

Abstract

For at least 50 years, industry has needed an effective, efficient, and possibly the least interfering with the turbine system method of measuring the frequency of forced vibrations of rotor blades. This is essential to prevent costly repairs or even fatal accidents. No method is as non-invasive and surprisingly effective in its simplicity as the Tip-Timing method.

The Tip-Timing method of measuring the amplitude and frequency of the blades' vibration consists in measuring the arrival times of the rotor blades (ToA) in successive sensors placed in turbine housing and on its basis determining the amplitude, frequency and phase of each blade. For this, a harmonic oscillator model and a fitting algorithm are used. This is a reverse problem to that where the amplitude, frequency and phase are determined based on the displacements of the rotor blades using the approximation method.

Models and numerical programs for determining the frequency, amplitude and phase of vibrations of each of the rotor blades based on the measurement of the blade arrival time obtained from three or more sensors placed in the turbine housing and the sensor once per revolution have been developed in this thesis. Vibration analysis was carried out for the rotor blades of the last stage LP of a 380 MW steam turbine from measurements on a centrifuge during turbine run-down and measurements at EC Bełchatów during nominal operation of 3000 rpm, rotor blades of the first stage compressor of the SO-3 engine, and rotor blades in own laboratory.

Chapter 1 lists the most important abbreviations and symbols used in this thesis. Chapter 2 presents the introduction and scope of the work. Chapter 3 provides a literature review that also includes the history of Tip-Timing. Chapter 4 describes the aims of the thesis.

Chapter 5 describes the mathematical models and algorithms used in the author's Tip-TimingSolver numerical program, along with some implementations.

In Chapter 6, to verify the written program, a comparison with the results of numerically simulated Tip-Timing measurement data from another program developed at The Szwedowski Institute of Fluid-Flow Machinery was presented.

Chapter 7 compares the results obtained from the algorithm presented in the paper with the results of experimental tests of the last stage of low-pressure rotor during run-down in the centrifuge.

In Chapter 8, the influence of pressure in the capacitor on the forced vibration of the blades was analyzed using the TipTimingSolver program.

Chapter 9 analyzes the vibrations of the rotor blades of the last stage of low-pressure steam turbine in nominal operating conditions using the developed numerical program.

In Chapter 10, the vibrations of the blades were analyzed on own measuring laboratory, the set parameters of vibrations were compared with the parameters obtained with the developed program.

Chapter 11 presents the amplitudes and frequencies of the rotor blades of the 1st stage of the SO-3 aircraft engine compressor. They were also compared with the experimental and numerical results available in the literature.

Chapter 12 presents conclusions and directions for further work and research.

References are provided after the last chapter.

At the end of the thesis there are appendices from A to H. Appendix A contains the results of frequency fitting for the EO3 area for data from the centrifuge. Appendix B contains the results of the amplitude fitting for the EO3 region for the data from the centrifuge. Appendix C shows the time series available from the power plant for the study of vacuum breaking. Appendix D shows the measured number of blades with the The Szwalski Institute of Fluid-Flow Machinery measurement system in the Bełchatów power plant at several approaches. Appendix E contains a sample input file for TipTimingSimulator. The F appendix contains a configuration file for the measurement of the amplitude of the rotor blades vibrations for various pressures in the condenser. Appendix G contains the results of fitting the frequency and amplitude of vibrations of the rotor blades of the 1st stage of the SO-3 aircraft engine compressor. Appendix H includes the determination of the exact angular positions of the sensors for the measurement of the amplitude of rotor vibrations for various pressures in the condenser.