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EXPERIMENTAL INVESTIGATION OF ROTOR DYNAMICS IN AIRCRAFT ENGINE WITH TWO-AXIS STIFFNESS ANISOTROPY OF SUPPORTS

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Abstract

The paper is dedicated to the features of aircraft engines rotor systems with supports stiffness anisotropy vibration characteristics experimental investigation. The problem of rational accelerometers mounting scheme is considered in particular. Informativity of two mounting schemes experimental comparison analysis is provided via model test rig and real gas turbine engine rotor dynamics experimental investigation.

1 Introduction

Modern aircraft engines designing are supposed to take into consideration dangerous vibrations eliminating problem. The main source of vibrations in gas-turbine engines are rotors. It is known that vibration problems have to be solved at the early stages of engine designing otherwise it will be cost-ineffective. Therefore it is seemed to be important to improve quality of mathematical models and methods of their experimental verification.

Aircraft engines weight reducing and applying of new engineering solutions [1] lead to appearing of shaft and case units stiffness decreasing tendency. This may cause the problem of support stiffness anisotropy which leads to additional resonant mode and shaft reverse orbiting appearing.

It is known that traditional (in vertical plane of engine) accelerometers mounting scheme is not effective for anisotropy support stiffness detecting [2]. So it might be more useful to place sensors at a 45 degree angle to weak and strong stiffness axis [3].

The main problem of support stiffness anisotropy analyzing is a complexity of vibration spectrum which is obtained from a real gas turbine engine tests. Therefore, it seems to be rational to use a special test rig which simulates main features of gas turbine engine rotor systems and allows providing better interconnection factors separation.

Thus, the first stage of evaluation of both sensors mounting schemes informativity was made by providing experimental investigation of vibration characteristics at rotor model test rig. The second stage of investigation was based on full-scale gas turbine engine testing.

2 Model rotor test rig

Experimental test rig represents a rotor with one load disk, two supports and flexible coupling with AC motor which is controlled via AC drive (see Fig 1).

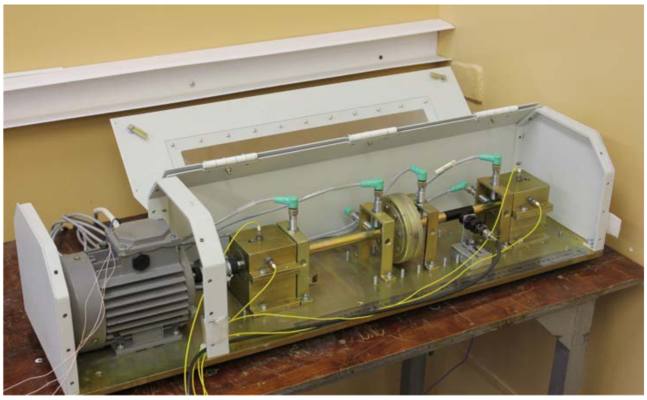
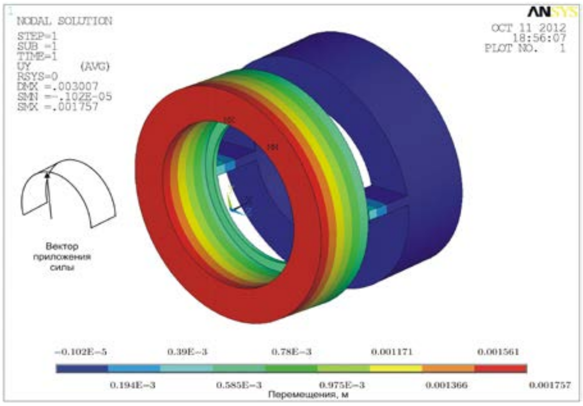
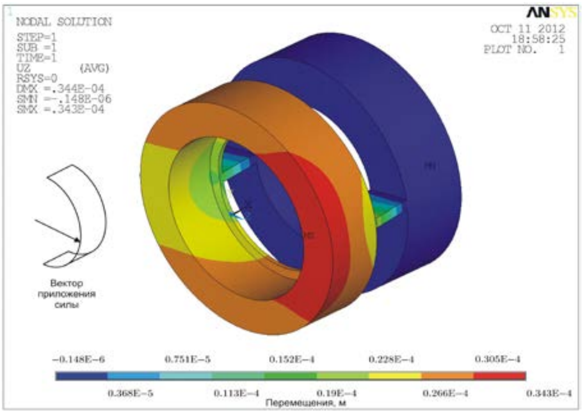


Fig. 1. Experimental test rig

The test rig allows changing its design variables (weight and position of loading disk, arrangement of supports, unbalance value). One of the supports was equipped with specially prepared bush (see Fig. 2) to simulate two-axis support stiffness anisotropy.



a



b

Fig. 2. Deformations of bush with two-axis stiffness anisotropy (a – deformation toward weak direction, b – deformation toward strong direction)

Experimental investigation consisted of measuring of supports acceleration, dynamic displacement of the shaft and rotational speed. All this data were analyzed via Fast Fourier Transform (FFT). Critical speeds and shaft rotating orbits were determined. Measurement and control system was based on National Instruments (LabView) and LMS SCADAS Mobile (Test.Xpress) equipment [4].

3 The analysis of mounting schemes informativity

Analysis of dynamics rotor with two-axis stiffness anisotropy of rotor supports was provided. Resonance frequency splitting and reverse orbiting were obtained. Two following mounting schemes were tested: the basic and alternative.

Basic scheme of mounting based on placing accelerometers along weak and strong stiffness axes is analyzed (see Fig. 3).

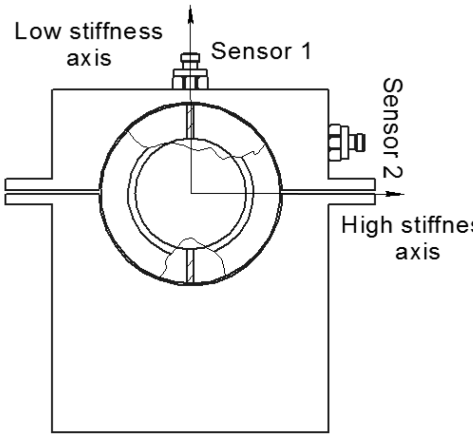


Fig. 3. The basic sensors mounting scheme

The values of critical speeds are 4368 rpm (72.8 Hz) and 4620 rpm (77 Hz) for this scheme. It is shown that the scheme allows detecting both critical peaks using two accelerometers. Also reversal orbiting between the splitted resonances was obtained (see Fig.4).

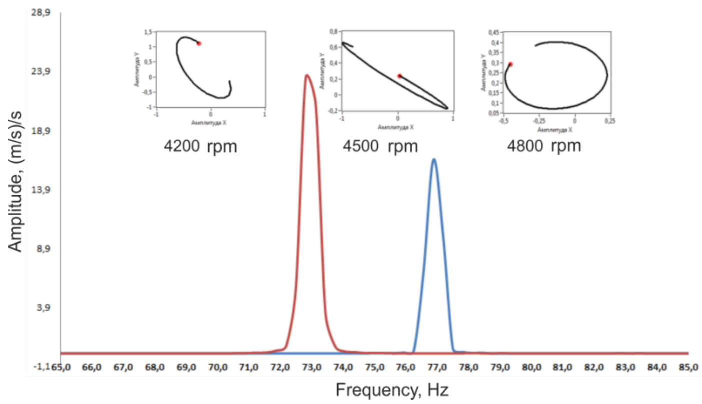
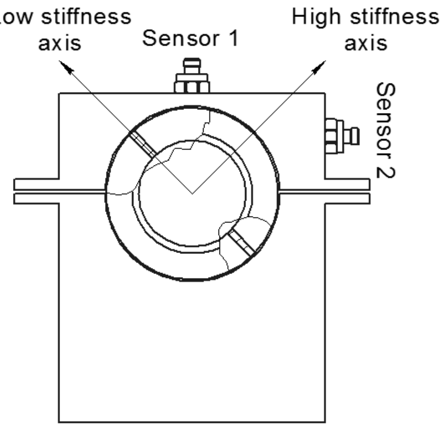
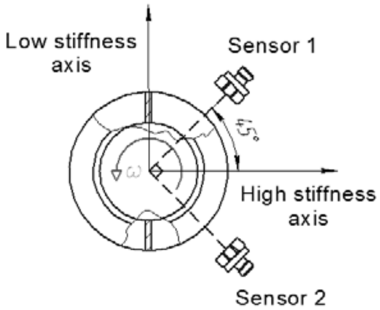


Fig. 4. The basic sensors mounting scheme investigation results (accelerometers signal FFT, red – sensor measuring horizontal vibration component, blue – sensor measuring vertical vibration component)

At the second scheme (alternative) accelerometers were mounted at a 45 degree angle to weak and strong stiffness axis (see Fig. 5).



a



b

Fig. 5. The alternative sensors mounting scheme

In this case the values of critical speeds are 4266 rpm (71.1 Hz) and 4590 rpm (76.5 Hz). It is shown that the scheme allows detecting both critical peaks using one accelerometer (see Fig. 6).

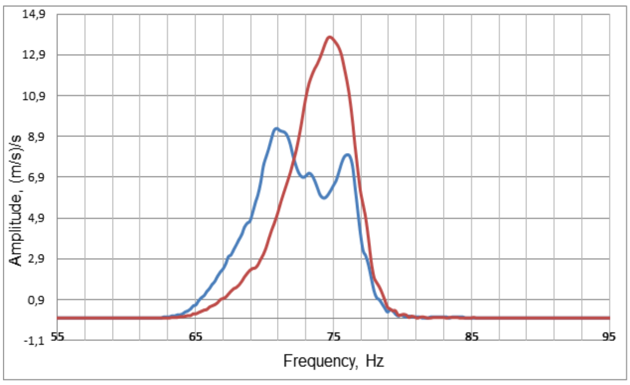


Fig. 6. The alternative sensors mounting scheme investigation results (accelerometers signal FFT, red – sensor measuring horizontal vibration component, blue – sensor measuring vertical vibration component)

Comparative analysis of the both schemes is provided. It was ascertained that standard scheme allows detecting only one resonance peak corresponded with bending vibrations eigenvalue in plane of each accelerometer. Alternative mounting scheme allows detecting both resonance peaks by one of the accelerometers placed at a 45 degree angle from weak stiffness axis against direction of rotor rotation (see fig. 5 b).

4 Mounting scheme test on gas turbine engine

At the second stage investigation was based on full-scale gas turbine engine testing. The engine was equipped by additional vibration sensors placed on the fan supports and on the case near front and rear suspensions. Some sensors were mounted at a 20 degree angle to vertical plane of engine.

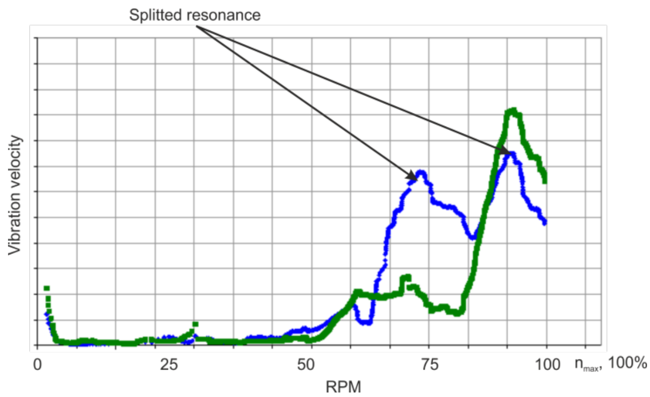
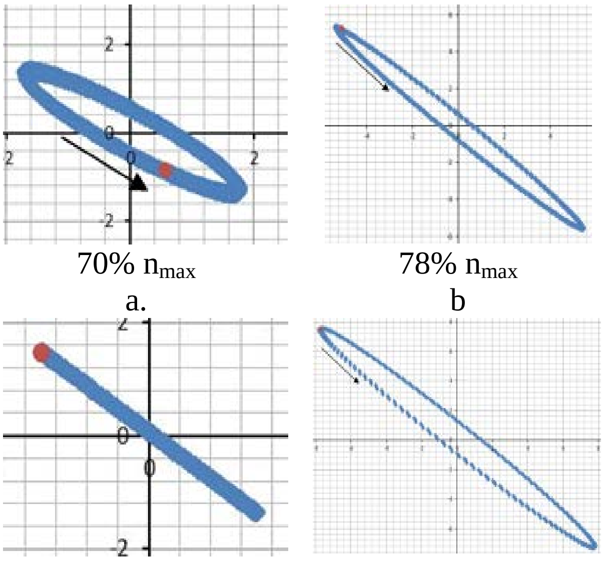


Fig. 7. Example of amplitude-frequency diagram. Green – sensor placed in vertical plane pf engine, blue – sensor placed at 20 degree to vertical plane (blue) of engine

Experimental investigation of full-scale gas turbine engine rotor dynamics consisted of frequency response and trajectory of fan supports vibration displacement analysis. Analysis of data gathered by additional vibration transducers shows that there are following signs of supports stiffness anisotropy in engine: the presence of splitted resonance (see fig.7), ellipsoidal orbits, degeneracy of fan supports vibration displacement trajectory (locus) to line (see fig. 8) when first resonance of high pressure rotor were passed, reverse orbiting of high pressure rotor appearing.



70% n_{max} a. 78% n_{max} b 82% n_{max} c 93% n_{max} d

Fig. 8. Example of fan supports vibration displacement trajectory alterations during speed up (c – moment of degeneracy to line)

5 Conclusion

The findings show that there is ability to improve informativity of traditional accelerometers mounting scheme. Also received data can be used for specific vibration transducers mounting schemes reasoning and for mathematical models verification.

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