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NUMERICAL MODELING OF LOAD OF FRONT TURBINE SHUTTER

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ABSTRACT
This paper presents a stress – strain analysis of a butterfly pre-turbine valve gate. The analysis was done both by the finite element method applying a special software suite ANSYS and analytically. A concrete engineering problem was considered here. One segment of the butterfly valve gate in the shape of a rectangular panel was also processed analytically, using the relations for a construction resistance. The results of a stress and strain are on a level of those obtained numerically by the finite element method, and these results show a validity and correctness of an applied method in the given conditions. The correctness of the applied FEM method which was confirmed as an efficient means for the calculation and analysis both of complex mechanical elements and structures and their behaviour under the load of working conditions was ascertained in this way.
Keywords: pre-turbine valve gate, finite element method, panel, deflection

1. INTRODUCTION
The hydroelectric power plant "Glava Zete" belongs to the first generation of objects built immediately after the Second world war. It can be considered as an object which is close to the end of working cycle in the sense of a term resource purporting the exploitation with rational , economically efficient maintenance, provided that the components of the system have still retained 90% of their characteristics. The resource is also dilapidated because of the wear of the equipment which is difficult for the maintenance. Beside this, the supply of original spare parts for a regular maintenance would also be difficult even if the resource was not obsolete.
One of the parts of the system which is specially designed and made is the pre-turbine butterfly valve gate. (Figure1.) of welded construction built in during the recovery of the turbine construction in HE "Glava Zete" in 1986, instead of the previous pre-turbine valve gate which was a part of forged structure and where cracks had been noticed.
The welded construction consists of a panel with diameter 2200 mm and 15 mm wide , with the sheet metal strengthening 40 cm thick and a circumferential ring in the seal zone 70 cm thick fastened on the steel axis and also additionally fastened with steel clamps in the rim zone of the valve gate.

Figure 1. Butterfly pre-turbine valve gate on HE"Glava Zete"

2. METHODS OF CALCULATION

The carrying structures of mechanical constructions are made from several primary, or basic elements as they are also named. These elements unite and provide a relative position for all other elements. On the other side, in the exploitation conditions of the construction, the flow of static and dynamic forces is closed in the carrying structure.

The development of analytical - numerical or experimental methods is necessary for the determination of necessary parameters in the design or identification of the existing state of the implemented structure [1].

The analytic calculation methods are based on a material resistance and the elasticity theory, and may be applied to a relatively small number of cases, only for the calculation of mechanical elements or elements having a simple geometric shape.

The numerical methods are used for the calculation and analysis of more complex structures. There are two methodologically different approaches in this case. First, for given differential equations of the behaviour of some element in the exploitation conditions - static or dynamic load - the result is obtained by solving of these equations with the finite difference method or with the method of a numerical integration. The second approach establishes the previous idealisation of the structure onto the elements of a regular geometric shape-finite elements- so as to , with the use of matrix methods : through the method of forces or methods of displacement, obtain the final result by solving of an algebraic equation system.

Figure 2 presents the scheme of a basic division of methods for an analysis and calculation both of elements and carrying structures as a system.

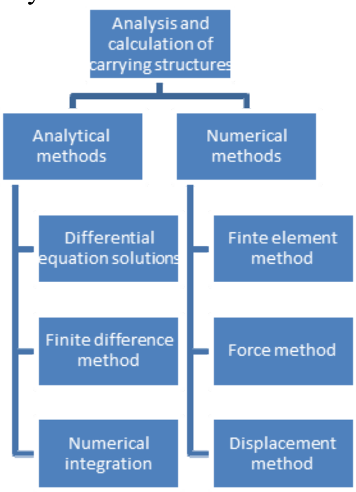

Figure 2. Methods for calculation of carrying structures

3. FINITE ELEMENT METHOD

The concept of the finite element method (FEM) is based on a discretisation of the construction continuum with the simple parts of finite dimensions. Through these parts - with finite element methods or principles of physics, the basic static, kinematic, dynamic and thermodynamic relations which are extended to the borders of a continuum [2] are established.
ANSIS [3] was used as a software for the numerical simulation.
Figure 3. presents the model of pre-turbine valve gate with the mesh of finite elements.

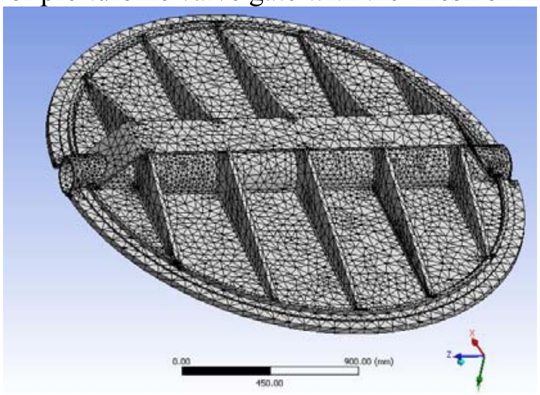

Figure 3. Model of pre-turbine gate with the finite element mesh

The results of the analysis obtained by the finite element method (FEM) are given at figures 4-7 , and table 1 gives the results of stress and displacement for the pre-turbine valve gate , obtained by the numerical simulation with a the software suite ANSYS.

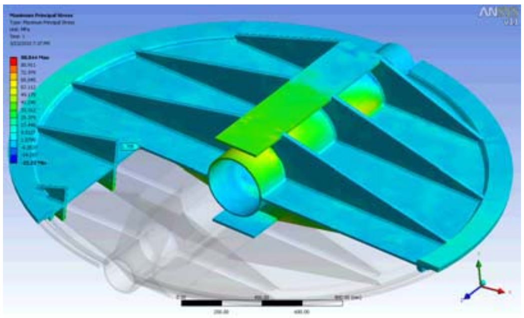

Figure 4. Stress σ_x in the centre of a panel for which the analysis was carried out

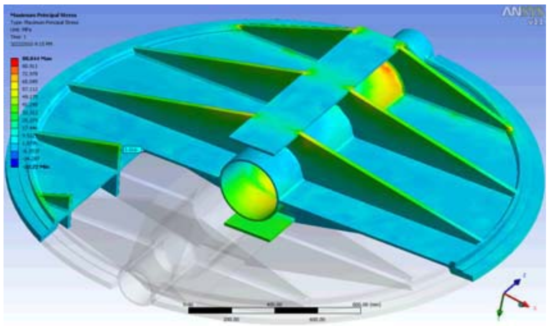

Figure 5. Stress σ_y in the centre of a panel for which the analysis was carried out

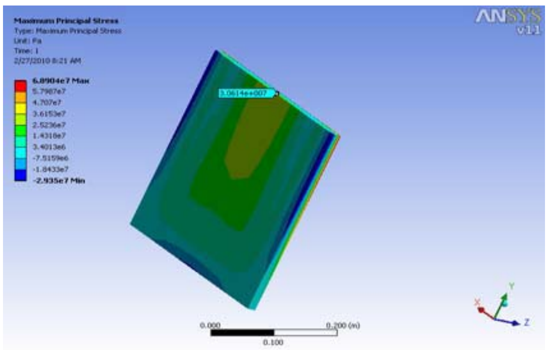

Figure 6. Panel's cross-section with a stress σ_x (3D)

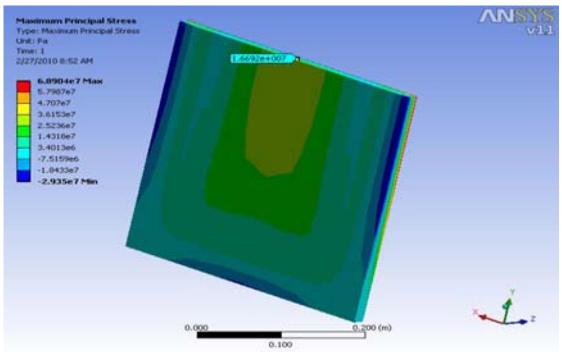

Figure 7. Panel's cross-section with a stress σ_y (3D)

Table1. Results for stress and displacement of pre-turbine gate obtained numerically –the result of analysis by the ANSYS

Maximal bend -W_{max} u [cm]	0.176
Maximal main stresses in [KN/cm^2]	8.884

4. ANALYTICAL CALCULATION

According to the character of strain in process of a panel bending due to cross load , three kinds of thin panels can be distinguished: solid, flexible and absolutely flexible. Solid panels are those panels having a bend smaller than 1/5 of their thickness; in this case it can be considered that the mean plane is not exposed to a tension or a compression strain. Flexible panels are those panels having a bend bigger than 1/5 of their thickness but smaller than 5 thicknesses: in case of fastened ends, a significant stresses emerge in the mean plane due to a strain. The absolutely flexible panels or membranes are those having a bend bigger than 5 their thicknesses.

The calculation of rectangular panels is fairly more complex than the calculation of circle panels with an axial-symmetric load , because of the fact that all weights (stresses, moment, bends etc.) are expressed through not one but two variables. The coordinates x and y are variables for the rectangular panels. The differential equation for an elastic area of a panel is partial differential equation whose solution is most frequently found by rows . Only finite results without a formation and solving of a differential equation [4] will be given here, in Table 2.

Table 2. Results of stresses and strains for a panel obtained analytically

Position of panel	*a)* supported panel	*b) clamped panel*
Maximal bend -W_{max} - cm	0.067	0.018
Stresses in centre -$\sigma_x;\sigma_y$ - KN/cm^2	σ_x=3.937, σ_y=1.482	σ_x=3.076, σ_y=1.705

The comparative results obtained analytically and numerically given at Table 3.

Table 3. Stresses and strains in a panel centre

Panel position	Maximal bend W_{max} - cm	Stresses / KN/cm^2
Ansys (complete model)	0.0176	σ_x=3.016, σ_y=1.705
Ansys (smaller segment)	0.028	σ_x=3.061, σ_y=1.669
Clamped panel	0.018	σ_x=3.076, σ_y=1.705
Supported panel	0.067	σ_x=3.937, σ_y=1.482

5. CONCLUSION

This paper presents the stress – strain analysis of butterfly pre-turbine valve gate which is exploited in the hydroelectric power plant “ Glava Zete”. The analysis was carried out both by the finite element method using the dedicated software suite ANSYS and analytically.

The concrete engineering problem was considered here and the obtained results ascertained the justifiability of use of the FEM which appeared as an efficient means for the calculation and analysis of complex mechanical elements and structures and their behaviour under the load in working conditions.

One segment of the butterfly pre-turbine valve gate was also analysed using the equations from the area of a structural resistance. The obtained results for a stress and strain are on the level of the results obtained numerically with the finite element method and these show validity and correctness of the applied solution in given conditions.

6. ACKNOWLEDGEMENTS

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