RESEARCH OF THE DYNAMIC PROPERTIES OF STRUCTURES THE MODELS OF INTERPRETATION

Witold Wiśniowski

Institute of Aviation
Aleja Krakowska 110/114, 02-256 Warsaw, Poland
tel.: +4822 8460993, fax: +4822 8462912
e-mail: witold.wisniowski@ilot.edu.pl

Abstract

Experimental research of the dynamic properties of structures is performed during of prototype perfectioning, current exploitation and even after the withdrawal from the exploitation for the estimation of the residual durabilities. The aim for research of the dynamic properties of structures is the assurance of its safety, reliability, economic management and comfort. Researcher records the amplitudes of vibrations in the function of the actuation frequencies. Local raise of the amplitude is qualified as resonance. From the researcher point of view, the shape of resonance curves justifies the discrimination of two types of phenomena's: „single resonance" and „close frequencies resonance".

For better understanding of these occurrences „the models of interpretation" were proposed.

Up to three models of interpretation were assigned to the single resonance:

- *one-degree-of-freedom system,*
- *one-degree-of-freedom system with share of the backlashes,*
- *two one-degree-of-freedom systems with the same frequencies.*

From above reasoning, the conclusion results that researcher can expect that the preliminary isolated single resonance belongs to one from the three, mentioned above cases.

The judgment of these occurences, just as the disentanglement of relations in the resonance pair with close frequencies, determines next challenge for the researcher.

Keywords: *transport, aviation, vibration, structure testing, resonance analysis, modal analysis*

1. Introduction

Experimental research of the dynamic properties of structures is performed dering of prototype perfectioning, current exploitation and even after the withdrawal from the exploitation for the estimation of the residual durabilities.

The aim for research of the dynamic properties of structures is the assurance of its safety, reliability, economic management and comfort.

2. Researcher's stage fright

Researcher undertakes the task of determining the structure properties. Object under examination do not have „willingness" to reveal its mysteries without the resistance or even battle. Between the researcher and object fascinating relation sets in. This relation, researcher - object under examination has in itself something from a mysterious investigation and satisfaction from overcoming of the acquaintance barriers. Researcher has whole set of necessary workshop tools at disposal. They are measuring devices, research procedures, personal experience and knowledge.

In experimental research the personal experience of researcher plays special role. Researcher must actuate the movement of structure in the competent manner and record its reaction. The art of the research relies on the understanding and interpretation of perceived and recorded reactions.

3. Resonance tests

For investigations of dynamic properties, the principle role is played by defining the structure resonances, which can have significance and can influence the properties and the structure characteristics in the process of exploitation.

Resonances must be detected and investigated in detail individually. Research relies on the actuation, measurement and the interpretation of recorded vibrations of investigated structure. The cycle „actuation - measurement - interpretation” is repeated many times in many various points and various types of the actuation.

4. The interpretation process of the measurements results

The increase of the vibrations amplitude in a certain range of the actuation frequencies the researcher qualifies as resonance phenomena. The graph of the vibrations amplitude in the function of the actuation frequencies is called resonance curve, and it usually assumes one of two possible shapes. Those shapes correspond to the single resonance and close frequencies resonances.

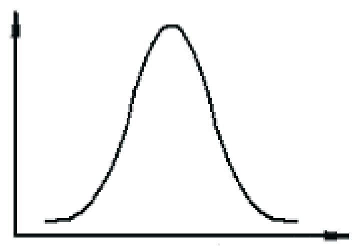


Fig. 1. Single resonance

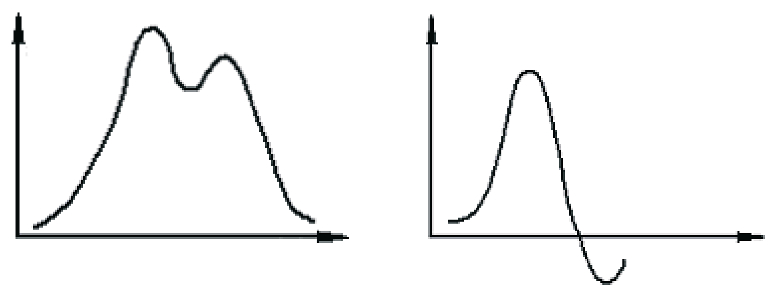
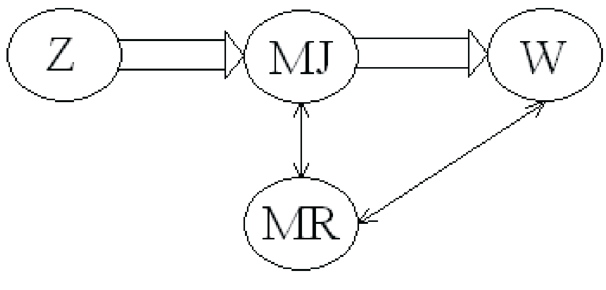


Fig. 2. Close frequencies resonances (two variants of the resonance curve)

The task of researcher is interpretation and explanation the physics for the recognized resonances. Researcher has two kinds of models at disposal.
They are:
- Reference models: results of investigations performed in the past, interpreted and generalized,
- Interpretation models: models describing separate types of resonances.

The process of the measurement results interpretation is presented on the schema, shown at Fig. 3.



Z - measured phenomena,
MJ - interpretation model,
MR - reference model,
W - result of the investigations.

Fig. 3. The schema of the interpretation process of measurements results

5. Reference models

The experience obtained during investigations should be utilized in the future. In order to attain this aim, reference models are designed. As reference models we name the tabular or graphic presentations of the investigation results or their statistic generalizations. Thanks to the reference models we have the possibility of prediction and comparison of the results of investigations of new structures. As the example of the reference model, it is presented below, the list of the symmetrical modes of resonance vibrations of light aircraft and gliders.

Tab. 1. Name of the vibration modes

Item	Name of the vibration mode	Notes
1.	pitch oscilations	airplane on undercarriage
2.	vertical oscilations	airplane on undercarriage
3.	1st mode wing bending	-
4.	central wing bending	twin engine airplanes
5.	2-node vertical fuselage bending	-
6.	1st mode horizontal wing bending	-
7.	horizontal engine sway	twin engine airplanes
8.	vertical engine sway	twin engine airplanes
9.	2-node vertical fuselage bending contrary to horizontal stabilizer bending	-
10.	main undercarriage bending in x-x direction	airplanes with fixed or mobile undercarriage
11.	main undercarriage bending in y-y direction	airplanes with fixed or mobile undercarriage
12.	front undercarriage bending in x-x direction	airplanes with fixed or mobile undercarriage
13.	2nd mode wing bending	-
14.	1st mode wing twisting	-
15.	3-node vertical fuselage bending	-
16.	3rd mode wing bending	-
17.	2nd mode horizontal wing bending	-
18.	2nd mode wing twisting	-
19.	1st mode horizontal stabilizer twisting	-
20.	wing braces bending	airplanes with wing braces

6. The model of the single resonance interpretation

If it happens that in the certain actuation frequency range the amplitude of vibrations clearly raises, it usually means that researcher has detected resonance occurrence. On Fig. 2. the course of a recorded occurrence is presented, and also its interpretation models.

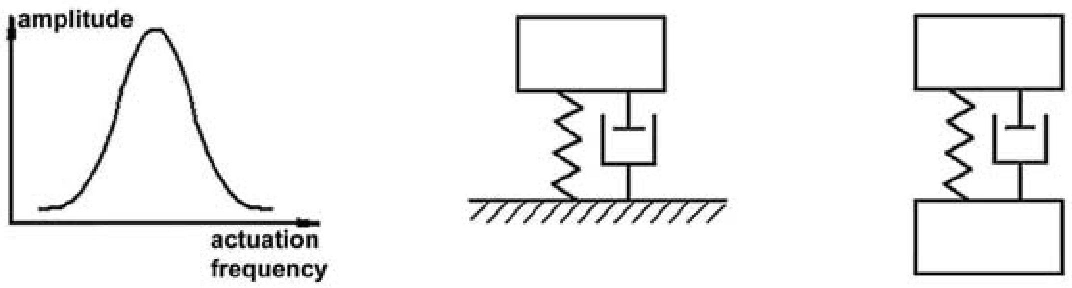


Fig. 2. „Single" resonance interpretation models

7. The model of the resonances interpretation in the close or equal frequencies

If in the certain actuation frequency range, the amplitude of vibration takes form, like shown on Fig. 3, this means that researcher deals here with close frequency resonances. On Fig. 3. the course of the recorded occurrence is presented, and also its interpretation model.

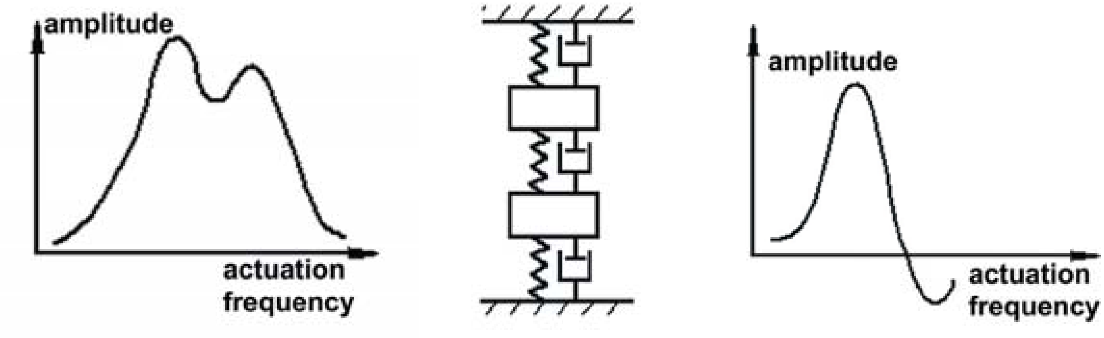


Fig. 3. The course of the occurrence for resonances with the close frequencies and the interpretation model of the occurrence

Special case of the occurrence of resonances with close frequencies are resonances with the equal frequencies. The course of this occurrence and its interpretation model is presented on Fig. 4. The example of two resonances with the equal frequencies is submitted on Fig. 5.

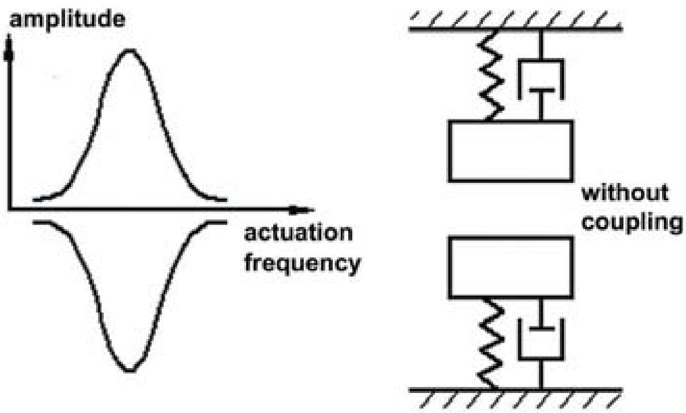


Fig. 4. The course of the occurrence for resonances with the equal frequencies and the interpretation model of the occurrence

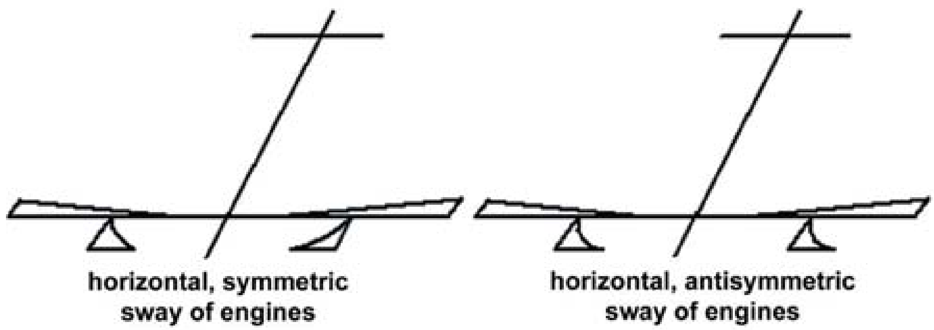


Fig. 5. Example of the two resonances with the equal frequencies

8. The model of resonance interpretation, in kinetics of which the backlash has the substantial influence

In some configurations of the vibrations of investigated structure, backlashes have the substantial influence on the frequency of resonances. The vibrations of the mechanical control linkages can be an example. The backlash share the amplitude of vibrations lower the resonance frequencies. The course of this occurrence is presented on Fig. 6, together with the reference model of the system with backlash and the dependence of the of vibration resonance frequency from the value of backlash in the entire amplitude of vibrations.

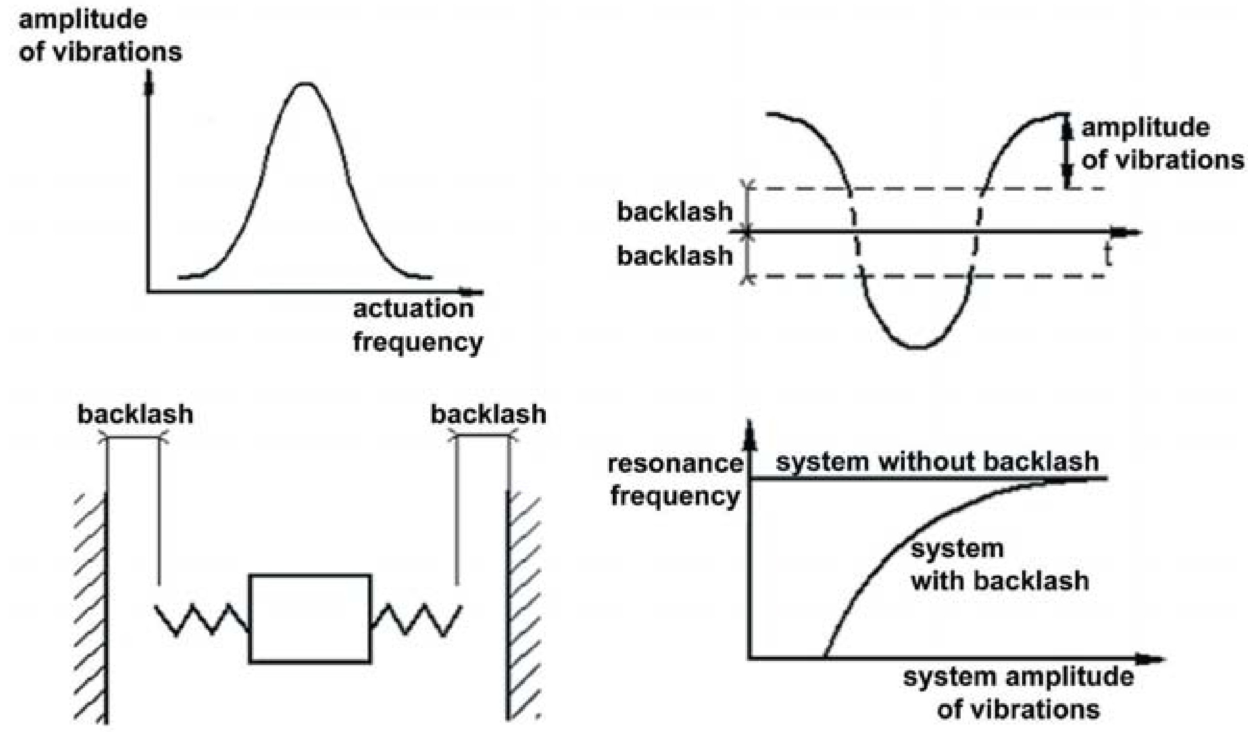


Fig. 6. The dependence of the resonance frequencies resulting from the backlash in the entire range of amplitudes of vibration, and the interpretation model of the phenomena

References

[1] Bijak-Żochowski, M., *Mechanika materiałów i konstrukcji*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2006.

[2] Capell, S., Green, S., Curless, B., Duchamp, T., Popovic, Z., *Interactive skeleton-driven dynamic deformations*, Proceedings of SIGGRAPH 2002, July 2002.

[3] Gallina, A., Martowicz, A., Uhl, T., *An Application of Response Surface Methodology in the Field of Dynamic Analysis of Mechanical Structures Considering Uncertain Parameters,* ISMA2006 Conference on Noise and Vibration Engineering, Leuven, Belgium 2006.

[4] Hanss, M., *The Transformation Method for the Simulation and Analysis of Systems with Uncertain Parameters,* Fuzzy Sets and Systems, 130(3), 277-289, 2002.

[5] Kleiber, M., (Ed.), *Komputerowe metody mechaniki ciał stałych*, PWN, Warszawa 1995.

[6] Moens, D., *A Non-probabilistic Finite Element Approach for Structural Dynamic Analysis with Uncertain Parameters,* Ph.D. Thesis, KU Leuven, Departement Werktuigunde, Leuven 2002.

[7] Rajbhandari, S. P., *An Approach to Modelling and Predicting Impact Damage in Composite Structures*, ICAS 2002 Congress, pp. 862.1-862.10, 2002.