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Fatigue Analysis of an Outer Bearing Bush of a Kaplan Turbine

The paper presents the fatigue analysis of an outer bearing bush of a Kaplan turbine. This outer bush, together with an inner one, bear the pin lever - trunion - blade subassembly of the runner blade operating mechanism. For modeling and simulation, SolidWorks software is used.

***Keywords**: Outer bearing bush, Kaplan turbine, fatigue analysis*

1. Introduction

The failure of machine parts often occurs due to variable loads, even though the stress is below the yield strength value. This phenomenon is known as fatigue.

Most important factors contributing to decrease of strength to cyclic loads are likely to be constructive, technological and operational [6].

These factors are as follows [6]:

- constructive factors: shape and dimensions of part and assembling way;
- technological factors: the material and the surface quality;
- operational factors: loading type, level of cycle asymmetry, short-term overloads and underloads, jerks, load frequency, temperature, chemical influence of environment.

The stages of fatigue damage evolution are: crack initiation, crack propagation and final fracture [7].

In the case of turbines, studies on fatigue of different component parts were made [1], [2], [4].

This paper presents the numerical fatigue analysis of an outer bearing bush of a Kaplan turbine, using SolidWorks software.

2. Presentation of the 3D Model of Runner Blade Operating Mechanism

The parts of the 3D model of runner blade operating mechanism are as follows [5]: 1 – hub; 2 – bush; 3 – fork head; 4 – connecting rod; 5 – pin lever; 6 – trunnion; 7 – inner bearing bush; 8 – outer bearing bush; 9 – blade (fig. 1).

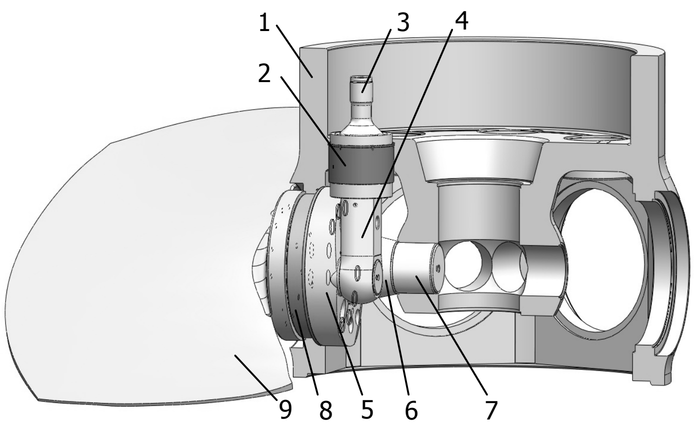


Figure 1. 3D model of runner blade operating mechanism.

The hub (1) is considered fixed part; the bush (2), inner bearing bush (7) and outer bearing bush (8) are locked within the hub (1). The fork head (3) drives the *pin lever (5) – trunnion (6) – blade (9)* subassemly through the connecting rod (4).

All parts have assigned materials from SolidWorks materials library. For the outer bearing bush, tin bearing bronze is chosen.

3. Motion Definition

The motion is defined on the basis of *fork head displacement* versus *time* (fig. 2). The limit values of blade angle φ are 8,47 [º] and 8,66 [º].

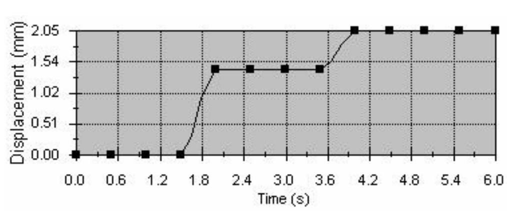


Figure 2. Fork head displacement versus time [5].

4. Forces Acting on Mechanism Links

The forces that act on the mechanism links are as follows:

- action force F_a on the fork head; its magnitude is computed by Solidworks software on the basis of all other acting forces, as shown in fig. 3;

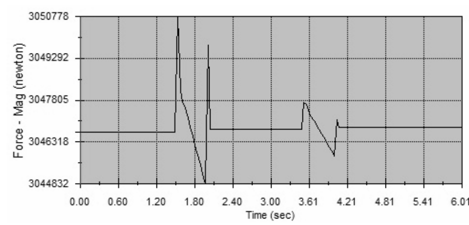


Figure 3. Magnitude of action force F_a versus time.

- water axial force on the blade $F_{ax} = 1{,}771 \cdot 10^6$ [N];
- water tangential force on the blade $F_t = 1{,}025 \cdot 10^6$ [N];
- centrifugal force of the *pin lever – trunnion - blade* subassembly $F_c = 4{,}070 \cdot 10^6$ [N].

Action force is applied on upper surface S of the fork head and all other forces are applied in points (fig. 4)

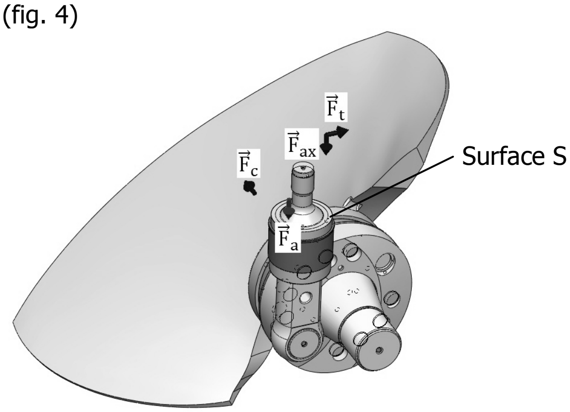


Figure 4. Forces acting on mechanism links.

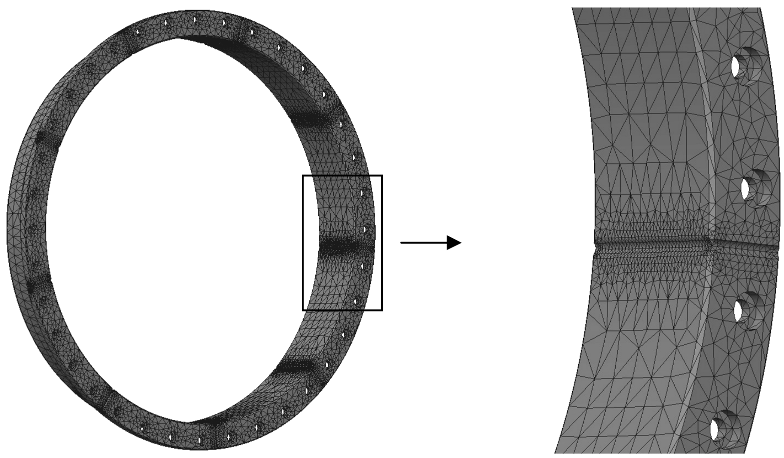
5. Stress Calculus for the Outer Bearing Bush

Stress calculus can be achieved using finite element methods [3], [8].

For stress calculus and fatigue analysis, SolidWorks Simulation module is used [9].

In order to make the stress calculus, the variable loads for entire period of motion are imported from the motion analysis file in a dynamic study file.

The outer bearing bush is meshed using standard mesh with automatic transition option, as shown in fig. 5. The value of global mesh size is 34 [mm].



a) b)

Figure 5. Meshed model of outer bearing bush (a) and detail (b).

Numerical calculus (using FFEPlus solver) for *von Mises* stress is performed; the plot of *von Mises* stress is presented in fig. 6. The highest stress value is 78,4 [MPa], under the yield stress limit 110,3 [MPa].

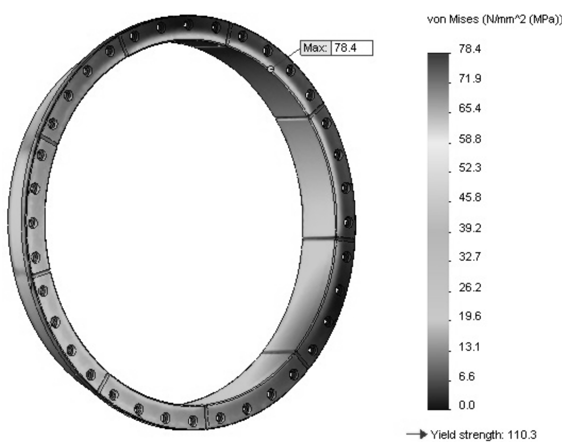


Figure 6. Plot of *von Mises* stress.

6. Fatigue Analysis of the Outer Bearing Bush

In order to make the fatigue analysis, the dynamic study file previously used for stress calculus is chosen. Fully reversed (LR = -1) loading type is used.

The fatigue (S-N) curve for outer bearing bush material is shown in fig. 7.

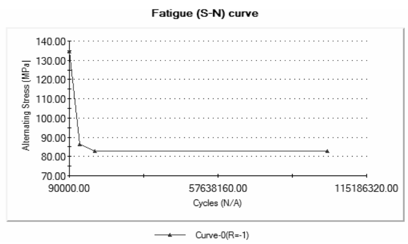


Figure 7. Fatigue (S-N) curve.

The plot of total life (cycle) for the loads previously considered is presented in fig. 8.

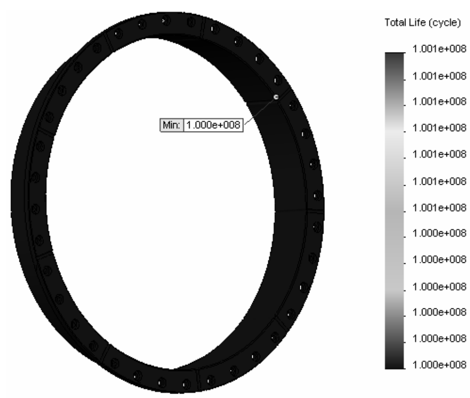


Figure 8. Plot of total life (cycle) for outer bearing bush.

7. Conclusions

Using SolidWorks software, forces are applied on parts of 3D model of runner blade operating mechanism and a numerical stress calculus is done for the outer bearing bush.

Even the highest stress value (78,4 MPa) is below the yield strength value (110,3 MPa), the fatigue analysis shows failure after 10^8 cycles.

As further research, stress calculus and fatigue analysis for other parts of runner blade operating mechanism are to be accomplished.

8. Acknowledgement

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