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DIMENZIONIRANJE I 3D OBLIKOVANJE POVRATNE ZAKLOPKE S POLUGOM I UTEGOM

DIMENSIONING AND 3D MODELING OF A SWING CHECK VALVE WITH LEVER AND WEIGHT

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Professional paper

Abstract: *This article presents the dimensioning and 3D modeling of a swing check valve with lever and weight in welded design, based on the existing 2D workshop documentation in cast design and reverse engineering. Based on analytical calculations, pipe wall thickness of a swing check valve housing was selected for the nominal pipe diameter DN 300 and water test pressure p = 2.4 MPa. All 3D models of components, as well as the assembly, were made in the program tool SolidWorks. The 3D model of the swing check valve with flanges was subjected to stress analysis (Finite Element Analysis) for the purpose of checking the accuracy of the analytical calculations. Fluid flow analysis (Flow Simulation) was used for presenting fluid flow process and rate through the swing check valve assembly. A low-budget 3D MakerBot Replicator 2X printer was used for constructing a reduced-scale 3D assembly model of the swing check valve with lever and weight, by implementing the FDM (Fused Deposition Modeling) technology.*

Key words: *stress analysis, fluid flow analysis, 2D workshop documentation, 3D printer, swing check valve housing, pipe wall, weight, valve*

Stručni članak

Sažetak: *Prikazano je dimenzioniranje i 3D oblikovanje povratne zaklopke s polugom i utegom u zavarenoj izvedbi na temelju postojeće 2D radioničke dokumentacije u lijevanoj izvedbi i reverznog inženjeringa. Na temelju analitičkog proračuna odabrana je debljina stjenke cijevi kućišta povratne zaklopke za nazivni promjer cijevi DN 300 i vodni ispitni tlak p = 2,4 MPa. Svi 3D modeli dijelova, kao i sklop, izrađeni su u programskom alatu SolidWorks. Na 3D modelu kućišta povratne zaklopke s prirubnicama u zavarenoj izvedbi provedena je analiza naprezanja (Finite Element Analysis) sa svrhom provjere točnosti analitičkog proračuna. Analizom strujanja fluida (Flow Simulation) prikazan je tijek i brzine strujanja fluida kroz sklop povratne zaklopke. Na niskobudžetnom 3D MakerBot Replicator 2X pisaču, primjenom FDM tehnologije taložnog očvršćivanja materijala, izrađen je umanjeni 3D model sklopa povratne zaklopke s polugom i utegom.*

Ključne riječi: *analiza naprezanja, analiza strujanja fluida, 2D radionička dokumentacija, 3D pisač, kućište povratne zaklopke, stjenka cijevi, uteg, zaklopka*

1. INTRODUCTION

A valve is a fitting for direct closing and regulation (throttling) pipe lines. A valve may be in the shape of a disk, lens or box, round or square, and it turns around the axis vertical to the flow direction. The axis around which the valve turns may be located in the middle of the valve or beside it. Opposed to the situation when it is open, when closed the valve is positioned in an almost vertical position relative to the flow rate. A valve is driven manually or by a motor over transmission elements (gear segment and small gear, worm wheel and worm) (Figure 1) [1].

For the purpose of further development and optimization of the existing product, by applying reverse engineering, the dimensioning and 3D modeling of a swing check valve with lever and weight is shown, as well as the thickness calculation of the housing wall of the flanged swing check valve in welded design, based on the existing 2D documentation in cast design. For the creation of the 3D model, the program tool *SolidWorks* was selected due to the advanced techniques of 3D modeling, the conducted stress analyses *(Finite Element Analysis)* and the fluid flow analysis *(Flow Simulation)*.

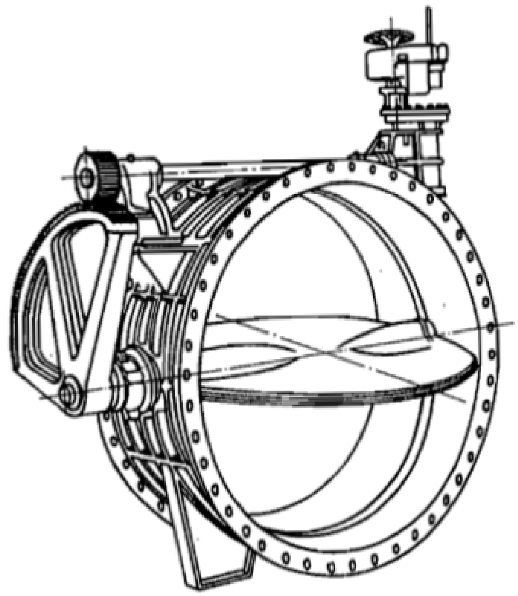

Figure 1 Throttle valve with a lens stopper [1]

2. SWING CHECK VALVE WITH LEVER AND WEIGHT

The swing check valve with lever and weight represented in Figure 2 is a valve that allows for medium flow in a single direction, while in the other direction it closes due to the influence of the weight mass, valve disc and medium back-flow. The valve rotates with a shaft. On the left end of the shaft (observed in the flow direction) a lever with a weight is attached.

Figure 2 Swing check valve with lever and weight [2]

It is installed in pipelines, pipelines for transporting water / seawater, systems for the preparation and distribution of water, waste water purification, heating systems, communal activities and irrigation in agriculture. In the pipeline it is installed between flanges in horizontal or vertical position behind the pump in order to prevent medium back-flow (Figure 3).

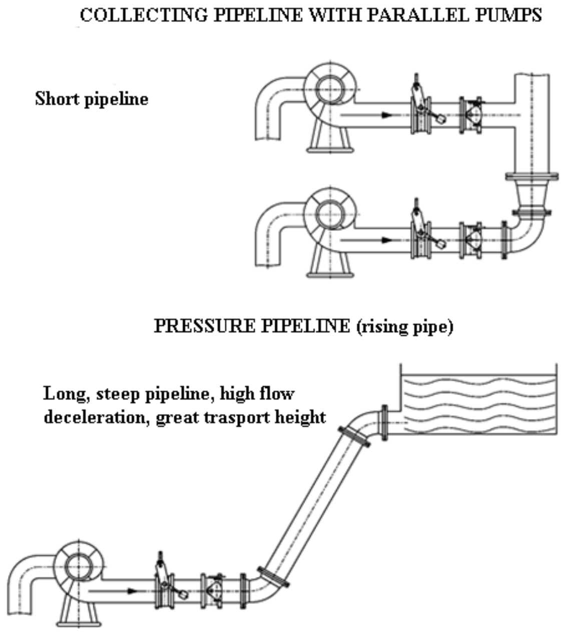

Figure 3 Application examples of swing check valves with lever and weight and shock absorber [3]

3. DIMENSIONING THE HOUSING OF THE SWING CHECK VALVE WITH FLANGES

Dimensioning housing wall thickness of the swing check valve with flanges in welded design is carried out for a nominal diameter DN 300, water test pressure p = 2.4 N / mm^2, the selected standard pipe of the outside diameter amounting to d = 355.6 mm, and the pipe material Č1212 (Figure 4).

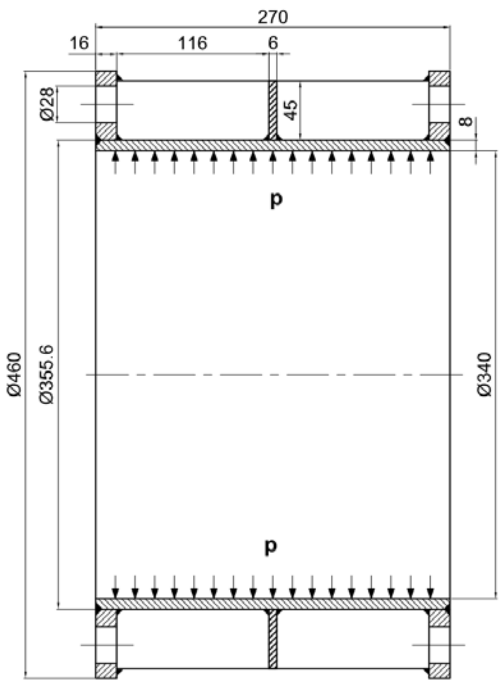

Figure 4 Housing of the swing check valve with flanges

3.1. Housing wall thickness calculation of the swing check valve

Calculation of pipe wall thickness is carried out in accordance with the pressure vessels calculation. For the calculation of wall thickness of steel pipes exposed to internal pressure up to $d_v / d_u \leq 1,7$ and for temperatures from -50 to +600 ºC the equation (1) is valid.

$$s = \frac{d_v \cdot p}{2 \cdot v \cdot \frac{K}{S}} + c_1 + c_2 \qquad \text{mm}, \qquad (1)$$

whereat:
s = wall thickness, = 5.56 mm,
d_v = outside pipe diameter, = 355.6 mm,
p = water test pressure, = 2.4 N/mm^2,
K = characteristic value of material strength, = σ_d at the temperature +20 °C, = 240 N/mm^2 for Č1212,
S = safety, = 1.7 for pipes with material certificate,
v = weld weakening factor, = 0.9 for a double-welded seam, annealed with special access requirements,
c_1 = addition for the permissible difference in the thickness of the pipe wall, = 1.2 mm,
c_2 = addition for corrosion and wear amounts to a maximum of 1 mm and is usually contained in rounding the calculated thickness of the pipe wall.

The standard pipe wall thickness of the swing check valve housing was adopted s = 8 mm [4].

4. DESIGN OF A 3D MODEL OF COMPONENTS AND ASSEMBLY OF A SWING CHECK VALVE WITH LEVER AND WEIGHT

Based on the existing 2D documentation in cast design, 3D modeling procedure starts with the modeling of the valve bearing, i.e. creating a sketch, and with rotational adding of material onto the sketch (Figure 5).

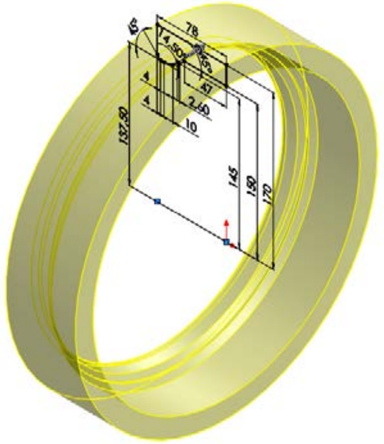

Figure 5 Rotational adding of material onto the sketch of the valve bearing

By using the available tools for advanced 3D design, a rendered (photorealistic) 3D model of a swing check valve in welded design was made (Figure 6).

Figure 6 Rendered (photorealistic) 3D model of the housing of a swing check valve in welded design

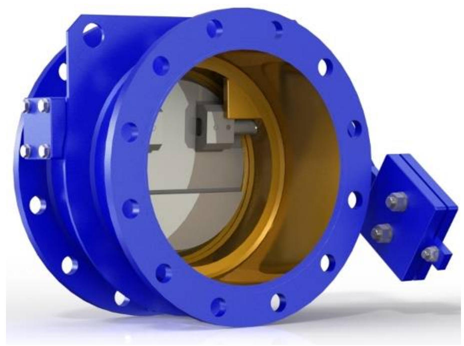

Figure 7 3D assembly model of the swing check valve with lever and weight – direct closing

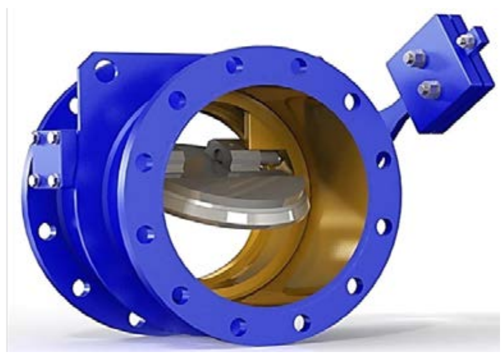

Figure 8 3D assembly model of the swing check valve with lever and weight – regulation (throttling)

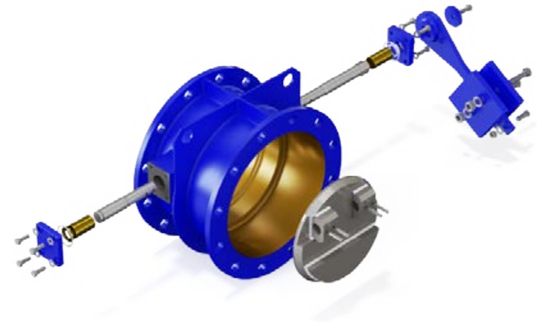

Figure 9 3D assembly model of the swing check valve with lever and weight – exploded view

In the same way other parts that form the assembly of the swing check valve with lever and weight were designed as well (valve, gland, cover, axle, outside shaft, radial and axial bearing, washer, weight lever and weight). After 3D modeling of all components they were assembled and rendered by the feature *Final Render* (Figures 7, 8 and 9).

5. 3D PRINTING OF THE ASSEMBLY MODEL OF A SWING CHECK VALVE WITH LEVER AND WEIGHT

3D print-out of the model of the swing check valve with lever and weight was made by applying the FDM technology using the low-budget 3D printer *MakerBot Replicator 2X* (Figure 10).

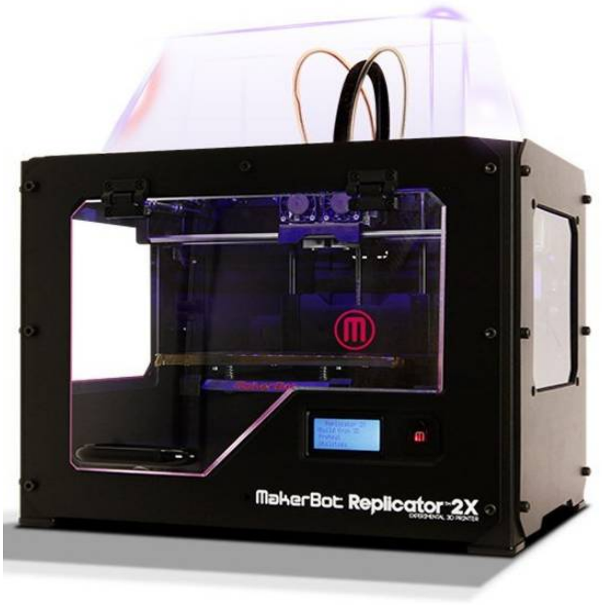

Figure 10 Low-budget 3D printer *MakerBot Replicator 2X* [5]

MakerBot Replicator 2X is a 3D printer with two heads, so 3D printing in two different colors is possible, or printing in two different materials. The heated platform is made of aluminum, while the frame is made of steel and the protective windows are made of glass fiber reinforced polymer. The compact construction of the 3D printer allows for a satisfactory 3D printing accuracy. The positioning accuracy along the x-y axis amounts to 0.011 mm, and along the z axis amounts to 0.0025 mm.

For printing a 3D model, it is necessary to create a virtual 3D model in one of the CAD 3D modeling tools, and after that save the 3D model in one of the formats supported by the 3D printer program tool. The 3D printer program tools for the 3D printer *MakerBot Replicator 2X* is *MakerBot MakerWare* (Figure 11).

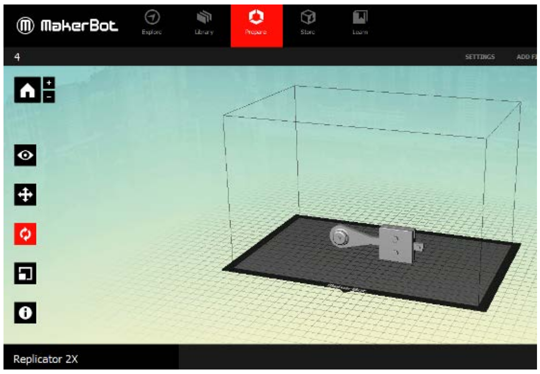

Figure 11 Program tool *MakerBot MakerWare* [6]

The tool *MakerBot MakerWare* supports three 3D model formats: stl., obj., thing. The assembly of the swing check valve with lever and weight is "divided" into four separate units (dimensions of the 3D model and printing length). Once the 3D model is recorded in stl. file format, it is loaded in the programming tool *MakerBot MakerWare*, and positioned onto the virtual "platform" for 3D printing.

All the required parameters of 3D printing are configured and stored in a file format that 3D printer "understands" (*Export print file* - stl. File), and the resulting file is stored on the SD card inserted in the 3D printer. After 3D printing, all parts (sub-assemblies) are clipped into an assembly.

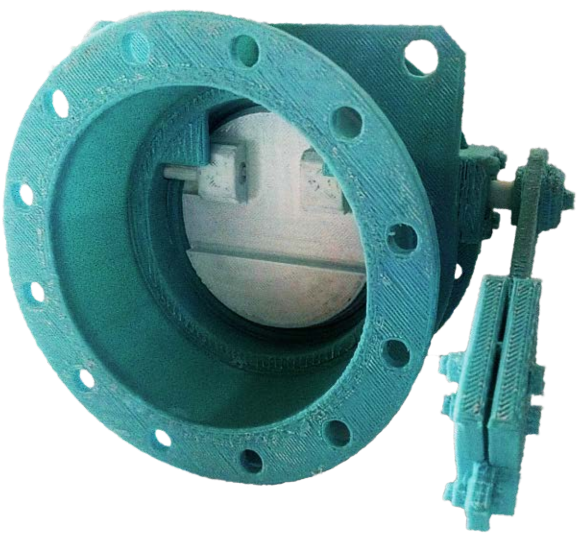

Figure 12 Reduced-scale 3D model of the swing check valve with lever and weight made on a low-budget 3D printer *MakerBot Replicator 2X*

Figure 12 shows the reduced-scale 3D model of an assembly of the swing check valve with lever and weight printed out by a low-budget 3D printer *MakerBot Replicator 2X*.

6. STRESS ANALYSIS (FINITE ELEMENT ANALYSIS – FEA)

After the analytical calculation and dimensioning the housing wall thickness of the swing check valve for the water test pressure p = 2.4 N / mm^2 and creating a 3D model, stress analysis of the swing check valve housing was carried out in the programming module *SolidWorks Simulation*.

The results of the analysis indicated that the nominal stress (according to the scale in Figure 13) were "significantly lower" than the allowed stress specified in Section 3.1 (σd = 240 N / mm^2, material Č1212), and it was determined that the analytical calculation for dimensioning of the swing check valve housing wall was correct, which is visually and analytically shown by an analysis conducted in the programming module *SolidWorks Simulation*.

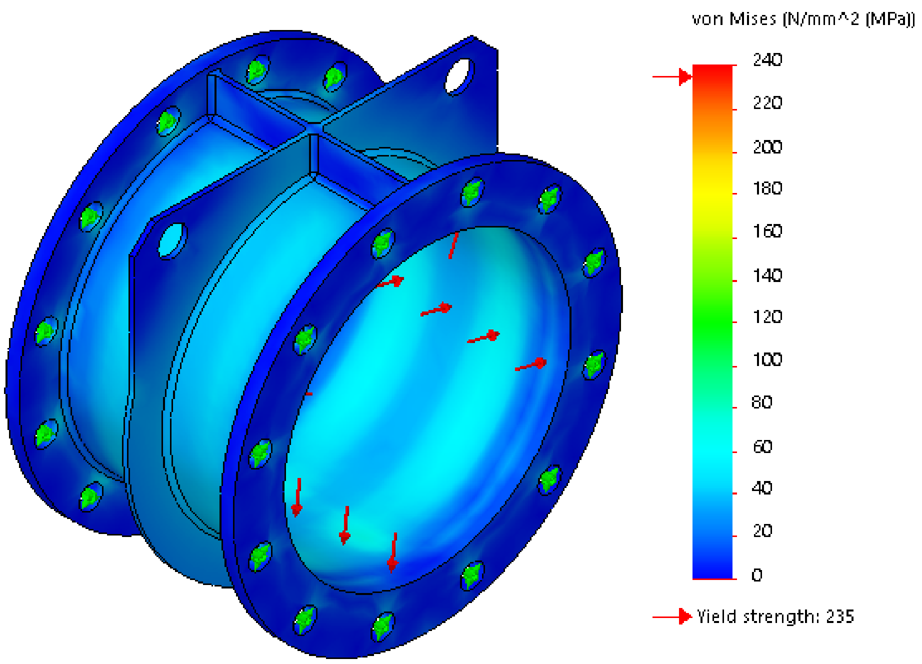

Figure 13 Results of the stress analysis within the housing of the swing check valve housing for the water test pressure amounting to p = 2.4 N/mm^2

7. FLUID FLOW ANALYSIS (FLOW SIMULATION)

In the program supplement *SolidWorks Flow Simulation* a fluid flow simulation through the swing check valve with lever and weight was conducted. The input – pressure pipe was exposed to the flow rate amounting to 0.15m^3/s, and the outlet pipe to the atmospheric pressure amounting to 0.1 MPa. After defining all the necessary parameters, the fluid flow analysis was carried out. Figure 14 shows the fluid flow with explanatory diagrams showing the fluid flow rate through the swing check valve with lever and weight.

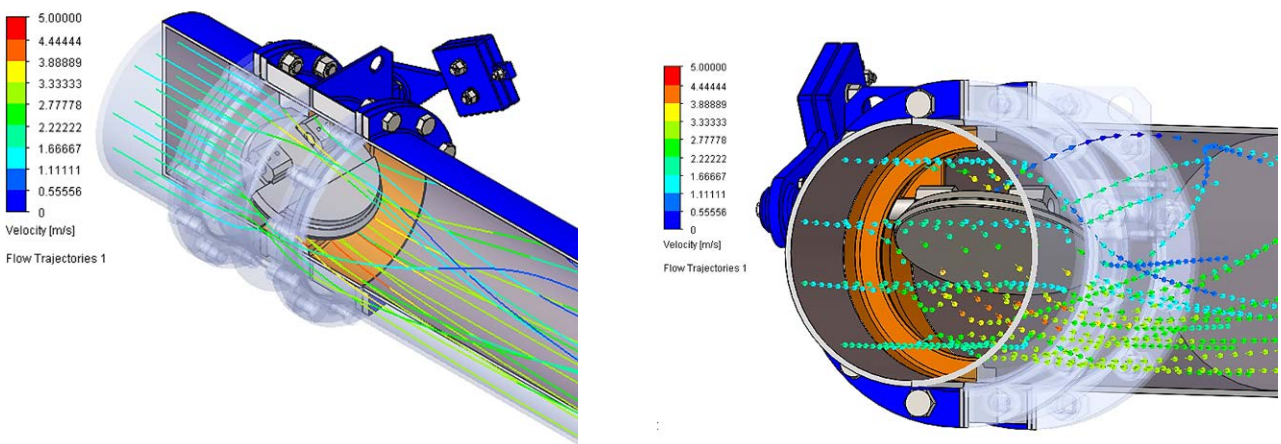

Figure 14 3D representation of the fluid flow simulation through the assembly of the swing check valve with lever and weight (longitudinally and left view)

8. CONCLUSION

Based on the existing 2D workshop documentation in cast design and the assembly reconstruction of a swing check valve with lever and weight, analytical calculation of the housing wall thickness of the swing check valve with lever and weight in welded design for the nominal diameter of DN 300 and the water test pressure p = 2.4 N/mm^2 was made. A flexible computer 3D model of the finished product of optimal size and performance was made. A complete workshop 2D documentation of all parts of the assembly of the swing check valve with lever and weight as a final product was “generated”. The analytical calculation was shown, as well as the stress analysis (*Finite Element Analysis - FEA*) and the fluid flow analysis (*Flow Simulation*) through the swing check valve assembly. Customized software and program tools were used for determining that a swing check valve with lever and weight may reliably “endure” the test stress and assure correct closing and regulation (throttling) of pipeline systems.

9. REFERENCES

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