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IDENTIFICATION OF MAIN HELICOPTERS RESONANCES BY GROUND VIBRATION TEST

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Abstract

Six resonances of the helicopter body standing on the airport apron and at least two resonances of the free helicopters the frequencies of which are within the range of basic loadings by the helicopter rotor is called (8+) model. It was proposed to identify (8+) model with the use of resonance tests. It was indicated that (8+) model allows for detuning the resonances from the frequency of working loads, tracing the process of moving through resonances as well as taking off and landing.

The paper presents: example of a helicopter on a test rig and visible vibrations inductors; induction of resonance vibrations, induction of resonance vibrations with the forms of pitching, yawing, rolling; induction of resonance vibrations with the forms of pitching with opposite pylon yawing and tipping with opposite pylon yawing; model of helicopter resonances; the multiplication of the resonance amplitude for various velocities of moving through with visible growth of the resonance frequency and reduction of vibrations amplitude; change of the frequencies at the taking off and landing.

Keywords: *helicopter, resonance, modelling, ground vibration test*

1. Introduction

The main resonances of the helicopter are those resonances the frequencies of which are lower or equal to the loading frequencies from the rotor. The group covers 6 resonances of the helicopter standing on the airport apron and at least 2 resonances of a free helicopter. In the work herein, the main resonances are shortly called (8+).

The objective of work is to present the (8+) model of the helicopter main resonances as a set of experimentally identified systems of one degree of freedom.

2. Resonance tests

Resonance tests are experimental methods for building the modal model of structure dynamics [1]. A model of a system of one degree of freedom determined by the coordinates, which characterize with the vibrations form, resonance frequency value and vibrations damping coefficient is connected with each 'isolated' resonance [4, 5].

3. (8+) model of the helicopter main resonances

The resonances the frequencies of which are within the range of possible inductions caused by the main helicopter rotor are called (8+) model. These are six resonances of a helicopter standing on the airport apron and at least two, which are independent from the undercarriage rigidness. The experimental induction of the resonances requires applying special configuration of harmonic forces (adjusted forces) for each of them. The configuration of inductive forces is presented in Fig. 2-4.

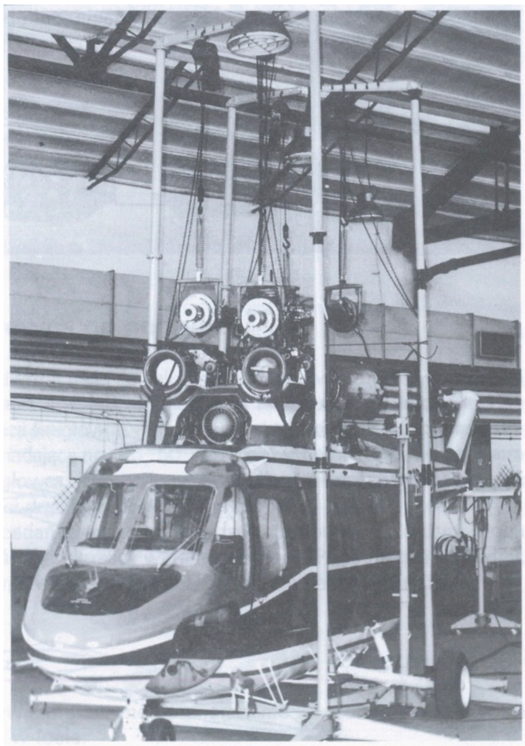

Fig. 1. Example: a helicopter on a test rig. Visible vibrations inductors [3]

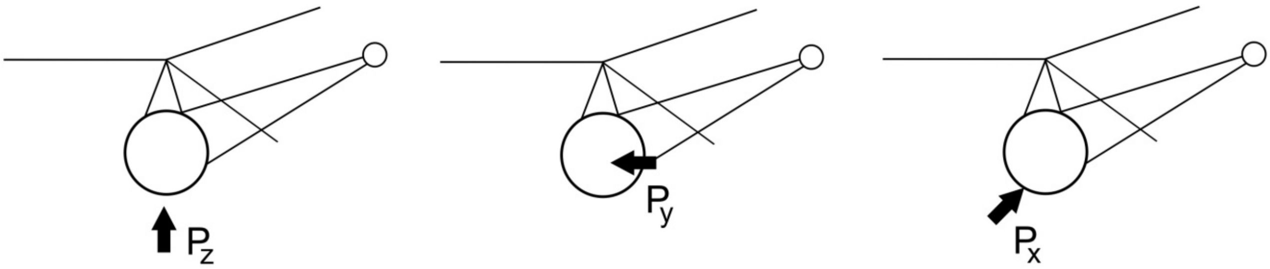

Fig. 2. Induction of resonance vibrations in directions z, y, x

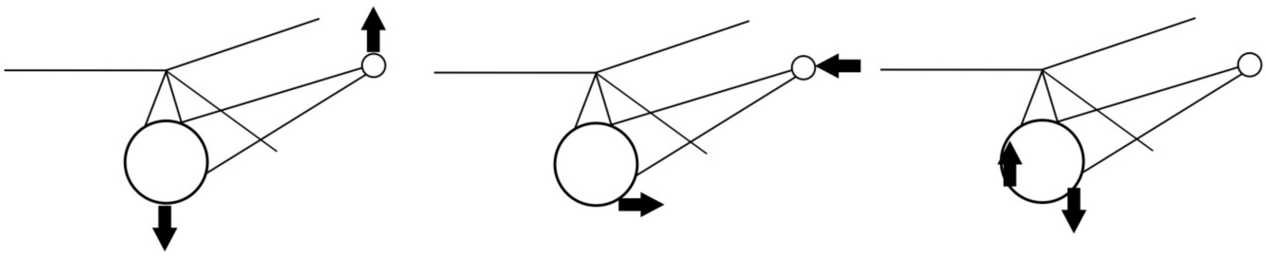

Fig. 3. Induction of resonance vibrations with the forms of pitching (α), yawing (β), rolling (γ)

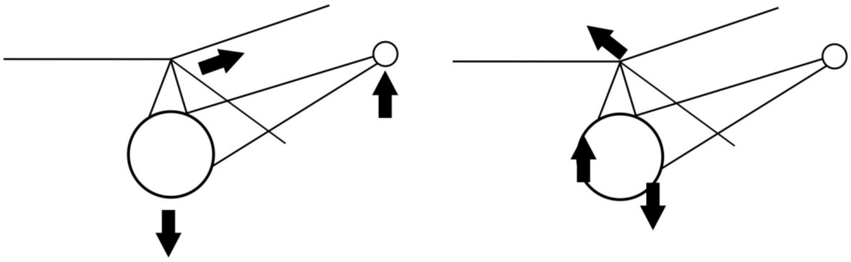

Fig. 4. Induction of resonance vibrations with the forms of pitching with opposite pylon yawing and tipping with opposite pylon yawing

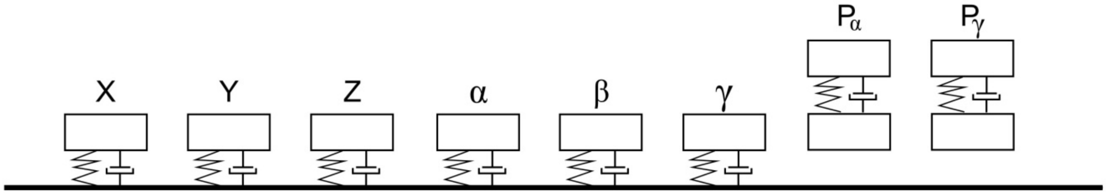

Fig. 5. (8+) model of helicopter resonances

4. Moving through the resonance

In real conditions of the helicopter operation, the basic inductor of vibrations is the main rotor [6]. The rotor operates in 3 stages: taking off, nominal rotations while flying and braking. During taking off and braking the inductions move through the resonances of '8+' group.

The safety from the possibility of reaching the hazardous conditions while taking off depends on the velocity of moving through and damping of the resonance. In the case of slow moving essential increase of the vibrations, amplitude may take place. With the moving velocity gain, the amplitude growth is smaller and smaller.

The dependence of the resonance amplitude from the velocity of moving through is shown in Fig. 6 [2].

Based on the results of calculations presented on the figure one may conclude that with the increase of the moving through velocity, the resonance frequency moves towards higher values and the resonance amplitudes be reduced with the moving velocity gain.

In the braking process with reduced number of rotor's rotations a similar phenomenon of moving through the subsequent resonances of '8+' group takes place. In this case, the resonance frequencies move towards smaller values.

In the braking process the higher vibrations amplitudes correspond to the analogical velocities of moving through.

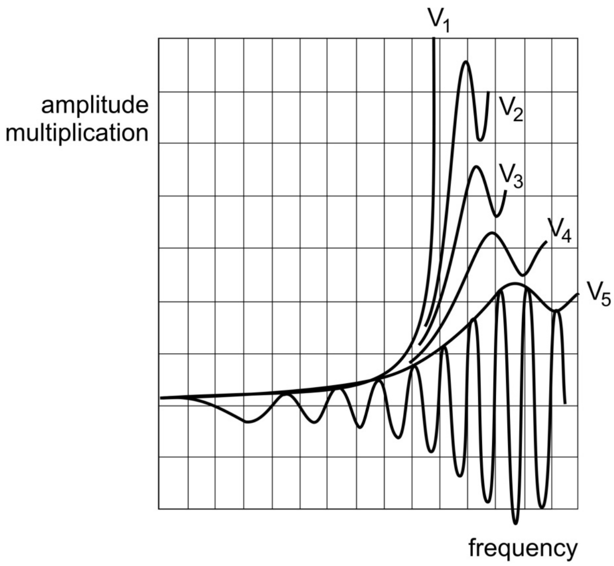

Fig. 6. The multiplication of the resonance amplitude for various velocities of moving through with visible growth of the resonance frequency and reduction of vibrations amplitude [2]: V_1 – moving through velocity = 0; V_2, V_3, V_4, V_5 – growing moving through velocities

5. Taking-off and landing

The helicopter standing on the airport apron is a body supported on a spring-loaded undercarriage. The taking-off is the lifting of a helicopter on an air cushion created by the rotor.

Until the moment the undercarriage loses its contact with the airport apron assuming the linear rigidity of the undercarriage, 6 resonances of the helicopter body keep their frequencies. After it leaves the airport apron, the interactions of the undercarriage restoring forces cease. The frequencies of 6 resonances drop suddenly. However, the 7 and 8 resonances of the (8+) model remain unchanged.

The information is presented graphically in Fig. 7.

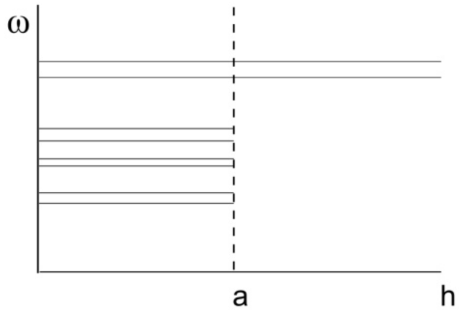

Fig. 7. Change of the frequencies of '8+' resonances at the taking off and landing: a – loss of the undercarriage contact with the airport apron, h – flight height, ω – frequency

6. Detuning resonances from the frequencies of work loadings

In the case when the inductive force has the frequency smaller than the frequency of '*i*-th' resonance there are subcritical vibrations present with the shifts close to static ones.

In the case when the inductive force has the frequency greater than the frequency of '*i*-th' resonance, there are supercritical vibrations present of very small amplitude.

In the case when the inductive force has the frequency close to the frequency of the main vibrations (resonance identified during ground vibration test) a resonance is present.

The inductive force depending on the frequency while moving through may cause subcritical induction for one resonance, supercritical for another one and resonance induction for any other

Despite calculations and theoretical analyses the full knowledge of the properties of (8+) main resonances is possible after carrying out resonance tests. If it appears that any of the induction components (with nominal rotations) is close to the frequency of one of the main resonances, it is necessary to detune it from the hazardous induction frequency. It is possible to do it in at least 3 ways.

1. Adding mass in the resonance vibrations arrow in order to reduce the resonance frequency [3].
2. Application of dynamic vibrations damper in order to break the resonance into two of frequencies lower and higher than the loadings.
3. Reduction or increase of the structure rigidness.

7. Conclusions

1. The helicopter main resonances (8+) characterize with relatively simple forms of vibrations and are relatively easy to isolate and induce.
2. The induced resonances may be registered: their form may be measured so as the frequency and damping coefficient and they may be identified as independent, linear degrees of freedom.
3. (8+) model of main resonances may be the basis for constructing mathematical models and their further analyses.
4. Induced vibrations from every of (8+) resonances may be safely watched and their features and nuances may be noticed on the test stand, what gives the constructors great possibilities for drawing conclusions and making decisions.
5. (8+) model may be the basis for:

a. identifying which of the resonances (which of own vibrations) is threatened with the occurrence of ground resonance or the resonance while flying,
b. the analysis of the safety of moving through the resonance during rotor taking off and braking,
c. analysis of the process of the helicopter taking-off the ground,
d. analysis and guidelines for detuning of the main resonances from the loadings resulting from nominal rotations,
e. taking into account real damping (damping coefficients) while selecting dampers and precise assessment of their essential parameters.

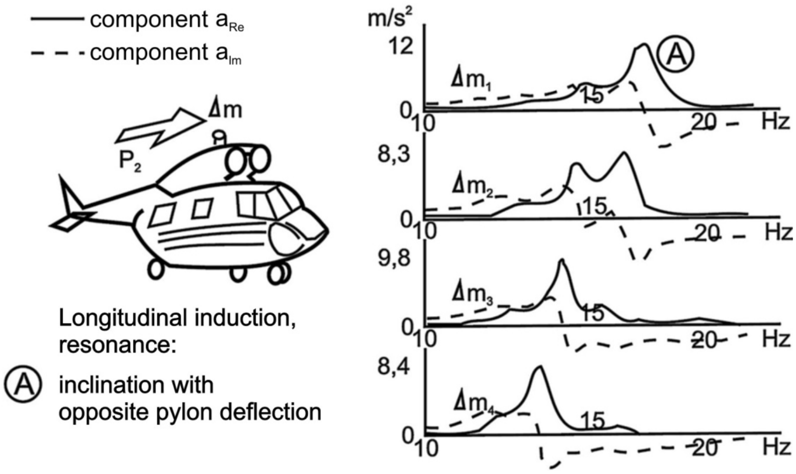

Fig. 8. Example of the impact of the mass added at the end of the main rotor shaft on the resonance frequencies presented with the help of measured characteristics of frequency amplitudes [3]

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