ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XX, NR. 2, 2013, ISSN 1453 - 7397

Florin Peris-Bendu, Adelina Bostan, Viorel Câmpian, Dorian Nedelcu

Considerations Regarding the Stresses and the Deformations of the Butterfly Valve Body

In the present paper it is analyzed the "von Mises" equivalent stress distribution, respectively strains, which appear in the body of a butterfly valve with nominal diameter (DN) of 2800 mm and operates at a nominal pressure (PN) 19 bar. The paper examines the body of a butterfly valve using finite element method and the followings data is considered to be known: boundary conditions for which the analysis is made in both positions, the valve disk in the closed position and the open position, mechanical characteristics and resistance of the materials for valve body components and loads to which it is subject. The result of the analysis obtained allow optimization of the valve body size by highlighting the oversized areas respectively areas where efforts are maximized.

Keywords*: von Mises equivalent stress, strains, body valve, butterfly valve, finite element method*

1. Introduction

Due to the simple, compact and robust design and low price, butterfly valves are commonly used as isolation organ for Francis turbines. Butterfly valves consist of a jointed biplane disk mounted by two trunnions on the cylindrical casing. Biplane disc is profiled in the flow direction in order to ensure minimum hydraulic losses and to balance the forces on the valve [3].

The main seal is on the circumference of the valve disk and consists of a shaped rubber gasket mounted on disk with a ring. The disk trunnions is sealed with type "V" gaskets set [4].

The valve body is made in welded construction: cast manganese steel billets and rolled steel sheets for general use. It consists of two half-cases assembled using bolts mounted into the vertical separation planes. In order to prevent the axial displacement in the horizontal direction and the vertical direction, the separation planes between of the two half-cases are provided with centering pins. The seat seal is accomplished by depositing stainless steel. In order to make the sealing with the upstream joints and with the mounting compensator, the end faces of the body are provided with channels in which are mounted rubber cord. Likewise done and sealing planes separating the two cases which compose the valve body.

2. Boundary conditions

The calculation is made, with the finite element method [2], for the assembly of the upstream pipe, valve body, valve disk and downstream pipe. The calculation is made for the following boundary conditions:

2.1 Open disk

- the symmetry plan – frictionless support – Figure 2;
- the valve disk trunnions in contact (frictionless support) with valve body on the bearing length 250 mm – Figure 3;
- the valve disk trunnions frontal surface fixed on x direction – Figure 4;
- the flanges ND 2800 bounded contact on the surface outside the pitch circle diameter – Figure 6, 8;
- the valve body sole plates on the embedded plates setting surface – frictionless support – Figure 2;
- threaded bolts and valve body – bounded contact – Figure 5;
- compensating flange and cylindrical surface of downstream pipe – frictionless support - Figure 7.

The loading case:

- internal pressure 19.1 MPa (maximum dynamic pressure)
- open disk position – Figure 1;
- internal pressure 28.65 MPa (hydraulic test pressure of valve body, upstream and downstream pipe
- open disk position.

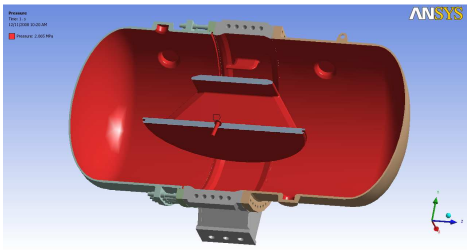

Figure 1. Open disk position

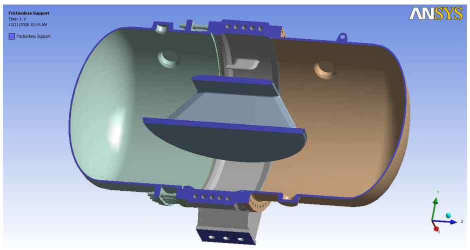

Figure 2. The symmetry plane and the frictionless support

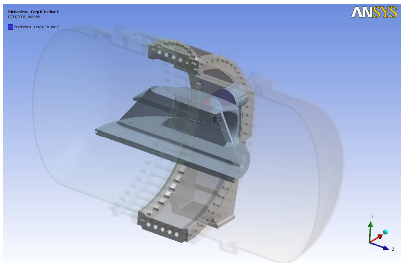

Figure 3. The disk trunnions in contact with valve body

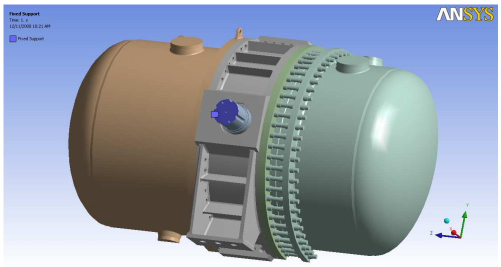

Figure 4. The valve disk trunnions frontal surface fixed on „X" direction

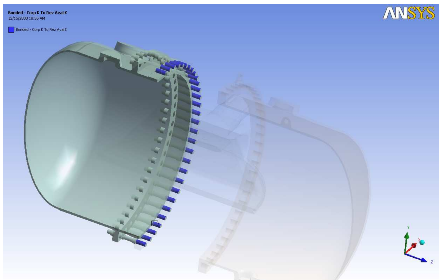

Figure 5. Threaded bolts and valve body – bounded contact

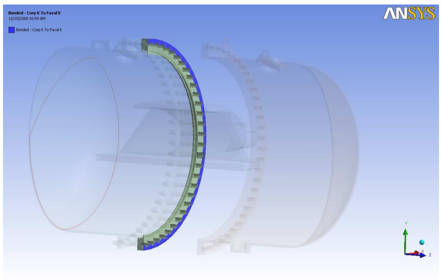

Figure 6. The flanges ND 2800 bounded contact on the surface outside the pitch circle diameter

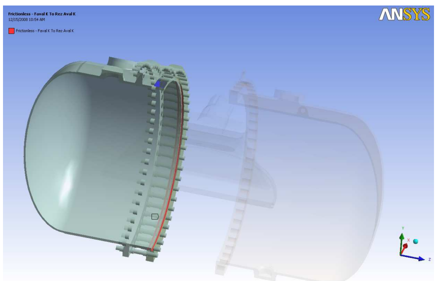

Figure 7. Compensating flange of downstream pipe – frictionless port

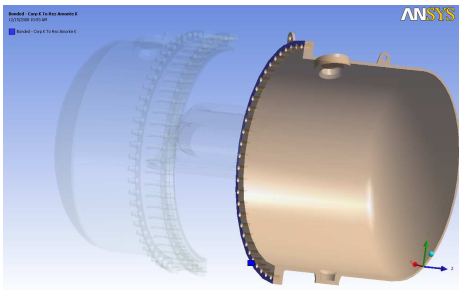

Figure 8. The flanges ND 2800 bounded contact on the surface sup outside the pitch circle diameter

2.2 Closed disk

- the symmetry plan – frictionless support – Figure 10;
- upstream shell end of upstream pipe – fixed support – Figure 11;
- the valve disk trunnions in contact (frictionless support) with valve body on the bearing length 250 mm – Figure 3;
- the valve disk trunnions frontal surface fixed on x direction – Figure 4;

- the flanges ND 2800 bounded contact on the surface outside the pitch circle diameter – Figure 12;
- valve disk – stopper – bounded contact – Figure 13;
- the valve body sole plates on the embedded plates setting surface – frictionless support – Figure 2.

The loading case:

- internal pressure 19.1 MPa (maximum dynamic pressure)
- closed disk position – Figure 9.

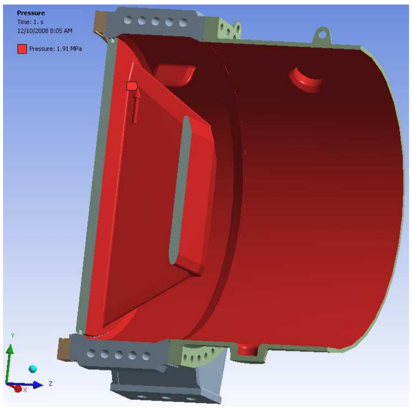

Figure 9. Closed disk position

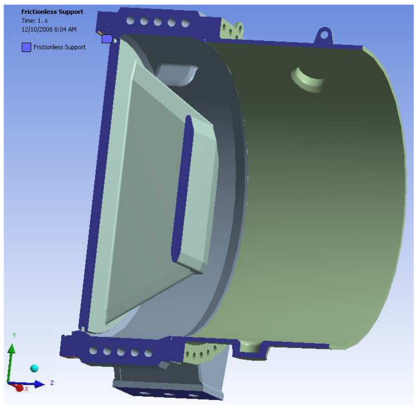

Figure 10. The symmetry plane and the frictionless support

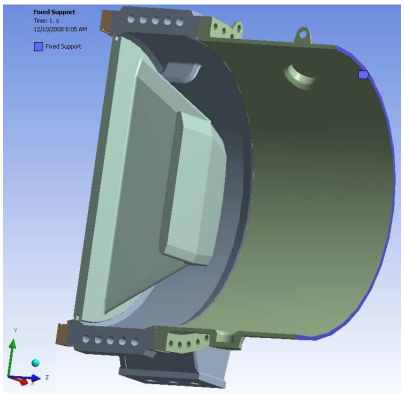

Figure 11. Upstream shell end of upstream pipe – fixed support

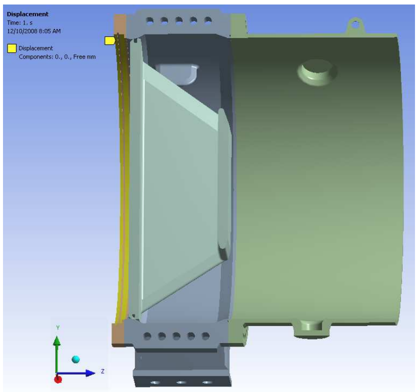

Figure 12. The flanges ND 2800 bounded contact on the surface outside the pitch circle diameter

For mesh in close disk position was considered an element with the average size of 18 mm and after meshing were obtained 2315486 nodal points and 1403826 finite elements (figure 14).

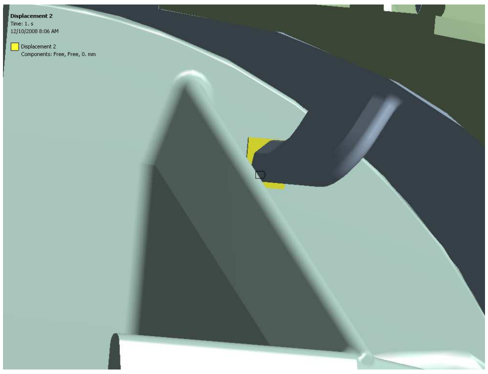

Figure 13. Valve disk stopper – bounded contact

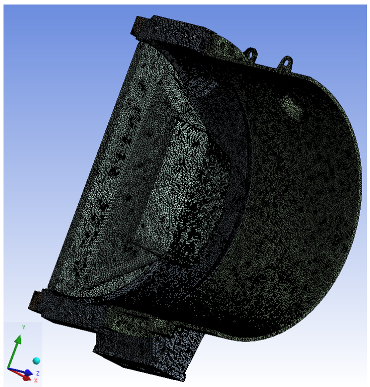

Figure 14. Griding for the closed disk position

For mesh, in open disk position was considered an element with the average size of 50 mm, and after meshing were obtained 1555292 nodal points and 860109 finite elements (figure 15).

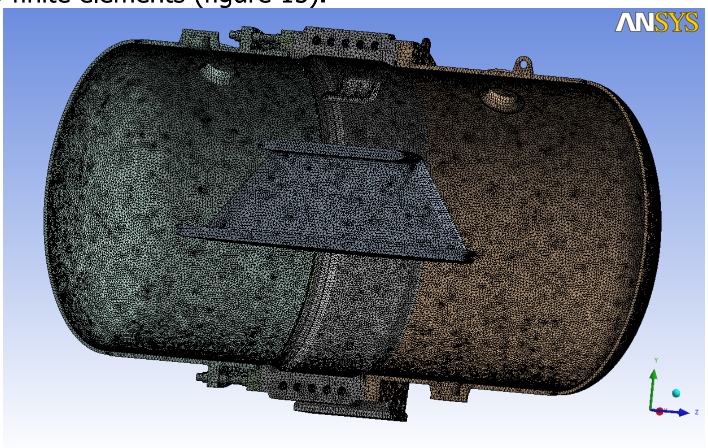

Figure 15. The valve mesh for the opened disk position

3. Valve body calculation.

Valve body calculation is done by finite element method both for the working pressure of 19.1 bar and for the hydraulic test pressure of 28.56 bar. The calculation include the study of the equivalent stresses (von Misses) and deformations. For the working pressure value, the calculation of the equivalent stresses (von Misses) is done for both the valve body in case the disc is in the closed position and in case the disc is in the open position.

The valve body is of welded construction from:

	Cast hubs and split flanges of G20Mn5 N EN 10293	Flanges (rolled plates) of S355J2+N EN 10025-2	Shell (rolled plates) of S355J2+N EN 10025-2
Yield point R_c	240 N/mm^2	295 N/mm^2	345 N/mm^2
Tensile strength R_t	450 N/mm^2	450 N/mm^2	470 N/mm^2
Allowable stress $\sigma_a = R_t / 3$	150 N/mm^2	150 N/mm^2	156.6 N/mm^2
Allowable shear stress $\sigma_a = \sigma_a / 3^{1/2}$	86.6 N/mm^2	86.6 N/mm^2	90.4 N/mm^2

As a result of finite element analysis of equivalent stress (von Mises) at working pressure of 19.1 bar are highlighted the most required areas for both the situation in which the disk is in the open position (figure 16) and the situation in which the disk is in the closed position (figure 17). Also we obtained the maximum values for the equivalent stresses in these areas.

The maximum equivalent stress value for valve disk in open position 275.78 N/mm^2 is due to boundary conditions. The major part of equivalent stresses don't exceed σ_{max} = 137.89 N/mm^2 < σ_a = 150 N/mm^2 allowable stress.

The major parts of equivalent stresses don't exceed: σ = 126.35 N/mm^2 < allowable stress σ_a = 150 N/mm$^{2.}$ The maximum value 586.04 N/mm^2 is not relevant being considered peak stress (see detail, figure 18).

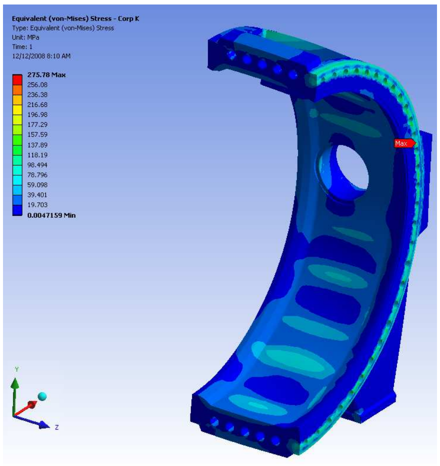

Figure 16. Stress analysis at 19.1 bar – open disk

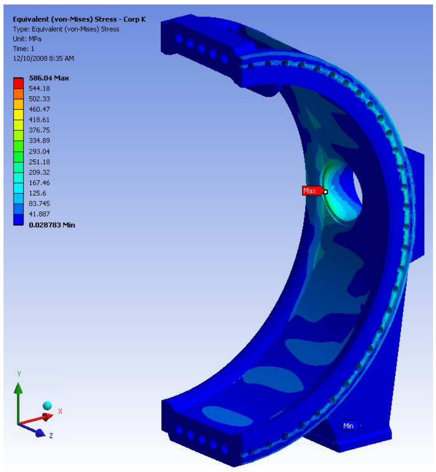

Figure 17. Stress analysis at 19.1 bar – closed disk

As a result of finite element analysis of equivalent stress (von Mises) at hydraulic test pressure of 28.65 bar are highlighted the most required areas for the situation in which the disk is in the open position (figure 19). Also we calculated the maximum values for the equivalent stresses in these areas.

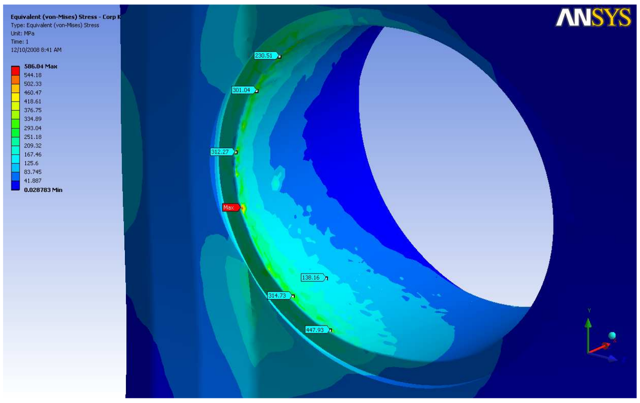

Figure 18. Maximum Equivalent stress (von Mises) – closed disk 19.1 bar

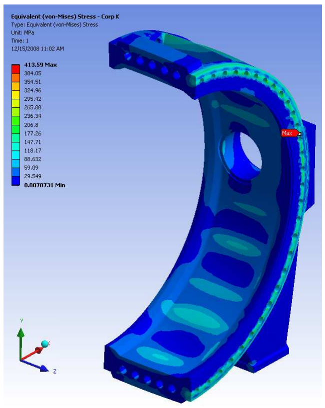

Figure 19. Stress analysis at 28.65 bar – opened disk

The major parts of the values don't exceed the allowable stress σ_a = 150 N/mm^2. The maximum value σ_{max} **=** 413.59 N/mm^2 is considered peak stress (see detail, figure 20); it occurs due to boundary conditions.

Like the calculation of the equivalent stresses (von Misses), for the working pressure value of 19.1 bar, the calculation of the deformations is done for both the valve body in case the disc is in the closed position (figure 21) and in case the disc is in the open position (figure 22). The deformation values are acceptable taking into consideration that the corresponding stresses are under the allowable stress value.

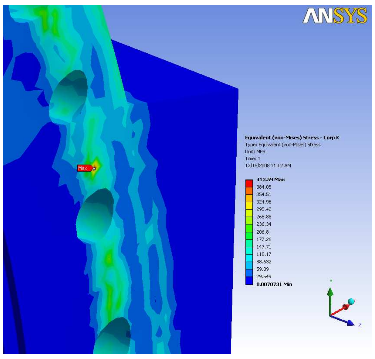

Figure 20. Maximum Equivalent stress (von Mises) – opened disk 28.65 bar

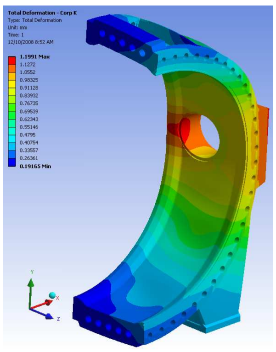

Figure 21. Deformations at 19.1 bar – closed disk

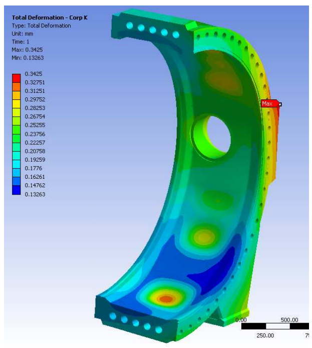

Figure 22. Deformations at 19.1 bar – opened disk

4. Conclusion

Static analysis of finite element valve body allows quantitative and qualitative assessment of the state of stress and strain by highlighting critical areas: the valve body - surface contact between trunnion disc and hub body.

Von Mises equivalent stresses do not exceed = 225 N/mm2 $\sigma < \sigma$ a = 1.5x150 = 225 N/mm2 accordance to ASME Code Section VIII / Division 2 / Appendix 4, [1].

Maximum deformations are produced on the top and bottom of the valve body and do not exceed 1.2 mm.

The maximum value of von Misses equivalent stress of 586 MPa is obtained at a single point and are due to boundary conditions.

References

[1] ***** *ASME Boiler and Pressure Vessel Code, Section VIII/Division 2/Appendix 4.*

[2] Manescu T.S., NedelcuD., *Analiza structurala prin metoda elementului finit,* Orizonturi universitare, Timişoara, 2005.

[3] Praisach Z.I., Manescu T.jr., Peris-Bendu F., *Stresses and deformations on the disk-valve body assembly of the butterfly valve ND 2800 NP 19 bar*, Ştiinţă si inginerie – Lucrările celei de-a noua Conferinţe Naţionale cu participare internatională "Profesorul Dorin Pavel-Fondatorul hidroenergeticii româneşti", Sebeş, Romania, Editura AGIR Bucureşti 2009.

[4] Pop M., Birou F., *Performances valaves designed to HYDRO ENGINEERING*, Conferinţa naţională "Think Hydro", Resita, 2-4 noiembrie, 2011, Romania, 99-101.

Addresses:

- PhD student Eng. Florin Peris-Bendu, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, fpbendu@yahoo.com
- PhD student Eng. Adelina Bostan, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, adelinag85@yahoo.com
- Prof. Ph.D. Viorel Câmpian, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, v.campian@uem.ro
- Prof. Ph.D. Eng. Dorian Nedelcu, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, d.nedelcu@uem.ro