ISSN 1864-6168
UDK 62

PROJEKTIRANJE I OBLIKOVANJE DVOSTRUKOG PROČISTAČA ULJA I GORIVA ZA UKLANJANJE MEHANIČKIH PRIMJESA

DEVELOPMENT AND DESIGN OF A DUAL OIL AND FUEL FILTER FOR THE REMOVAL OF MECHANICAL ADMIXTURES

Božidar Hršak, Ante Čikić, Dino Kus

Stručni članak

Sažetak: *Opisana je funkcija i namjena dvostrukog pročistača ulja i goriva te proračun debljine stjenke i dna kućišta pročistača u zavarenoj izvedbi za nazivni tlak PN 4,0MPa (40 bara). Primjenom reverznog inženjeringa, a na temelju postojeće 2D radioničke dokumentacije u lijevanoj izvedbi, izrađen je 3D model dvostrukog pročistača kao gotovog proizvoda, provedene su FEA analiza(Finite Element Analysis) naprezanja za nazivni tlak PN 4 MPa (40 bara) u kućištu pročistača u programskom alatu SimulationXpress Analysis Wizard i analiza strujanja fluida (Flow Simulation) unutar kućišta pročistača i razvodnika u programskom alatu FloXpress Analysis Wizard. Izrađena je potpuna 2D radionička dokumentacija za izradu svih potrebnih dijelova dvostrukog pročistača ulja i goriva.*

Ključne riječi: *dvostruki pročistač, filtarski element, gorivo, kućište, protok, razvodni ventil, tlak, ulje*

Professional paper

Abstract: *This paper describes the function and purpose of a dual oil and fuel filter, as well as the thickness calculation of the housing wall and bottom in welded construction for the nominal pressure PN amounting to 4.0 MPa (40 bar). Using the reverse engineering and based on the existing 2D workshop documentation in cast construction, a 3D model of the dual filter as a final product was made. Furthermore, FEA stress analysis (Finite Element Analysis) for the nominal pressure PN amounting to 4 MPa (40 bar) in the filter housing was made in the SimulationXpress Analysis Wizard software, while the flow simulation inside the filter housing and the valve was performed in the FloXpress Analysis Wizard software. Thereafter, complete 2D workshop documentation was made for all required parts of the dual oil and fuel filter.*

Key words: *dual filter, filter element, fuel, housing, flow, directional valve, pressure, oil*

1. INTRODUCTION

Filters are devices that are installed in hydraulic systems in order to remove undesired mechanical impurities from the working fluid (petroleum and petroleum products, mineral, semi-synthetic and synthetic oil, all types of hydraulic oils, light, medium and heavy fuel). Impurities may develop as the result of working fluid oxidation, wearing of parts that are in contact with the fluid or as production or assembly remnants (seal parts, burrs, slag or metal drops as residues of the welding process) [1].

For the purpose of further development and optimization of an existing product and by applying reverse engineering, the design of a 3D model of a dual oil and fuel filter is shown, as well as the calculation of the housing in welded construction based on the existing 2D documentation (in cast construction), product catalogues and assembly, operation and maintenance instructions. For designing the 3D model the *SolidWorks* software was selected due to high requirements set by the design of the 3D model, stress analyses and fluid flow analysis.

2. DUAL OIL AND FUEL FILTER

A dual oil and fuel filter consists of two housings with two filter elements (filter chambers) that are connected by a directional valve on two levels, so that each chamber may be operational separately (Figures 1 and 2).

Figure 1. Dual oil and fuel filter with reinforcement (front view) [1]

Figure 2. Dual oil and fuel filter (back view) [1]

A filter element (multi-chamber type, basket type etc.) is installed in the filter chamber. It consists of the load-bearing structure and corrosion-resistant metal fabric or filter paper that retains particles larger than the nominal filtration fineness (Filter 3) [2].

Figure 3. Filter elements [3]

Dual filters are used at plants where medium flow must not be interrupted for the purpose of cleaning the basket or replacing a filter element. This allows for continual flow by using two separated chambers with an integral distributional valve which enables direct medium flow into one of the filter chambers (Figure 4) .

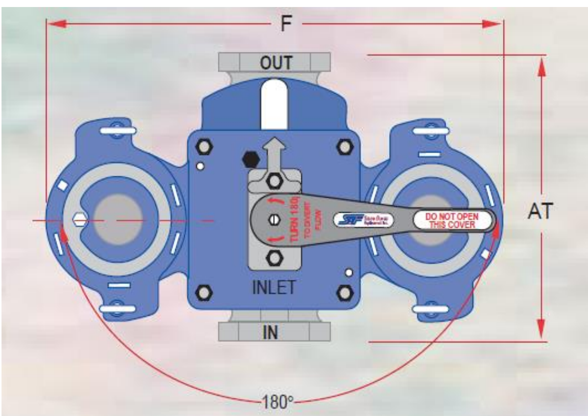

Figure 4. Distributional valve switching [4]

Directional valve switching is carried out without hydraulic impacts, attenuation and other flow disturbances that would have an unfavorable influence on the system operation, as one side is switched off at the same time as the other side is switched on. In this way the filter does not have to be switched off while cleaning or replacing a filter element. It suffices to turn the directional valve and switch off that half of the filter that will be cleaned or where a filter element will be replaced. Therefore, dual filters are installed in systems that do not allow for interruptions or operation without constant filtration [1].

When the filter is used for viscous fluids, steam or electric heating is installed in it. The purpose of heating is to "warm up" the filter chamber before the operation starts. Upon request a magnetic particle retriever and differential pressure indicator are installed in the filter, which signalize that filter elements are clogged [2].

3. CALCULATION OF THE THICKNESS OF FILTER HOUSING WALL AND BOTTOM

The dimensioning of filter housing wall and bottom in welded construction is carried out for the nominal pressure PN 40 (4 MPa) using a standard pipe with the external diameter D_v = 323.85 mm and pipe material Č0361.

3.1. Calculation of the thickness of filter housing wall

The pipe wall thickness must not be lower than the value obtained according to the following expression: [5]

$$s = \frac{D_v \cdot p}{200 \cdot \sigma_d \cdot \varphi + p} + c, \text{ mm} \qquad (1)$$

whereat:
s = wall thickness, = 6.246 mm,
D_v = external pipe diameter, = 323.85 mm,
σ_d = allowed stress, = 132.35 N/mm^2,
φ = welded joint weakening coefficient = 0.9,
c = add-on due to corrosion, = 1 mm,
p = calculation pressure, = 392,266 N/cm^2.

$$\sigma_d = \frac{R_e H}{n}, \text{ N/mm}^2 \qquad (2)$$

whereat:

$R_e H$ = material strength characteristic, = 225 N/mm^2,
n = safety coefficient, = 1.7.

The housing wall thickness s = 9.53 mm – wall thickness of a standard pipe is accepted [6].

3.2. Calculation of the thickness of filter housing bottom

The thickness of flat and non-solid bottom must not be lower than the value obtained according to the following expression:

$$s = A \cdot D \cdot \sqrt{\frac{p}{\sigma_d}} + c \quad \text{mm}, \qquad (3)$$

whereat:
s = wall thickness, = 10.97 mm ,
A = calculation coefficient, 0.38 ,
D = calculation pipe diameter, = 152.395 mm ,
p = calculation pressure, = 3.923 N/mm^2 ,
σ_d = allowed stress, = 132.35 N/mm^2 ,
c = add-on due to corrosion, = 1 mm.

The housing bottom thickness s = 12 mm – standard sheet metal thickness is accepted [7].

4. DESIGN OF A 3D MODEL OF DUAL FILTER PARTS AND ASSEMBLY

Based on the existing 2D documentation (cast construction), the 3D modeling procedure starts with modeling the cylindrical part of the housing and connection for the directional valve. First the sketch is made and then it is modified by adding or cutting material (Figures 5 and 6).

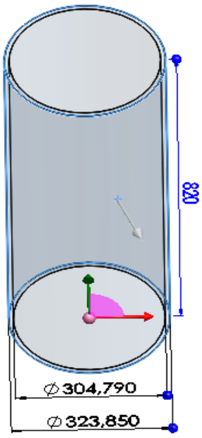

Figure 5. Cylindrical housing part

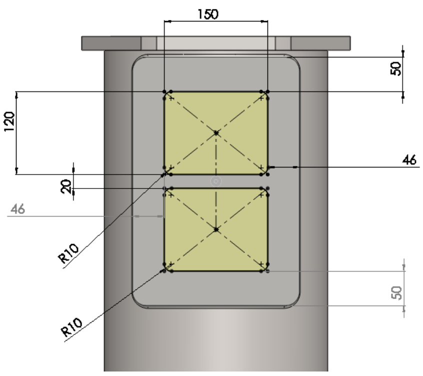

Figure 6. Directional valve connection

By using available advanced modeling tools, a model of filter housing was made (Figure 7).

Figure 7. 3D model of filter housing

In the same way other parts of the dual filter (piston, knee connection, filter elements, handle, directional valve, directional valve cap and filter housing cap) were modeled. After the 3D modeling of all parts, they are assembled and rendered in the *Photo View 360* software (Figures 8 and 9).

Figure 8. 3D model of a dual oil and fuel filter – rendered view

Figure 9. 3D model of a dual oil and fuel filter – exploded view

4.1. Finite Element Analysis – FEA

After the calculation and dimensioning of the filter housing were carried out for the nominal PN 4.0 MPa (40 bar) and a 3D model was made, a filter housing stress analysis was made in the *SimulationXpress Analysis Wizard* software.

The analysis results confirm that nominal stress read according to scale (Figure 10) was lower than the allowed stress represented in 3.1 and 3.2, which amounts to σ_d = 132.35 N/mm^2. Therefore, it may be concluded that the initial calculations for dimensioning the housing wall and bottom are accurate, which is visually and analytically proven by the analysis carried out in the *SolidWorks Simulation* software.

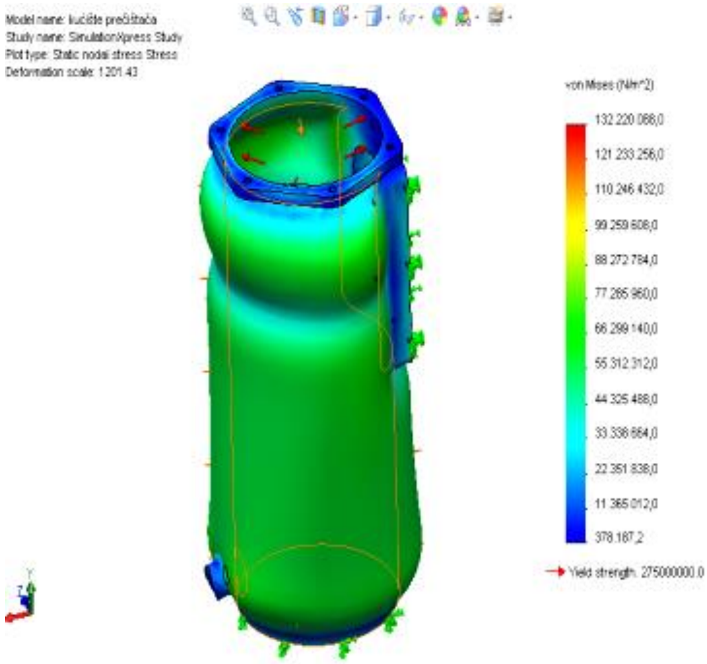

Figure 10. Pressure stress inside the filter housing for the pressure amounting to 4 MPa

4.2. Flow Simulation

In the *FloXpress Analysis Wizard* software, the flow simulation was carried out. For the upper (input) pipe the nominal pressure amounting to 4 MPa and the flow of 0.055 m^3/s were defined, while the lower (output) pipe was defined by the atmospheric pressure amounting to 0.1 MPa and the flow of 0 m^3/s. after defining all required parameters, the flow simulation was carried out. Figure 11 shows the fluid flow with additional graphical representations of the flow velocity in the filter housing.

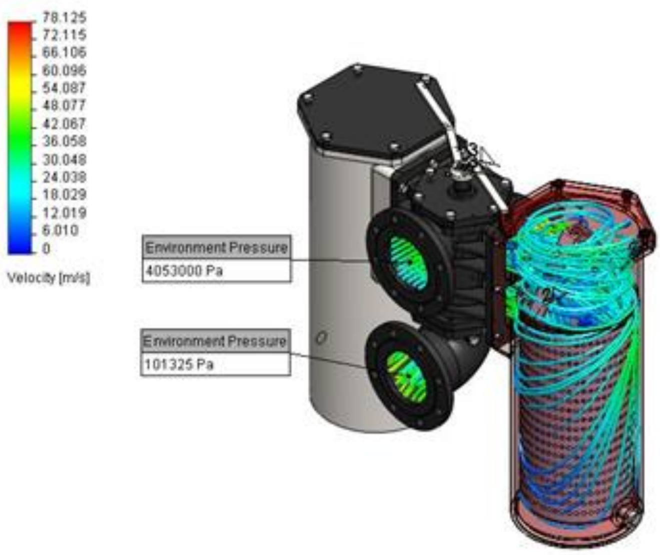

Figure 11. 3D representation of the fluid flow simulation

5. CONCLUSION

By redesigning (reverse engineering) and reconstructing the housing of a dual oil and fuel filter (final product) based on the existing 2D workshop documentation (cast construction), the calculation of the filter housing wall and bottom was carried out in welded construction for the nominal pressure PN 40 (4 MPa). A flexible computer 3D model of the final product of optimal dimensions and operating characteristics was made. Furthermore, a complete workshop 2D documentation was designed for the purpose of constructing all dual filter parts as a final product. The calculations, FEA and flow simulation in the filter housing point to the fact that the filter may dependably endure the given drive load and assure a continual oil and fuel filtration process in production processes.

6. LITERATURE

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Contact:

Božidar Hršak, graduate engineer of mechanical engineering
Technical College in Bjelovar
Trg Eugena Kvaternika 4, Bjelovar
E-mail: bhrsak@vtsbj.hr

Ante Čikić, PhD, Assistant Professor
Technical College in Bjelovar
Trg Eugena Kvaternika 4, Bjelovar
E-mail: acikic@vtsbj.hr

Dino Kus (former student)
Technical College in Bjelovar
Trg Eugena Kvaternika 4, Bjelovar
E-mail: kus.dino@gmail.com