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Short Communication

Experimental verification of blade elongation and axial rotor shift in steam turbines

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ABSTRACT

The experimental research of static and dynamic characteristics of rotating parts of turbomachines is a very important part of the design and verification of the machine parameters as well as optimization of their operational regimes. The described method of measuring dynamic and static characteristics, especially blade elongation and rotor axial shift, are based on the utilization of the non-contact magnetoresistive sensors developed in the Institute of Thermomechanics AS CR. These sensors exhibit positive properties for this purpose.

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1. Introduction

Long blades of steam turbines are exposed to extreme stress caused by centrifugal forces. Variable aerodynamic and many other excitation forces, e.g. bending and torsion vibrations of the shaft, cause vibration of the turbine blades especially in the low-pressure stages. Dynamic stress components are superimposed on the static stress component and may cause a fatigue failure of the blades with consequent large economic losses. Therefore, it seems most appropriate to investigate experimentally the status and behavior of the long turbine blades using non-contact diagnostic measurement systems (Procházka, and Vaněk, 2014). It was concluded in the study (Procházka, and Vaněk, 2012) that the most suitable electromagnetic sensors for the harsh environment of steam turbines are the magnetoresistive (MR) sensors. These sensors feature high sensitivity, directional sensitivity, low noise and wide frequency range from 0 to 300 kHz. Therefore, they can be used for static measurements and also statically calibrated (Procházka, and Vaněk, 2015).

2. Results of the Experimental Research

Blade elongation is an important stationary characteristic for the assessment of blade straining and efficiency of the turbine stage. The value of the clearance (distance between the blade tip and the stator) and subsequently blade elongation may be evaluated from the magnitude of the output signal of the MR sensor. It is necessary to measure the maximum or minimum voltage of the impulse generated by the blade passage, or to use the peak-to-peak value for the evaluation. The output voltage of the MR sensor depends on the distance between the blade and the active element of the sensor hyperbolically. The real value of the clearance has to be determined on the basis of a laboratory calibration. First it is necessary to determine the appropriate value of the axial displacement of the rotor. This value is then used for the correction of the constant by the calculation of the clearance. The axial displacement of the rotor can be estimated by measuring the signal amplitudes of the axial sensor at the blade root.

An example of real signals from the stator and axial non-contact MR sensor is shown in Fig. 1. These signals were recorded at the steam turbine 280 MW at the operational speed 3000 rpm. The upper signal is the signal of the stator sensor. The course of the function expressing the dependence on the axial position of the rotor must be determined experimentally. The advantage of the MR sensors is that they can be calibrated statically in laboratory using a micrometric traverser. Fig. 2 shows compressed signals of the stator and axial sensors. Individual

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sections correspond to different regimes of the turbine: 1-2 standby revolutions 40 rpm, 2-3 warming revolutions 400 rpm, 3-4 warming revolutions 1500 rpm with turbine startup, 4-A 3000 rpm, A-B connected to network, B-C disconnected from network, C power 22 MW connected to network, D 130 MW, E 170 MW. The measured axial displacement of the rotor when changing speed from 40 rpm to 3000 rpm was 4.75 mm. The blade elongation due to the centrifugal force by this speed change was 4.1 mm.

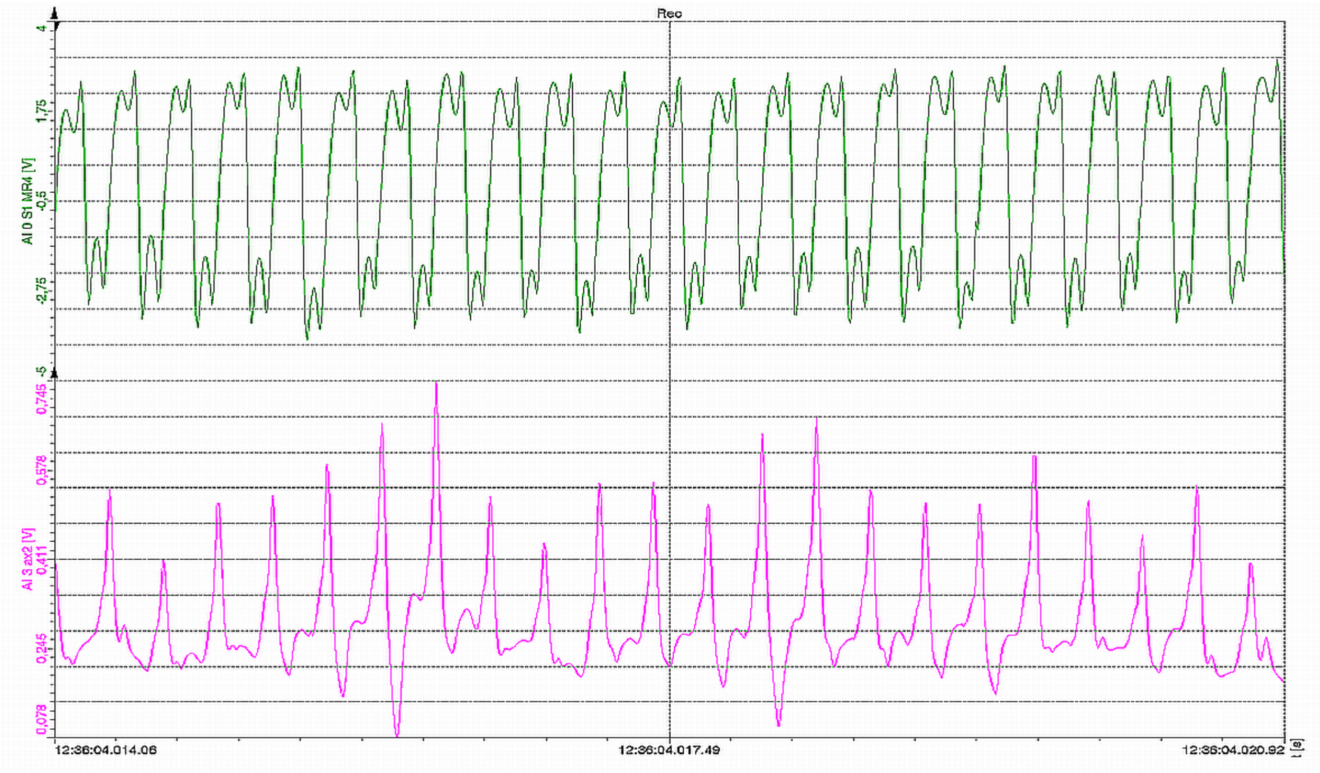

Fig. 1. Blade signals of the stator sensor (green) and the axial sensor (magenta).

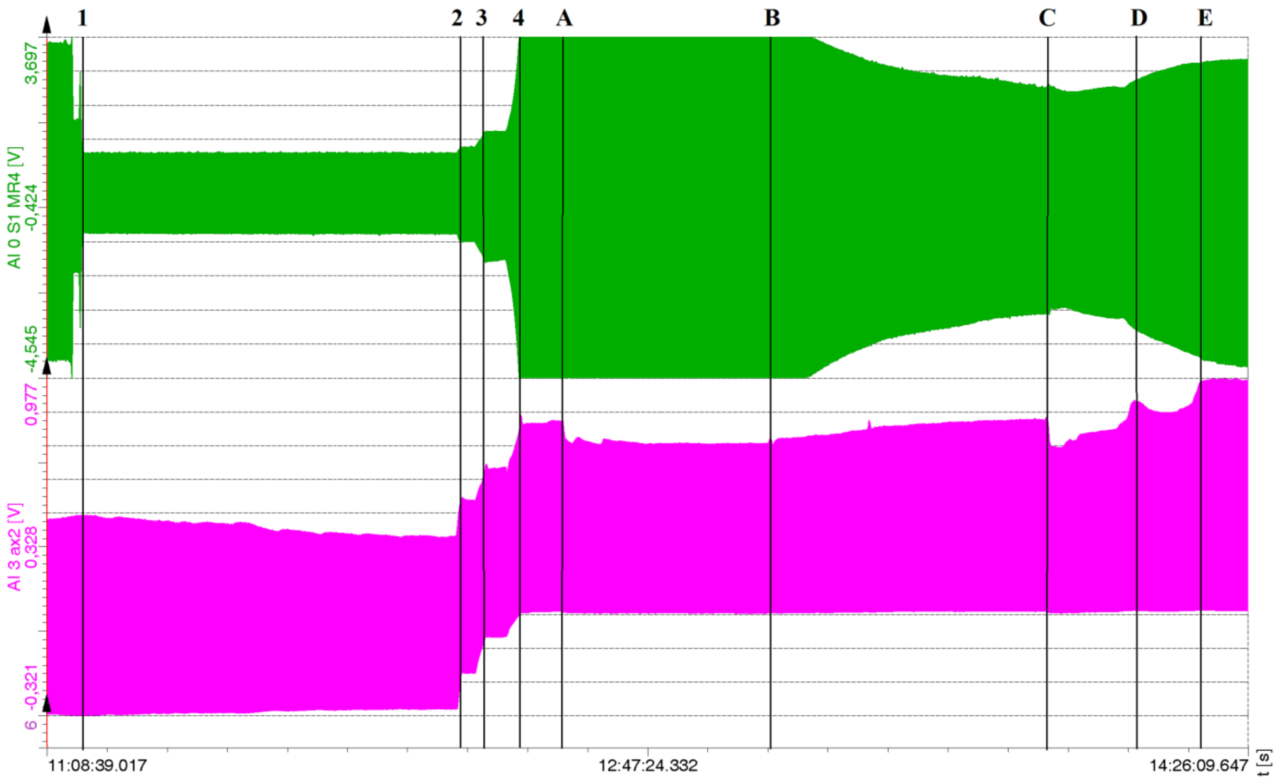

Fig. 2. Compressed signals of the stator sensor (green) and the axial sensor (magenta).

3. Conclusions

Magnetoresistive sensors proved to be a suitable mean for the experimental research of blade elongation and turbine rotor axial shift. These sensors feature high sensitivity and wide frequency range from DC values. This enables to calibrate them statically at lab using a positional traverser, which is a very important fact for improving accuracy and credibility of the measurements in harsh environment of the steam turbines.

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