Usage of modal test in verification of numerical model

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Abstract: *Tuning of the numerical model is very important step during designing process. Correctly tuned model ensures proper evaluation of dynamic characteristics of vibrating object. This paper presets comparison of experimental modal analysis and theoretical numerical modal test of axial fan casing. Thanks to properly tuned model, it was possible to receive results of the numerical simulations similar to real test.*

Key words: *modal analysis, fans vibrations, numerical simulation*

1. Introduction

Many technical objects are subjected to some input functions. In such case natural characteristics (natural frequencies, mode shapes and damping) of subjected object should be evaluated. With such knowledge it is possible to avoid dangerous effects during operation of device. The most dangerous phenomenon that can occur when forced vibrations has similar frequency to one of the natural frequencies of vibrating object [1]-[3]. Most of the devices subjected to vibrations needs to fulfill some standard requirements which provide information what should be minimal difference between natural frequency of object and excitation frequency. This allowable difference in case of fans depends on rotational velocity.

During designing processes it is important to evaluate natural frequencies of object in order to avoid dangerous effects. In many cases numerical objects are used in this process [4]-[6]. Unfortunately these models in most cases are unable to faithfully describe behavior of real object without tuning. The tuning process is very important in order to validate numerical models and use them in further work. Thanks to properly tuned model, it is possible to save money and time.

Presented article tends to be an example of verification of numerical models with use of experimental data. The problem is referred to vibrations of axial fans used in order to ensure proper local ventilations in underground mines. These fans are newly designed series of axial fans (table 1 presents basic geometrical of this series). In the article experimental as well as numerical methods of evaluating natural frequency of axial fan casing are presented.

Tab. 1. Geometrical parameters describing WL-S axial fan series

Parmeter	Size of the WL-S axial fan			
	315	400	500	630
Outside diameter of casing [mm]	315	400	502	630
Diameter of reducing pipe [mm]	78	65	84	105
No. of guide vanes	16	15	15	17
Length of casing [mm]	370	410	485	700
Length of casing with confusor converging cone and with reducing pipe [mm]	620	685	842	1140

2. Evaluation of characteristic frequencies of forced vibrations

Evaluation of Basic frequencies in case of rotating equipment is not demanding task. That is due to fact that basic frequencies are directly related to rotational velocity of the rotor. In most cases this velocity is equal to rotational velocity of electrical motor. The resultant basic excitation frequency is equal to [1]-[3]:

$$f = \frac{n}{60} [Hz] \qquad (1)$$

where:
n – rotational velocity of rotor [rpm]

In case of fan not only revolutions frequency but also its harmonic frequency and in many cases blade passing frequency. Resultant basic frequencies in case of designed series of fans are presented in table 2.

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Tab. 2. Technical parameters describing rotational velocity of fan's impeller and resultant characteristic revolutions frequencies

Parameter	Size of the WL-S axial fan			
	315	400	500	630
Rotational velocity of electrical motor [rpm]	2820	2845	2880	2930
Characteristic revolutions frequencies [Hz]	47	47,42	48	48,83

3. Evaluation of resonance frequencies with use of experimental methods

The are many experimental techniques used in order to extract natural frequencies from data collected during test. During experimental investigations conducted in case of described fans, Laser Doppler Vibrometry was used to measure vibration velocity of measured object. Vibrations measurements were conducted during flow measurements. Results of measurements of fan size WL-S 500 was described in this article. Figure 1 shows tested fan on experimental set-up. There are visible point in which vibration velocity was measured. LDV measuring techniques provides possibility to measure vibrations within whole surface but in many cases it is not important since more measuring points means more time needed for measurements. Figure 2 presents whole measuring set-up during test.

Thanks to realized measurements wide range of vibration data of fan was collected. Exemplary result is a spectrum received with use of well-known Fourier analysis [2]. Figure 3 shows one of this spectrums as a vibration velocity of fan casing in function of frequency. First important frequency similar to that received from numerical model, visible on this spectrum is this equal to 10Hz.

Fig. 1. Casing of WL-S 500 axial fan prepared to experimental measurements with use of LDV

Fig. 2. Laser Doppler Vibrometer during measurements of casing vibrations

Numerical model was prepared as FEM model and was tuned in order to reflect boundary conditions on real object. Thanks to such approach, first important natural frequency was similar to that received form experimental data. Figure 4 shows mode shape for first natural frequency of fan casing which is equal to 10Hz.

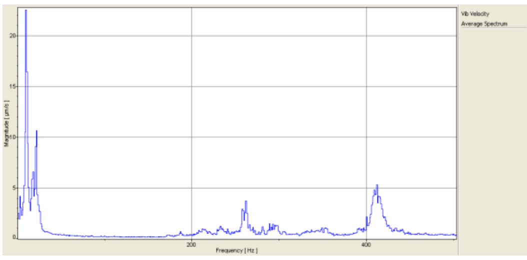

Fig 3. Spectrum as vibrational velocity in function of frequency

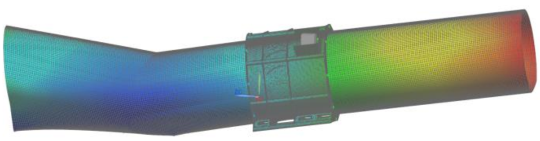

Fig. 4. Second mode of vibrations received thanks to numerical simulations; natural frequency equal to 10Hz (fan WL-S 500)

4. Conclusions

The article describes verification of dynamic numerical model with use of experimental data. Thanks to realized investigations, convergence of numerical model was received. That means that value of natural frequency of fan casing received from numerical analysis is similar to this get from experimental test. That gives possibility to use such model in further works in order to modify dynamic characteristics of model without need to construct real object.

Important to notice is that basic natural frequency of fan casing is far away from forced vibrations frequencies due to rotational movement of fan's impeller.

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References

[1] W. T. W. Cory : Fans&Ventilation – A Practical Guide. Elsevier, 2005
[2] Randall R. B., Vibration-based Condition Monitoring, A John Wiley and Sons, Ltd., 2011.
[3] S. Fortuna : Fans: theoretical foundations, construction-exploitation issues and application. TECHWENT, Krakow 1999
[4] Zienkiewicz O. C., Taylor R. L., Zhu J. Z.: The Finite Element Method – Its Basis and Fundamentals. 6th edition, ELSEVIER 2005
[5] Zienkiewicz O. C., Taylor R. L.: The Finite Element Method for Solid and Structure Mechanics. 6th edition, ELSEVIER 2005
[6] Rusiński E., Czmochowski J., Smolnicki T.: Advanced finite element method in supporting structures, Wroclaw University of Science and Technology Publishing House, Wroclaw, 2000