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Estimation of resonance frequencies for systems with contact using linear dynamics methods

MACIEJ WNUK[1*], ARTUR ILUK[1]

1. Wroclaw University of Science and Technology, Department of Machine Design and Research
* Presenting Author

Abstract: In the paper the method based on linear analysis was presented to estimate resonance frequency of systems with contact. Methods that are taking into account contact during vibrations nowadays are in time domain, for general purpose problems, or base on nonlinear solutions for specific problem. Both of them have high demand on solving resources. General method that is easy for application and cost effective with acceptable accuracy might be a helpful tool for quick prediction or for complicated models assessment. Equation that allows the prediction bases on two modal analysis with different constraints configurations is presented in the paper. The method was tested in a numerical way by nonlinear vibration simulations in time domain and in an experimental way for flat CFRP specimens with several contact lengths and additional masses attached to the moving end of the specimens. Additionally the estimation method was verified for ESEO satellite antenna as complex geometry. Detail description of preparing and validating the method is described in the paper as well as results and further possibilities of the research.

Keywords: vibrations, contact, resonance frequency estimation

1. Introduction

Vibrations assessment for systems where contact appears is not clear and easy for engineers and researchers. There is possibility to analyse such a systems in time domain, but these numerical simulations are very expensive in terms of resources. Application of the time domain methods is limited for simple cases only, because of the problem complexity. For specific geometries there were presented methods in frequency domain, like *Multi-Harmonic Balance Method* combined with *Alternating Frequency Time* [1]. Other alternatives are system DOF reduction, that was described in [2] and energy conserving schemes described in [3].

During nonlinear dynamic simulations of vibrating CFRP flat beam, it was observed, that frequency response in specimen resonance is built out of two different frequencies across “half-cycles”. The half-cycle with closed contact was characterized by higher resonance frequency and the half-cycle with open contact was characterized with lower resonance frequency. The idea appeared to verify these frequencies of both half-cycles according to the model and look for equation that connects both resonance frequencies values with the resonance frequency of the specimen.

Nonlinear dynamics was used for the research on the specimen with several variables. Basing on the results, equation that combines resonance frequencies of both half-cycles was created. The equation allows to estimate resonance frequency of the system with contact, basing on two modal analysis - closed and open contact variant of boundary conditions. Validation was performed in both numerical and experimental way for different geometries, contact length and mass of the system.

2. Results and Discussion

The equation that was created has form of:

$$f_i = \frac{1}{\left(\frac{1}{2 \cdot f_0}\right) + \left(\frac{1}{2 \cdot \left(f_e - \left(\frac{f_e}{f_0}\right)^2\right)}\right)} \tag{1}$$

where f stands for resonance frequency and indexes $i, 0, e$ are responding to – specimen, with open contact, with closed contact. An example of convergence of input data and calculated values is shown in figure 1.

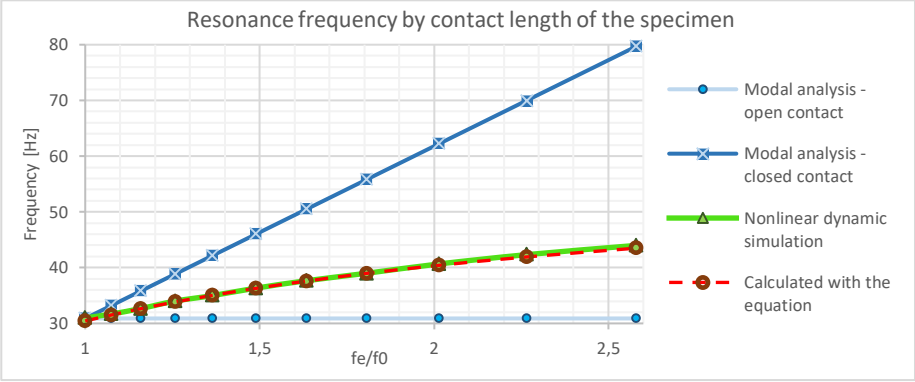

Fig. 1. Convergence of calculated resonance frequencies and obtained with nonlinear dynamic simulation

The numerical validation was done for 8 different shapes of the specimen. Experimental tests were done for 45 different cases, with 3 repeats for each. For all of the tests maximum registered error between estimated value and obtained by nonlinear dynamics or measured with barometer was 3,91%.

3. Concluding Remarks

The presented method of resonance frequency estimation based on modal analysis showed good correlation with real values of resonance frequency for studied specimens. The approach allows analysis of resonance frequency of systems with contact with usage of linear simulations, what makes it applicable for very big models. Further work should be done in verification the method for more complex geometries, where modal shape is not obvious for open and closed contact variant.

References

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