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Weight optimization of the butterfly valve housing

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ABSTRACT

Butterfly valves are machine elements which arecommonly used for regulation of fluid, semi-liquid and granular medium flow on variety of tanks and pipeline systems. Valves are widely used in various industrial branches, especially in power plant pipeline installations, transport systems for materials deposed in silos etc. This paper gives basic methodology of butterfly–valve design by using CAD technologies and FEM. Main purpose is weight optimization of the valve housing body.

Keywords: butterfly valve, stress and strain analysis of housing

1. INTRODUCTION

The valves are machine structures consisting of the housing and the sealing parts which are movable linearly or rotationally, perpendicular to the direction of fluid flow. They are used to regulate or to prevent fluid flow. Beside that, the contact area between the housing and the packing ring is too small and it leads to poor contact and fluid leakage. Numerous solutions are used nowadays to prevent leaking problem. The most common solution is to to perform analysis and to improve the existing design. According to their function, the valves can be divided into: valves for regulation of flow or pressure, valves to block or redirect flow and the valves for load balancing.

The valves can be made of carbon and alloyed steel, grey or alloyed cast iron and of other plastic or rubber materials. The gravity and centrifugal casting are major manufacturing methods used for these valves. Butterfly housing has complex geometry with axial symmetry and they used to be manufactured by gravity casting. Gravity casting enables better surface quality and material properties and narrower tolerances than sand casting. This method is the best method for valve housing manufacturing.

2. STANDARDS OF VALVES

A number of standards are used for design and testing components and structure of butterfly valve. DIN 3202 (EN 588) defines the basic geometrical dimensions of the valve. Basic dimensions are internal diameter and wall thickness. These dimensions can be calculated according to the procedure described in standards. The wall thickness is the dimension that can be modified, since diameters are limited by surrounding pipelines and other components of the assembly.

Wall thickness (δ) of the butterfly valve housing is being calculated as a function of the working loads, maximum working pressure in the pipeline, working temperature and mechanical properties of the used material, given by:

$$\delta = \frac{D \cdot p}{2 \cdot \sigma_d \cdot \xi} + C \qquad \ldots (1)$$

where: p - nominal pressure
D - outside diameter
ξ - 0.8 1
σ_d - allowed stress
C - addition for thickness, common value C=1 and for special purposes C= 2 -3

The standard DIN 3230 defines testing of the structure according to the working conditions. Testing is being performed under nominal pressure, maximum working fluid flow velocity, allowed working pressure and temperature. The standard DIN 2505 is used to define flange connections to pipelines.

3. VALVE HOUSING DESIGN

Existing design of the whole valve and especially of the housing body has been analyzed thoroughly, and it gave the information if it is possible to make corrections, and in which capacity these corrections in the design of valve housing can be performed. Figure 1 shows the existing valve design.

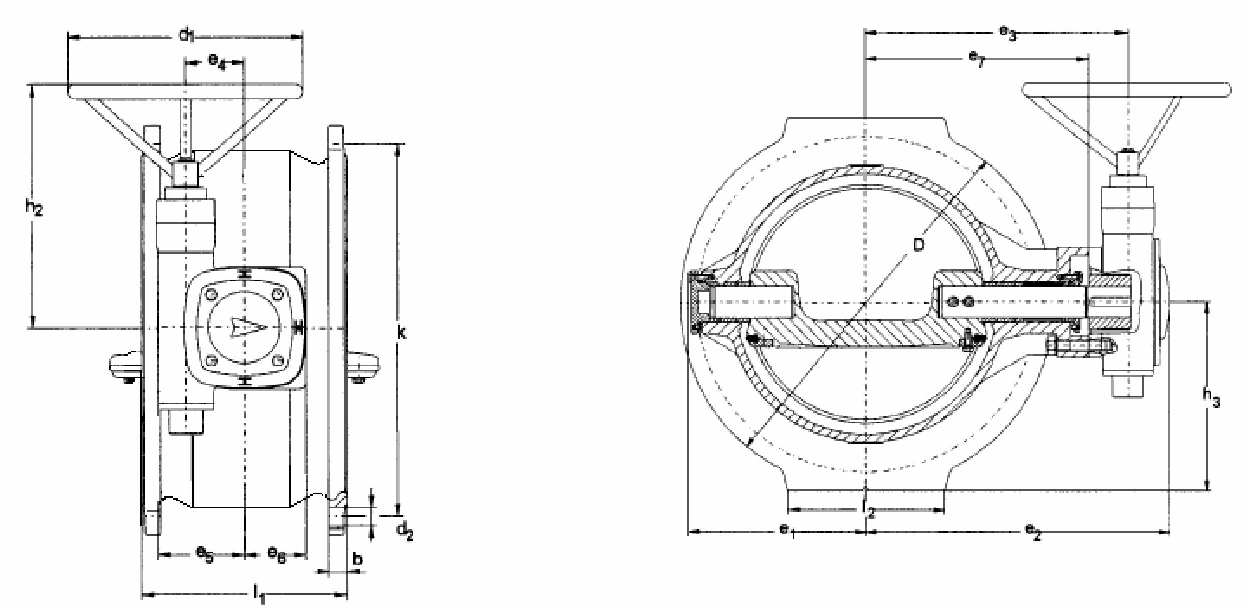

Figure 1. Existing valve design.

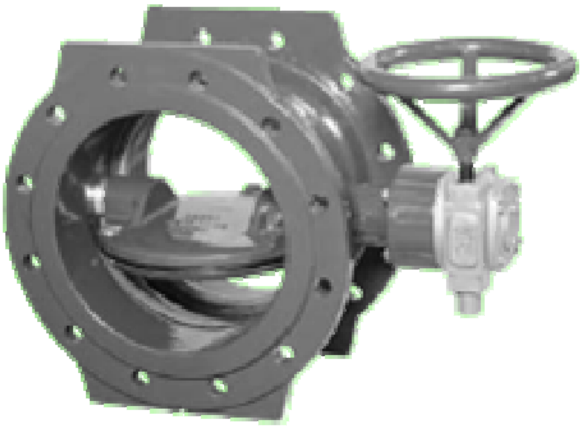

Figure 2. The typical valve.

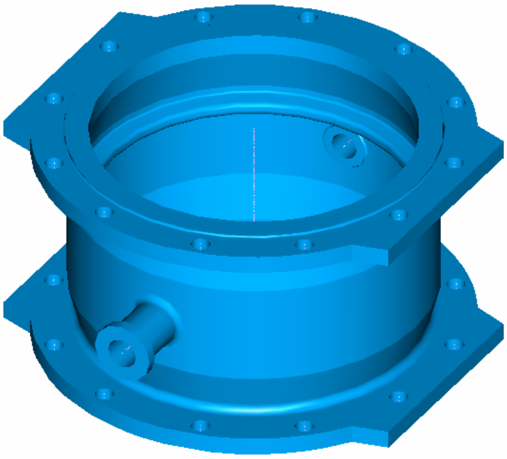

Figure 3. CAD model of the valve housing body.

In order to perform such an analysis, the CAD model of the valve housing is created using commercial CAD software "I-deas". The working pressure p = 16 bar and nominal diameter is D = 600 mm. Figure 2 shows the typical valve.
The CAD model created is shown at the figure 3. For such prepared CAD model analysis of stress strain state was performed. As one can see from the figure 3, some elements of the valve are neglected and were not included into CAD model. This was performed in order to simplify the analysis, and having in mind that these elements do not affect the pressure distribution and stress/strain state of the valve housing.

4. STRESS STRAIN ANALYSIS

The correct definition of the loads, boundary conditions and material properties are necessary preconditions to obtainin stresses. The three main steps in analysis are:

1. defining these input elements,
2. numerical analysis (calculation of stresses and strain) and
3. interpretation of results.

4.1. Loadings

Pressure is uniformly distributed to all parts the fluid is acting on. Maximum pressure value is 2.4 N/mm^2. The standard DIN 3230 shows that the testing pressure is 1.5 times greater than maximum value of working pressure of 16 bar.

4.2. Boundary conditions

The butterfly valve housing is axisymmetrical and there are no possibilities to introduce any simplification in the procedure of calculation. The model is fixed by the restraints to prevent all possible motions to the system of reference. At the flange connecting area more additional restrictions existed to prevent displacements and pouring of the fluid.

4.3. Material properties

Stresses and strains of the valve housing are essentially depend of the properties of the material of valve has been made. Modulus of elasticity $E = 2.2 \cdot 10^5$ N/mm^2, Poisson ratio 0.29, mass density 7.82 t/m^3 and shear modulus 85000 N/mm^2.

4.4. Analysis of the housing by FEM

This analysis is the base for the optimization of the valves. It consists of several steps and starts with CAD model and meshing of the CAD model in order to create FE model.

4.4.1. Meshing

Dimensions and number of FE have a direct influence to the accuracy and precision of calculations. The mesh is denser, results are more accuracy, with a limitation of hardware resources. Due that fact the most important is estimation of mesh density.

4.4.2. Results of solving

FE model, after analysis in IDEAS software, is presented in figure 4. The stresses obtained have values between 0,029 and 145 N/mm^2. Corresponding strains are between 0 and 0,078 mm. The values showed that valve housing may carry loadings greater than existing. Because of that, the optimization of the structure was performed through decrease in wall thickness.

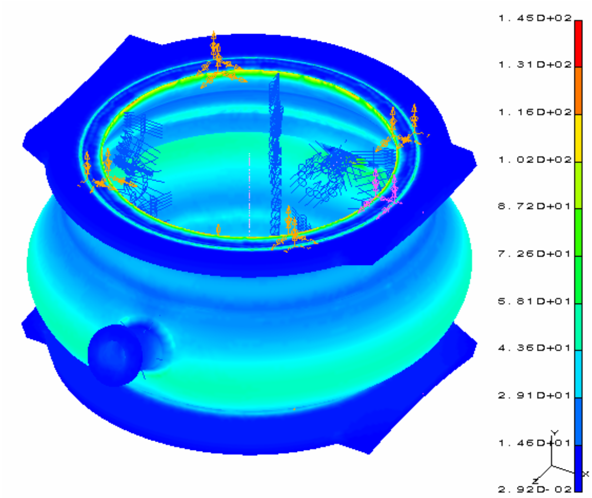

Figure 4. Stresses of the valve housing prior to optimisation.

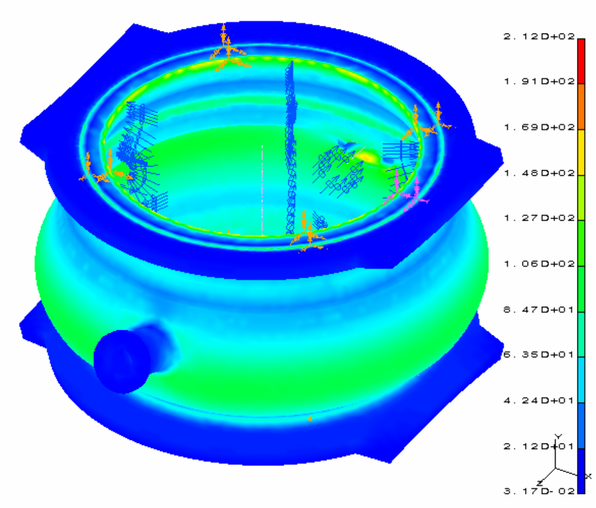

Figure 5. Stresses after first step of wall thickness reduction.

5. STRUCTURE OPTIMIZATION

Quality of the structure may be judged through: quality optimization, techno-economic aspect of the product value and computer supported product forming for the purpose of optimization.

Process of quality optimization is a compromise of quality and expenses to reach the appropriate quality. Techno-economic aspect of optimization comprises of functionality, exploitability, technological values and market demands. The optimization of the housing body can be carried out by computer aided design. During the exploitation, the structure is not exposed to the loading greater than 16 bar, therefore the optimal solution can be found in weight reduction. In that case, the wall thickness will be reduced untill the case of maximum stresses reaches allowed stress rate. That procedure for stress calculation is carried out at the model with wall thickness reduced for 2 mm presented at the figure 5.

The maximum values of stress are 182 N/mm^2. At the second step for additional 2 mm of thickness stress reached 212 N/mm^2. The stress obtained through analysis dictates the new design and corrections of the other parts of the valve.

6. CONCLUSIONS

Optimization of the complex shape constructions, such as the housing of the butterfly valve can be successfully performed using CAE techniques. In this case, the valve housing (D = 600 mm and p = 16 bar) was optimized by reduction of the weight. New construction will be cheaper and more competitive at the market. In order to confirm these results, it is necessary to perform the experiment with these new values of thickness.

7. REFERENCES

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