Experimentální Analýza Napětí 2011
Experimental Stress Analysis

Verification of Safe Operation of Hydraulic Power Station Stop Logs

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Abstract: Stop logs of hydraulic power stations are during their operation loaded by dynamic loading. With respect to their long-term operation it is necessary to verify their safe functionality to block watercourses. In the paper is presented stress analysis of stop logs with the aim to verify their functionality as well as determination of critical locations on stop logs for identification of potential failures of welds.

Keywords: Stop logs, Residual stresses, Critical locations

1. Introduction

Stop logs are steel welded structures the shape of which is obvious from Fig. 1. Their serve for blocking of water on the inlet and outlet of hydraulic power plant turbines.

Fig. 1. Stop log of hydraulic power plan

During operation of hydraulic power plant (Fig. 2) are the stop logs positioned on each other in order to perfectly seal water flow. With respect to their long-time operation (several decades) it is necessary to provide their periodical inspections as well as to verify their safe operation.

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In the paper is presented procedure for verification of stop log functionality that includes check of their geometry as well as analysis of stress states by the methods of experimental mechanics [1 - 3].

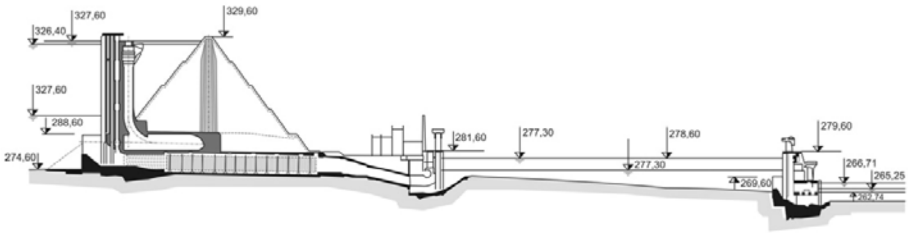


Fig. 2. Schema of hydraulic power plant

2. Analysis of stop logs geometry

Geometry check of stop logs includes, beside of visual inspection, (check of welds, corrosion, visible permanent deformation of individual parts), measurement of real wall thicknesses of individual structural members and planarity of function planes of stop logs.

The basic dimensions of one analyzed stop log are given in Fig. 3.

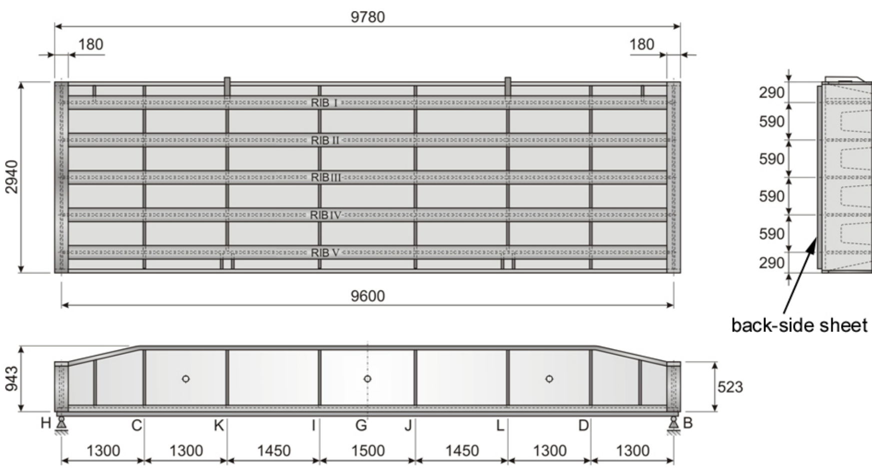


Fig. 3. Basic dimensions of stop log

Thicknesses of individual elements of stop logs were measured by contact ultrasound apparatus with precision of measurement 0.1 mm in four hundred measurement locations. The measurements indicated that real thickness was in some cases lower than the nominal one, but thickness decreasing did not exceed 5%. Measured thicknesses were then used in computation of stop logs by the finite element method [1].

Planarity of stop logs was checked on back side plane (Fig. 3) by total geodetic station Leica TCR 305 (Fig. 4) or by robotized geodetic total station Trimble VX Spatial Total Station 305 [3].

In Fig. 5 are given (as a result of measurement) spatial models of back sides of two stop logs in horizontal plane. Models represent spatial coordinates of surface points of back sides of stop logs with respect to ideal plane surface of back side.

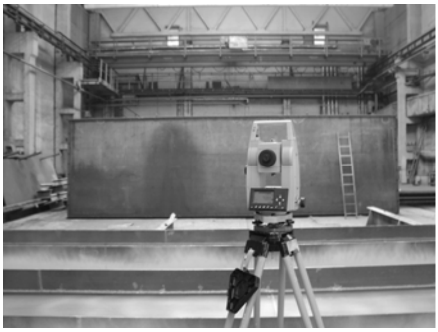


Fig. 4. Measurement of back side plane planarity of stop log by geodetic station Leica TCR 305

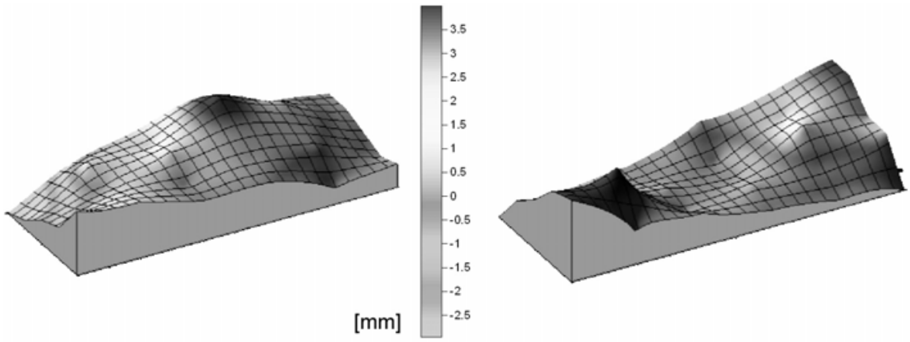


Fig. 5. 3D model characterizing planarity of stop log back walls

3. Determination of residual stresses in stop logs

For determination of critical locations of loading on stop logs it is necessary to know magnitudes of residual stresses due to production, reparation as well as overloading during operation because such stresses together with stresses resulting from common operation can be reason of lower functionality of stop logs and consequently of their failure.

Residual stresses were determined by the hole-drilling method with using hole-drilling apparatus RS 200 [4, 5]. For the measurement were used strain-gages RY 21-3/120 fixed by strain-gage glue X 60 and isolated by silicone protective coating SG-250. Measurement was realized by strain-gage apparatus P 3. On the basis of stress analysis of stop logs during their operation were chosen localization of strain-gages on the bottom flange of rib (location A Fig. 6) and on flange of boundary rib (location B Fig. 6). In location A (Fig. 6) were for individual stop logs chosen two variants of strain-gage distribution (A 1 – along flange width, A 2 – along flange). In Fig. 7 are given photographs of applied strain gages.

The hole drilling was realized by milling tool with diameter 3.2 mm to depth 5 mm in ten steps with proportional distribution of hole depth drilling.

The measured values of released strains were processed according to Standard ASTM E 837-01 [6]. Residual stresses in location B reached magnitude 100 MPa and they were mostly compressive. In location A maximum tensile residual stresses in sanding tables slightly exceed magnitude 100 MPa. The tables that were not processed by sanding had maximum residual stresses over 150 MPa, with positive and negative signs.

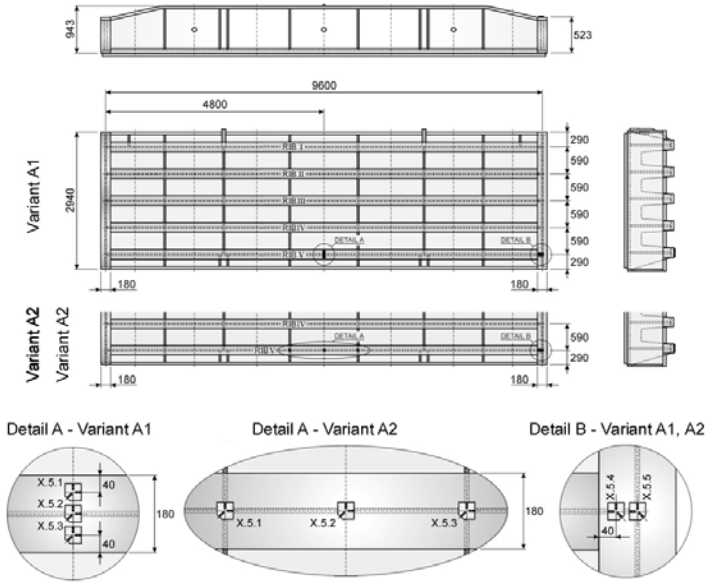


Fig. 6. Localization of strain-gages for the measurement of residual stresses

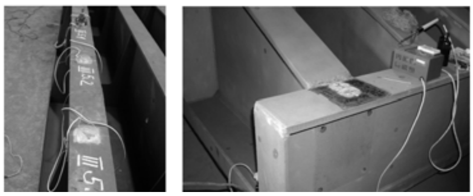


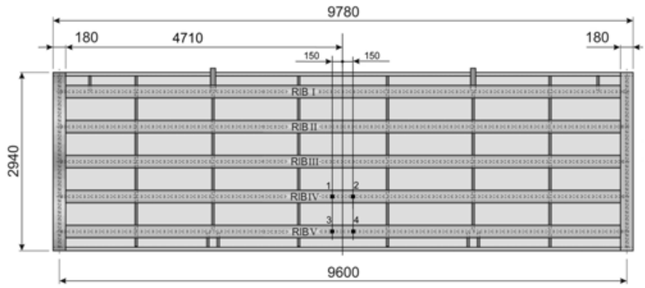
Fig. 7. Photos of applied strain-gages

4. Experimental determination of time-dependent charts of stresses in stop logs during their operation

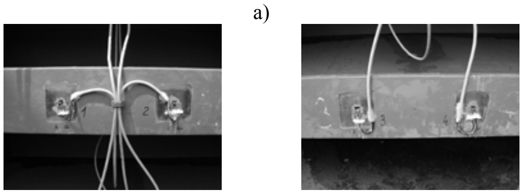
In the frame of functionality verification of stop logs was performed computation of their strength and stiffness by using analytical and numerical methods. Despite of this there were, in the frame of safety verification, accomplished strain-gage measurements of time-dependent stress increments in stop logs during operation of hydraulic power station. This ensured verification of analytical and numerical computations and taking into account real boundary conditions including constraints in positioning, dynamic of loading and other operational influences. Knowledge of time-dependent stresses in locations of extreme loading is necessary for assessment of stop log residual lifespan. Locations of strain-gage application on the stop log are given in Fig. 8a. In Fig.8b are details of applied strain-gages on flanges.

For the measurement were used strain-gage rosettes XY 91 with compensation of thermal influences by Wheatston bridge. Measurement was realized by the strain-gage apparatus SPIDER. In Fig. 9 is view to stop log with applied strain-gages during its positioning into working position. During measurements were sampled time-dependent stress changes during different regimes – transport and positioning of stop log under water to working position, water outflow, starting of turbine operation and its stopping.

In Fig. 10 are given time-dependent charts of stress increments in locations of strain-gages 1 to 4 at the beginning of water pumping from the space before stop log.



a)



b)

Fig. 8. Strain-gages for the measurements during operation. a) locations of strain-gages 1, 2, 3, 4 b) details of strain-gages

Fig. 9. Manipulation with stop logs into working position

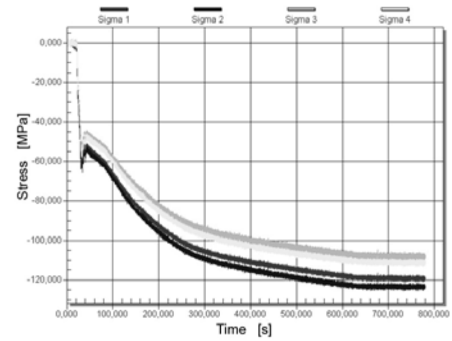


Fig. 10. Time-dependent charts of stress increments at the beginning of water outflow

There is and interesting jump in stress increments after starting of pumps, the detail of which is seen in Fig. 11. In Fig. 12 are time-dependent stress increments during water outflow till its to end of this operation.

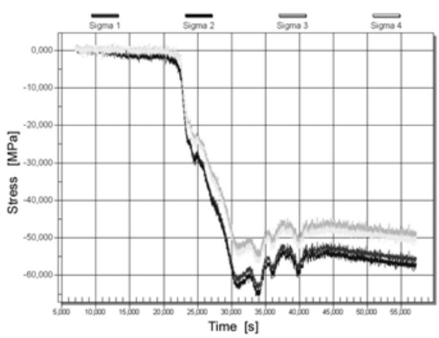


Fig. 11. Detail of time-dependent stress increments at the time of water pump start

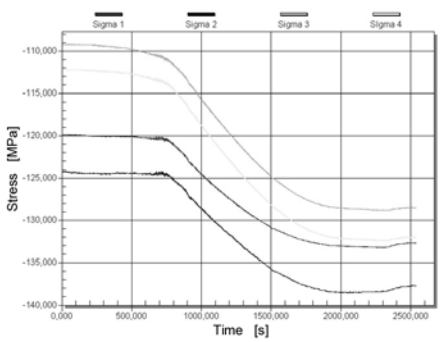


Fig. 12. Time-dependent stress increments after finishing water outflow

5. Conclusions

During verification of stop logs functionality of hydraulic power stations is possible in the frame of regular inspections to use experimental methods that include analysis of geometrical dimensions and stress analysis of stop logs. On the basis of evaluation of several stop logs can be stated that:

- From the point of view of measured wall thicknesses of structural members and their using in strength computation can be stated that corrosion do not endanger safe operation of stop logs.
- Measurement of planarity of function surfaces showed that deviations from planarity measured in direction perpendicular to the plane are in orders of millimeters.
- Measurements of residual stresses showed that their levels slightly exceed 100 MPa. Magnitudes of residual stresses documents that after superposition with operational stresses plastic deformation can occur in locations of stress concentrators.
- From the experimentally determined time-dependent charts of stresses in stop logs result that during operation the maximum stresses in flanges of ribs reach magnitude 140 MPa, which is by 10% smaller than maximum values computed by analytical or numerical methods. Difference can be explained by a fact that experiment was realized under real operational conditions (geometry, loading, boundary conditions) that cannot be considered in computational model.
- On the basis of stop log analysis were determined locations of possible weld failures. For some types of stop logs was determined strengthenings in locations of ribs because of presence of high stress levels obtained from modeled operational loadings.

Results obtained by experimental methods allowed to identify critical loations of stop logs and they serve as suitable base for assessment of their lifespan.

Acknowledgements

For the support of this work authors would like to express their gratitude to Research & Development Operational Programme funded by the ERDF,project: Center for research of control of technical, environmental and human risks for permanent development of production and products in mechanical engineering (ITMS: 26220120060),and to Scientific Grant Agency VEGA MŠ SR ,project No. 1/0289/11.

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