RESONANCE TESTS - VIBRATION MODE SHAPES FROM THE WING TORSION GROUP

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Abstract

Resonances of the „wings torsion" mode shapes to a large extent depend on the structural parameters of the wing, and more specifically to the existence or not of fuel tanks at the wings ends, munitions hardpoints or engines mounted on the wings. In the paper the group of resonances is presented with mode shapes in which the one, two or three node aircraft wing torsion is present. It is shown in the paper, that these vibration mode shapes consist both of fuselage bending or torsion. Resonance frequencies with mode shapes in which one, two or three node wing torsion occurs depend fundamentally on existence of wing hardpoints. If hardpoints are occupied by fuel tanks, these frequencies are varying continuously in wide range. The various interesting from cognitive point of view combinations have place then, including variable frequencies and variable mode shapes as a function of fuel consumption. The aim for the analysis of 3 cases of resonance a wing torsion mode shapes of airplanes and gliders was to investigate the relationships and mechanisms that are taking place and operate between the torsioningl vibration of the wings and bending or torsion vibrations of the fuselage. Recognition of these phenomena should facilitate the researcher to understand and search effectively and explore the resonances of „wing torsion" mode shapes.

Keywords: *transport, aircraft, resonance tests, vibration mode, torsion wing*

1. Introduction

The image of the vibration properties of aircraft structure is the list of resonances studied experimentally or analytically identified vibration mode shapes. A description of each of the cases contains, in particular, the resonance frequency and the geometric description of a vibration mode shapes.

Among the many different types of resonance vibrations mode shapes deserve attention mode shapes from the wing torsion group.

In the „wings torsion" resonant vibrations mode shapes the fuselage vibrations appear, this fact makes that with the relatively small differences in frequencies, in particular cases the wings torsion may occur, while even nodal bending occurs in other cases.

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The various interesting from cognitive point of view combinations have place then, including variable frequencies and variable mode shapes as a function of fuel consumption.

This paper is a study of such examined cases.

2. Resonances with the „wings torsion" mode shapes

The analysis concerns a group of resonances with the mode shapes where the one, two or three node wing torsion occurs.

Full form of these resonance vibrations also includes the vibration component of the fuselage, empennage, hardpoints control assemblies, etc.

In these resonances the vibration mode shapes within the wing are shown on Fig. 1.

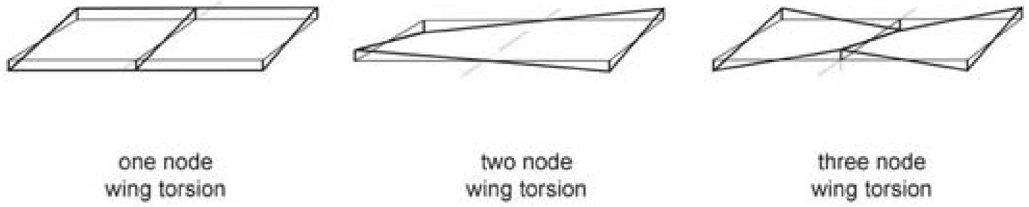

Fig. 1. Three basic modes of vibrations from the „wing torsion" group of resonances

In the case of 1 and 3 nodal torsion wings vibration, the fuselage vibrates in 2-node or 3-node bending mode shape. In the case of 2-node wing torsion vibrations, the fuselage vibrates in „fuselage torsion" mode shape.

3. Effect of underwing hardpoint tanks on frequencies of resonances of a „2 and 3-node wing torsion" mode shapes

Underwing hardpoint munitions or tanks have generally significant moments of inertia with respect to the axis of the wings. Hardpoints significantly affect on the resonance frequencies of a „wing torsion" mode shape.
In practice, there are two cases. The first one is when on the wing hardpoints the fuel tanks are mounted, and then the frequencies of these resonances increase continuously as a function of fuel consumed. Changes in these frequencies are shown on Fig. 2. It should be noted that for the specific filling of the tanks the wing torsion frequencies are approaching to the torsion frequency of the fuselage.
The second case concerns the hardpoints munitions dropped by aircraft (bombs, rockets, etc.). In this case the change of resonant frequencies occurs in a stepwise manner.

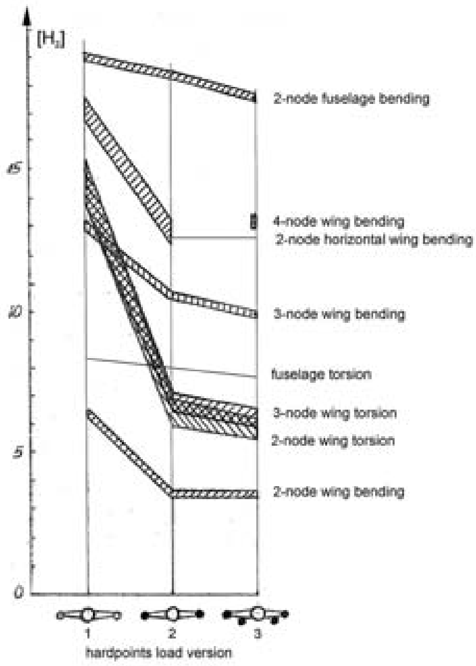

Fig. 2. Aircraft with hardpoint mounted fuel tanks. Change of the resonant frequencies as a function of fuel expenditure

4. Resonance of a „single node wings torsion" mode shape

Resonance of the „single node wing torsion" mode shape is a special case and the unique one. In this case, the wing „rotates" like a rigid body around its axis.

Such rotation is possible at frequencies lower than the other wing resonance frequencies.

Such case was identified during the investigations of classical single-engine airplane. The stiff engine and stiff fuselage are vibrating through the elasticity of their mutual mount.

Example of resonance of the „single node wings torsion" mode shape is shown on Fig. 3.

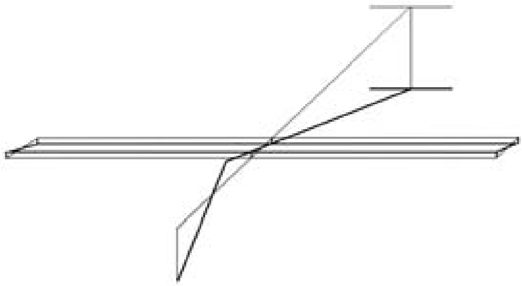

Fig. 3 Resonance of the „single node wing torsion, 2-node fuselage bending" mode shape

5. Resonance of a „two-node wing torsion" mode shape

Characteristic attribute of a „two-node wing torsion" mode shape resonances is the existence of one of the vibration nodes on the fuselage axis, and performance of „bite" oscillating movement by the leading and trailing edges of wings, accompanied by the fuselage twisting.

On Fig. 4 and Fig. 5 are shown the examples of a „2-node wing torsion" mode shape identified during the investigations of SZD-50-2 „Puchacz" glider and the aircraft with suspended external fuel tanks.

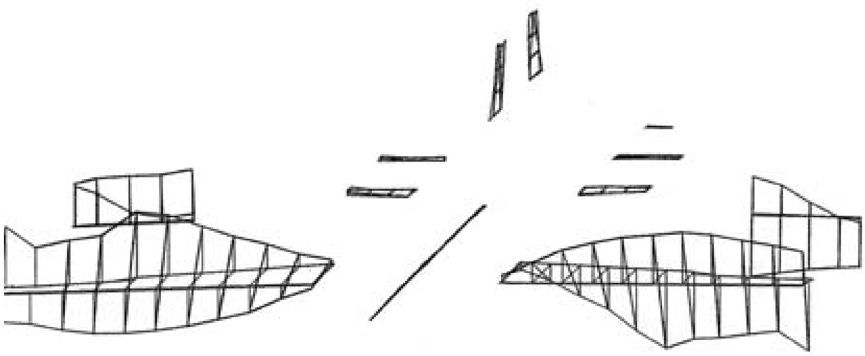

Fig. 4 Resonance of a „2-node wing torsion" mode shape of SZD-50-3 „Puchacz" glider

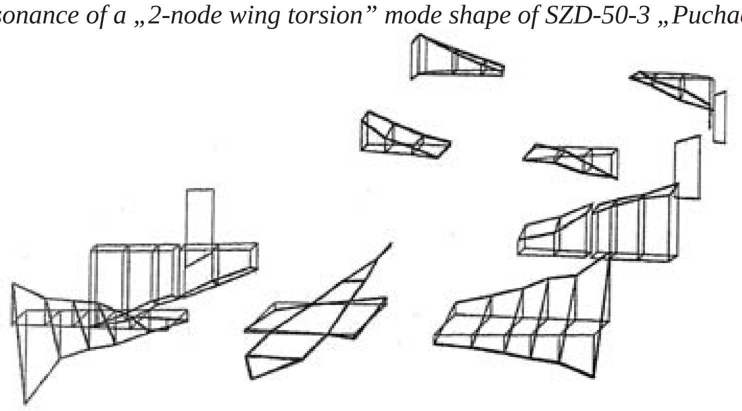

Fig. 5. Resonance of a „2-node wing torsion" mode shape of aircraft with full tanks at the wing tips

6. Resonance of a „3-node wing torsion" mode shape

Characteristic attribute of the „3-node wing torsion" mode shape resonances is the simultaneous occurrence of „fuselage bending".

On Fig. 6 is shown the resonance of a „3-node wing torsion" mode shape for aircraft with the full fuel tanks mounted on wing tips.

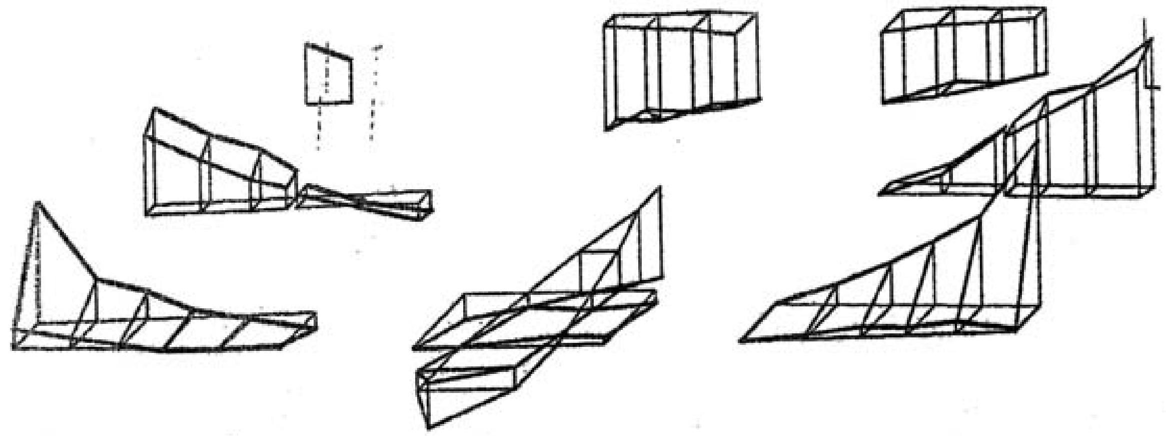

Fig. 6. Resonance of a „3-node wing torsion" mode shape of aircraft with full fuel tanks mounted on wing tips

Another possible attribute of the „3-node wing torsion" mode shape resonances is the simultaneous occurrence of the „3-node wing torsion" and the „4-node or 6-node wing bending" mode shapes.

An example of such resonance mode shape comes from the investigations of SZD-50-2 „Puchacz" glider.

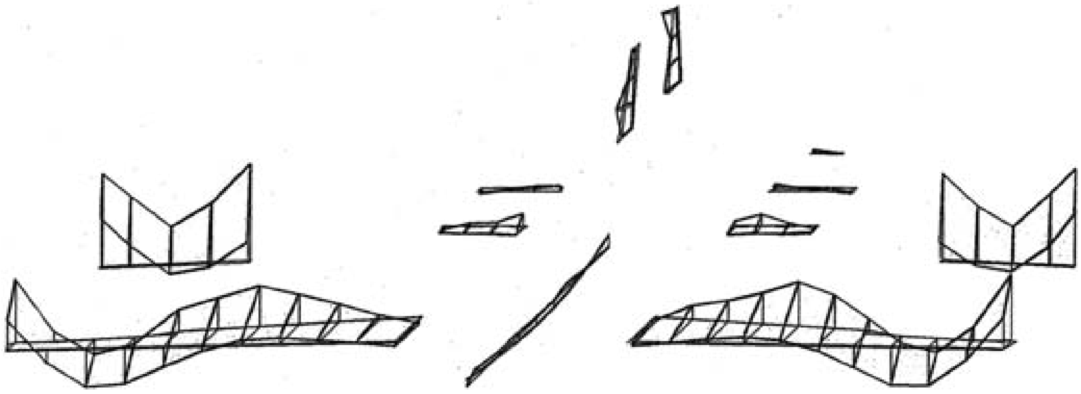

Fig. 7. Resonance of a „3-node wing torsion and 6-node wing bending" mode shape of SZD-50-2 „Puchacz" glider

In the resonance of a „3-nodal wing twisting" mode shape the aircraft fuselage is participating, which, depending on the resonance frequency, takes the 2, 3 or 4 - nodal bending mode shape.
This phenomenon reminds one of which occurred in the resonances presented in Chapter 2: the single-node wing twisting mode shape.
The central part of the wing together with the fuselage bends contrary to the wing tips.
The rest of the fuselage vibrates with two or three nodes, depending on the frequency of resonance.

On Fig. 8 is shown the resonance of a „3-nodal wing twisting" mode shape with the 3-node bending of the fuselage.

7. Conclusions

The aim for the analysis of 3 cases of resonance wing torsion mode shapes of airplanes and gliders was to investigate the relationships and mechanisms that are taking place and operate between the torsion vibration of the wings and bending or torsion vibrations of the fuselage.
Recognition of these phenomena should facilitate the researcher to understand and search effectively and explore the resonances of „wing torsionof" mode shapes.

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