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LABORATORY OPTICAL MEASUREMENT OF MODEL BLADE VIBRATION UNDER ROTATION

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Abstract: *The optical method for the accurate laboratory measurement of blade vibration under rotation was proposed in IT AS CR. This method is based on the fast optical-elements that register time passages of the blades. The description of the method and first experimental results of the model blade vibration under rotation will be discussed.*

Keywords: ***blade, tip timing, optical measurement.***

1. Introduction

The turbine blade and blade disc dynamics research started in the laboratory Vibrodiagnostics and non-linear dynamics, IT AS CR in late 70th years of the last century with turbine blade development and testing in Skoda Works, Plzen. After 1989 the blade disc research was first aimed on vibration diagnostics of blades in service and their residual life estimation Daněk et al. (1993). The latest research of dynamic behavior of blade discs deals with non-linear blade couplings and usage of high-damping materials Pešek et al. (2010).

For laboratory accurate contactless measurements of blade vibration under rotation the new optical method based on the optical displacement sensor was developed in IT AS CR. At first the optical sensor was assembled and tested under a static condition. Then the time responses of the sensor was tested under rotation and at last the circumferential vibration of the model blade wheel was evaluated. For the evaluation of the circumferential displacement of the blades the tip-timing method was used.

2. Design and dynamic tests of the optical sensor

The optical displacement sensor consists of minilaser FP-65/1A-LWL-SMA with the emissive power 10mW coupled with the optical fiber and the light beam detector Si-PIN diode SD200-11-31-241 with circular surface (∅5 mm) and response time 8ns. Homogenous parallel light beam transmission from the optical fibers is ensured by the collimators F-C5-S2-543 placed on the free ends of the fibers. For the light transmission between the laser and the collimator and the collimator and the PIN DIODE the optical multimode fibers ended by SMA connectors on both sides of the fibers.

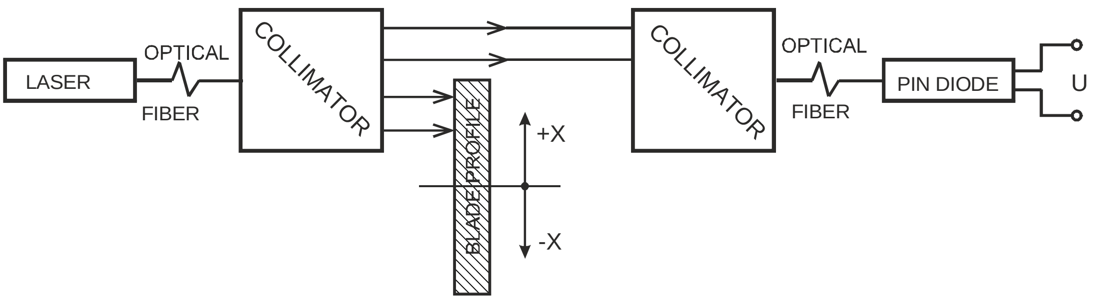

Fig.1 Scheme of the optical sensor measurement

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The fixtures of the optical sensor were manufactured for the dynamic calibration on the test blade wheel. Diameter of the disc was ∅505mm. The disc is equipped with sixty prismatic beam blades (190mm length). The strain-gauge was glued on the side surface of the blade at its root for measuring of the circumferential displacement. Its calibration was performed by the acceleration measurement of the blade tip at the impact excitation. The electromagnet UTM4 excited the blades under rotation. For maximizing electromagnetic excitation effect in the circumferential direction, the excitation frequency was tuned to the resonance frequency 332Hz of the first circumferential flexural mode of the blade and the revolution speed was set to the value 83rpm corresponding the 4th engine order excitation. The optical sensor ODS placed on the stator registered time passages of all blades. The strain gauge, ODS, supply current of the electromagnet and phase mark signals of the forced vibration of the blade B30 were recorded with a sampling frequency 2MHz by the digital oscilloscope YOKOGAWA DL750.

First the time characteristics of the output voltage of the DIODE detector without the collimator and optical fiber were analyzed without the electromagnetic excitation for different revolution speeds (300, 700, 800rpm). The results of voltage characteristics transformed from time to angle-position dependences showed some dependence of the characteristics on the revolution speed appears. Nevertheless the gradient of the diode opening and closing remains almost same in the operating range of speeds. After the analysis of the DIODE detector characteristics under rotation, the optical sensor (Fig.1) was tested for the blade vibration evaluation at the electromagnetic excitation. Besides the optical measurement of the blade passages, the passages of the rigid wheel with 60 notches were registered at the same time. Then the displacements of the blade tips were evaluated from the time differences Δt_{ij} of the leading edge arrivals of the blade passages and the corresponding notches in each revolution. The measured data were processed by the program developed in the MATLAB.

The amplitude spectrum of the blade B30 vibration confirmed the circumferential vibration of frequency 338Hz close to the resonant frequency 332Hz. The level of vibration (3μm), however, was very low almost on the noise level of the strain-gauge measurement. Therefore for the time result comparison with the ODS measurement, the strain-gauge signal was substituted by the "noise-free" sinus characteristic with frequency 338Hz and amplitude 3 μm. The ODS displacement time characteristic of the blade B30 and the downsampled "filtered" strain gauge characteristic was in a good agreement. The downsampling is inevitable because the ODS blade displacement characteristic is sampled only by the revolution frequency for the configuration of one sensor on the whole perimeter.

3. Conclusion

The new laboratory optical method for evaluation of displacements of rotating and vibrating blades was designed and implemented. The first results of the optical measurement of the blade vibration in non-rotating and rotating states were presented. The displacement of the blades were evaluated by the tip-timing method. The results were compared with the strain-gauge results of the blade vibration. The circumferential amplitudes of blade vibration caused by the weak electromagnetic excitation was very low (cca 3μm) under rotation. Nevertheless the vibration was detected by the optical measurement. The optical method will be futher tested for accurate contactless measurements of blade vibtration and callibrations of the sensors for vibrodiagnostics of the turbine blades.

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References

Daněk, O., Vaněk, F., Cibulka, J. (1993): Experimental Investigation of Turbine Blades in Service. Diagnostic of Rotating Machines in Power Plants. Springer , in: *Proc. Symposium on Diagnostic of Rotating Machines in Power Plants*, Udine.

Pešek, L., Půst, L., Vaněk, F., Veselý, Cibulka, J. (2010): Dynamics of model bladed disc with friction elements for vibration suppression, in: *Proc. 8th IFToMM International Conference on Rotor Dynamics*, MoD2-3, Seoul, Korea.