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The Lifetime of the Biplane Disc by Using the Mean Stress Theory

Butterfly valves in hydroelectric scheme are safety elements that ensure tightly closed access water into downstream equipment. The operation conditions of the biplane disc butterfly valve is subjected to cycles of varying loads. The paper present the lifetime of the butterfly valve disc by using the Soderberg mean stress theory to find the minimum number of cycles which the disc can be loaded and unloaded during the operation of the butterfly valve.

Keywords: butterfly valve, biplane disc, mean stress theory, lifetime

1. INTRODUCTION

Analysis of stress and strain state of the biplane disk by using the analytic methods from strength of materials requires the use of simplifying assumptions. The obtained results are different than the real values that appear in the biplane disc. The method not allowed a comprehensive analysis of the entire structure.

A global analysis of the biplane disc is performed using finite element method (FEM). The method involves the following steps [1]:

- creating the 3D model with material properties;
- apply the boundary conditions and loads;
- meshing the model;
- determining the type of analysis: static, transient, fatigue, etc.;
- proper analysis;
- visualization and interpretation of the results.

The method emphasizes: critical structural areas, ie those areas where stresses are dangerous [2, 3]; areas where stresses are low; gives information on optimization in terms of structural strength.

The modern design of the butterfly valve disc involves the determination of lifetime, estimating the number of operating cycles in operating conditions, respectively.

2. LOADING AND UNLOADING THE DISC

The operation conditions of the biplane disc butterfly valve is subjected to cycles of varying loads [4]. At opening command of the butterfly valve, the water pressure acts on the upstream side of the disc (p_{us}), but in the downstream side of the disc, the water pressure (p_{ds}) increase from zero to upstream pressure value (fig. 1.a). For this cycle, the stresses on the disc are reduced. Once the butterfly valve was closed, the downstream pressure of the butterfly valve drops from upstream pressure value to zero (fig. 1.b).

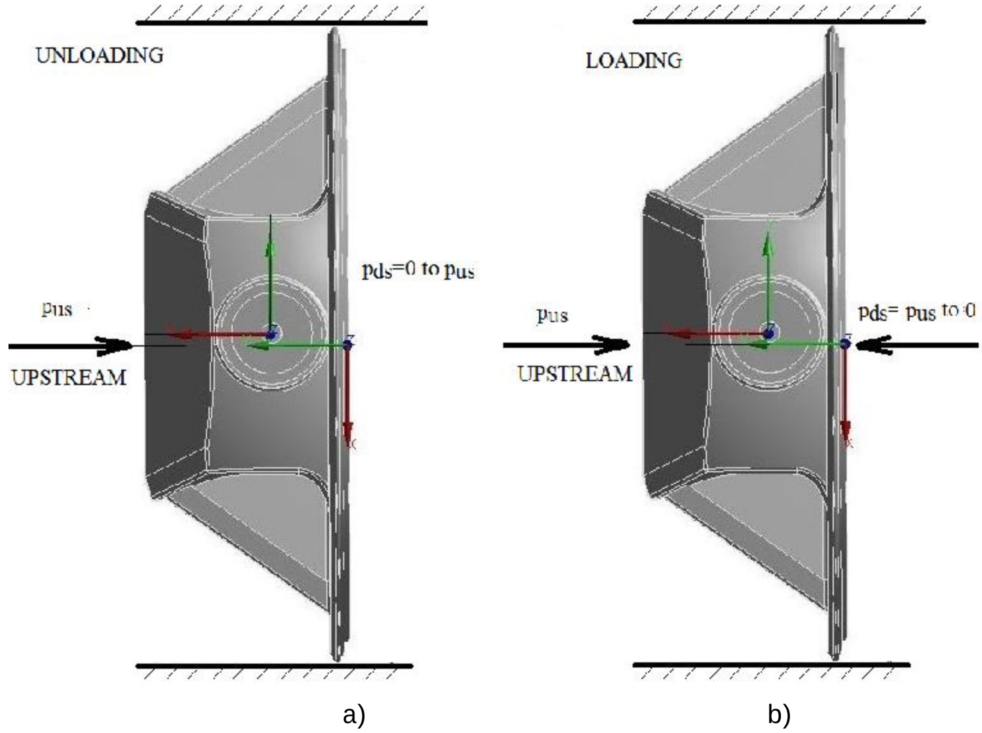

Figure 1. Unloading (a) and loading (b) the valve disc

Cycles of loading and unloading of the disc causing positive undulating pulsating asymmetric stresses [5] from zero to maximum values of the stress and vice versa, which lead to material fatigue.

The minimum number of cycles that lead to material fatigue determines the lifetime of the biplane disc.

4. FATIGUE CALCULATION

Under the rules [6] ASME (American Society of Mechanical Engineering): Criteria of the ASME Boiler and Pressure Vessel Code for design analysis in sections III and VIII, Division 2, fatigue calculating of the biplane disc consider maximum shear stress (τ_{max}).

Fatigue calculation by finite element method takes into account the mean stress theory [7, 8] by using Soderberg criterion (fig. 2), defined with (1).

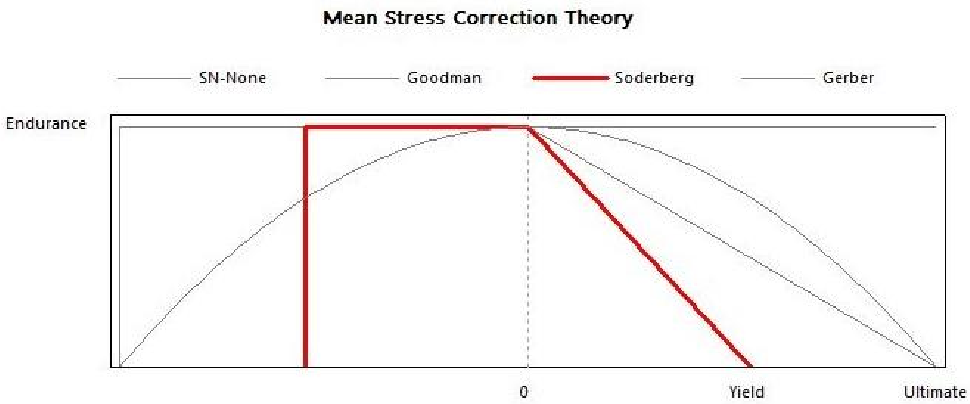

Figure 2. Mean stress theory - Soderberg criterion

$$\frac{\sigma_{am}}{\sigma_e} + \frac{\sigma_m}{\sigma_Y} = 1 \qquad (1)$$

where,

σ_{am} [MPa] is stress amplitude;
σ_e [MPa] is stress endurance;
σ_m [MPa] is medium stress;
σ_Y [MPa] is Yield stress of material

The input parameters and amplitude load are shown in fig. 3 and 4.

Materials	
Fatigue Strength Factor (Kf)	1.
Loading	
Type	Zero-Based
Scale Factor	0.7071
Definition	
Display Time	End Time
Options	
Analysis Type	Stress Life
Mean Stress Theory	Soderberg
Stress Component	Max Shear
Life Units	
Units Name	cycles
1 cycle is equal to	1. cycles

Figure 3. The input parameters

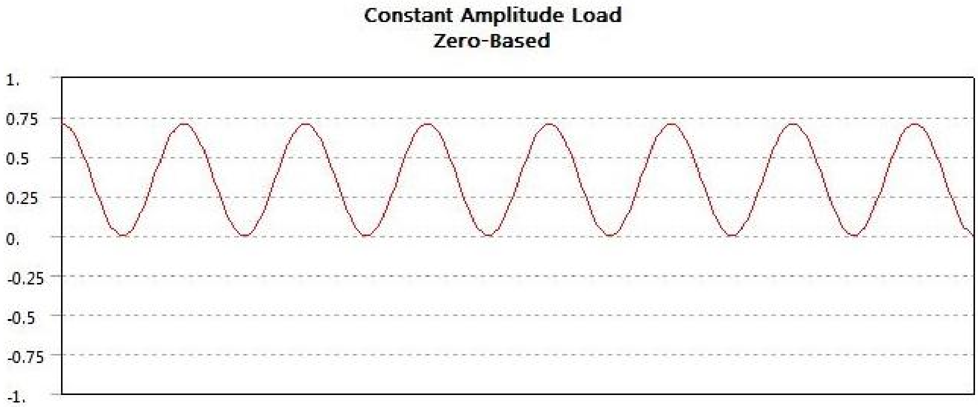

Figure 4. The amplitude load

3. RESULTS

After running the FEM analysis the equivalent alternating stresses are shown in figure 5.

The minimum number of cycles obtained from finite element analysis is illustrated in Figure 6

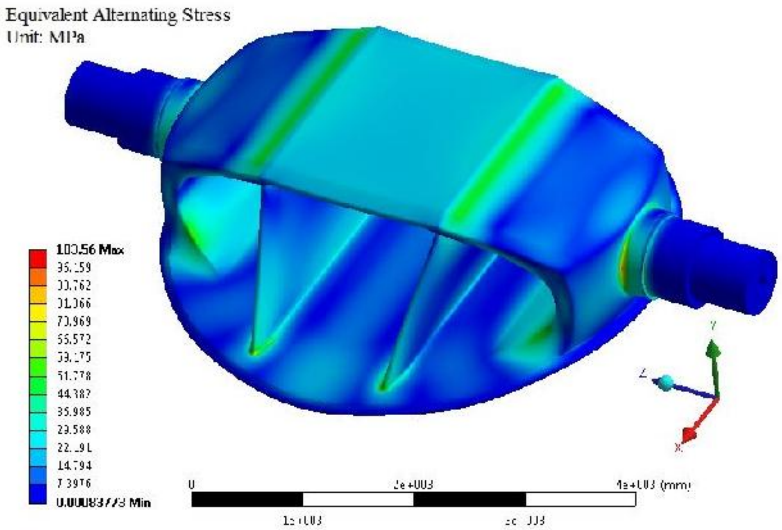

Figure 5. The equivalent alternating stress

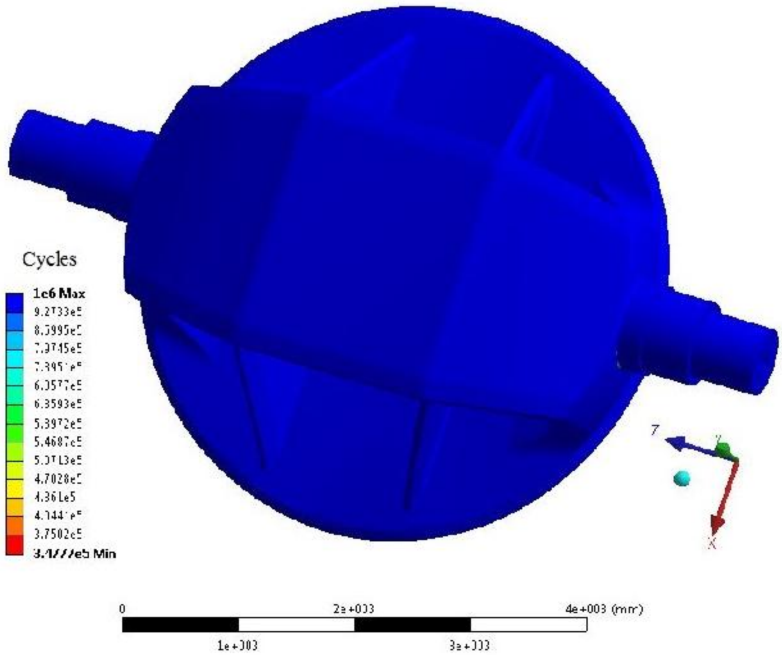

Figure 6. The minimum number of cycles

4. CONCLUSIONS

Mimim number of cycles obtained (Fig. 6) is nc = $3.4777 \cdot 10^5$ cycles. If it is considered that the disc daily average is subjected to: n_d = 4 cycles of unloading and n_i = 4 cycles of loading and in one year is t=365 days, the lifetime of the disc is obtained from the relationship:

$$T = \frac{n_c}{(n_d + n_i) \cdot t} = \frac{3,4777 \cdot 10^5}{(4+4) \cdot 365} = 119,1 \quad \text{years} \qquad (2)$$

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