta p_{s1} \tag{11}$$

If the upstream pressure and the downstream pressure are equal to the pressure of the working fluid ($p_1 = p_2 = p_n$):

$$\Delta F_{s_{\max}} = \frac{\pi}{4} \cdot \left(D_{se}^2 - D_{ee}^2 \right) \cdot \left(p_{sc} - p_n \right) \tag{12}$$

The maximum resistance force which opposes the inline discharge:

$$F_{rez_{\max}} = \Delta F_{p_{\max}} + F_a \tag{13}$$

In order to achieve the inline discharge the following condition should be met:

$$\Delta F_{s_{\max}} \ge F_{rez_{\max}} . \tag{14}$$

Because the forces on the two sealing seats is equal, discharge the overpressure from the body will be both upstream and downstream, overpressure force overcoming the forces of sealing.

$$p_{sc_{\max}} = \frac{F_{rez_{\max}}}{\frac{\pi}{4} \cdot \left(D_{se}^2 - D_{ee}^2 \right)} \tag{15}$$

Discharge pressure is given by the relation:

$$\Delta p_{s2} = p_{sc_{\max}} - p_{av} \tag{16}$$

2.2. Drive torque calculation for the fire-safe triunnion ball valve

„Fire - safe" ball valves are characterized by the existence of additional seals, such as metal - metal (figure 3). For the determination of drive torque, it takes into account the particular case when the friction and pressure needed to ensure the seal are higher.

Thus every situation will be analyzed, as done previously:

- If the upstream pressure is equal to the working fluid pressure ($p_1 = p_n$), and the downstream pressure is zero *($p_2 = 0)$*, the pressing force F_L exerted by the fluid on the sphere is taken over by the guides.

$$F_L = \frac{\pi}{4} \cdot D_{ei}^2 \cdot p_n \tag{16}$$

then the packing torque (torque required to overcome the rotational friction in the stuffing box) is:

$$M_{L1} = F_L \cdot \mu \cdot d_l / 2 \tag{17}$$

where: µ is the coefficient of friction metal - nonmetallic sealing ring (PTFE ring or filled, PTFE V-ring packing, grafoil, braided PTFE, asbestos free packing AFP etc.);

d_l – guide diameter.

- The minimum seat torque, required to ovrecome the friction of the nonmetalic seat on the ball is:

$$M_{s1\min} = \frac{\pi}{4}\left(D_{ee}^2 - D_{ei}^2\right) \cdot p_{et\ \min} \cdot R_r \cdot \mu_1 \tag{18}$$

$$R_r = R_{sf} \cdot \cos\alpha \ \cdot \tag{19}$$

When the nonmetallic ring is damaged (accidental fire) the mínimum seat torque required to overcome the friction of the metalic seat on the ball is:

$$M_{s2\min} = \frac{\pi}{4}\left(D_{em}^2 - D_{im}^2\right) \cdot p_{et\ \min} \cdot R_{r1} \cdot \mu_2 \tag{20}$$

where: μ_1 is the metal - nonmetal friction coefficient [-]

μ_2 - metal-metal friction coefficient [-] ;

D_{em} the outside diameter of the metal - metal seal [mm];

D_{im} – the inside diameter of the metal – metal seal [mm].

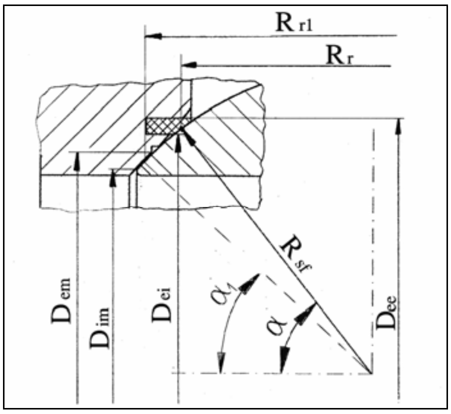

Fig.3 *Fire-safe* ball valve with double sealing

The maximum seat torque required to overcome the friction of the metalic seat on the ball is:

$$M_{s2\max} = \frac{\pi}{4}\left(D_{em}^2 - D_{im}^2\right)\cdot p_{et\ \max}\cdot R_{r1}\cdot \mu_2 \qquad (21)$$

The seat torque correspond to the maximum:

$$M_t = max\left\{M_{s1_{max}}; M_{s2_{max}}\right\} \qquad (22)$$

In the case of lever-operated valves (NPS 150mm, class 150) the stem is subject to torsion and bending.

The torque required for opening the valve in pressure is [1]:

$$M_a = M_{L1} + M_t + M_H + \Delta P_{\max}\left(C_B + C_S\right) \qquad (23)$$

where:

M_H – the torque required to overcame the friction of an attached lever,

$\Delta P_{\max}$ - pressure drop upstream downstream,

C_B – packing torque factor,

C_S – seat torque factor [1]

Also, it is necessary to take the dynamic moment given by the fluid action on the ball into account [1];

$$M_D = M_{L1} + \Delta P_{eff}\left(C_D + C_B\right) \qquad (24)$$

where : M_D – dynamic torque,

$\Delta P_{\max}$ - actual pressure drop when valve is in the open position,

C_D – dynamic torque factor.

The dynamic torque is variable according to ball rotation. It is dependent on the pressure drop, valve size and flow rate.

3. CONCLUSIONS

It is necessary to correctly dimension the trunnion ball valves seals to ensure all functions for which it was provided (sealing to pressure, fire safe and discharge of the overpressure from the body in line) and also the correct and economical choice solution for actuators that would provide the necessary moment for obturator rotation in pressure even during events (stiffness, fire etc).

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