11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

LIMITATIONS of AN EQUIVALENT LINEARIZED METHOD ON VIBRATION ANALYSIS OF A FLEXIBLE CANTILEVER BEAM

Bin Li[1], Wen Cai[2], Xiaobing Wang[3]and Wanyuan Dong[4]

1 Key Lab of FSND on Aircraft Structural Mechanics and Strength Technology, Northwestern Polytechnical University, Xi'an P.R. China, leebin@nwpu.edu.cn
2 Key Lab of FSND on Aircraft Structural Mechanics and Strength Technology, Northwestern Polytechnical University, Xi'an P.R. China, caiwen2008300197@163.com
3 Key Lab of FSND on Aircraft Structural Mechanics and Strength Technology, Northwestern Polytechnical University, Xi'an P.R. China, wangxiao200618020122@126.com
4 Key Lab of FSND on Aircraft Structural Mechanics and Strength Technology, Northwestern Polytechnical University, Xi'an P.R. China, dongwy050133@163.com

KEY WORDS: *Vibration; Equivalent linearized method; small amplitude hypothesis; nonlinear; Flexible beam*

An equivalent linearization method is an efficient and approximate method that analyses vibrating characteristics of a flexible beam with large deformation, but the small amplitude hypothesis is the precondition of this method. Unfortunately, there are few literatures to discuss the qualitative level of small amplitude hypothesis. On the other hand, the traditional fully nonlinear methods are usually hard to characterize explicitly the influence of geometric nonlinear properties on structure parameters, also can not satisfy with the requirements of the reduced-order models. The present paper considers the vibrating behaviours of a flexible cantilever beam with large deformation, and use Fertis D G's equivalent linearized method to calculate the vibrating response of this beam, and discussed the limitations of the equivalent linearized method through the experiment and simulation.

The equivalent linearized method can equivalently treat the effects of static large deformation on vibration properties of the beam as the variations of cross section moment of inertia and mass density distribution, so the physical significance of this method is clear. The experiment data from some literatures have been referred to verify the validity of the present method. In order to further determine the limitation of small amplitude hypothesis, a flexible steel cantilever beam with a large deformation was designed and manufactured, and three frequency responses function (FRF) curves in the first natural frequency band that have three different vibrating amplitude levels were measured by the fixed frequency steady state exciting method.

The comparisons between experimental and simulation results show that, when the ratio of tip dynamical displacement amplitude to static deformation amplitude is less than 10%, the changes of measured FRF curves are very small. So the system can be regarded as a linear system, and the relative error of the equivalent linearized method is less than 6%, and this approximate modelling method is feasible. But when the ratio of tip dynamic displacement amplitude to static deformation amplitude is more than 20%, the value of the measured FRF at resonant frequency point is significantly decreased, and the relative error of the equivalent linearized method is more than 50%, and this method will not longer suitable. Furthermore,

full nonlinear simulation show that the nonlinear vibration behavior of the experimental flexible cantilever beam is dominated by the structural damping nonlinear property.

Acknowledgement: This work was supported by the National Natural Science Foundation of China (Grant No. 11172238), and “111” Project (Grant No. B07050).

REFERENCES

[1] Demeter G. Fertis. Nonlinear Mechanics [M]. US: CRC Press LLC, 1999.
[2] Dowell E.H, Traybar J, Hodges D.H. An Experimental-theoretical Correlation Study of Non-linear Bending and Torsion Deformation of a Cantilever Beam[J], Journal of Sound and Vibration, 1977, 50(4): 533-544
[3] T. Kim, J. Dugundji. Nonlinear Large Amplitude Vibration of Composite Helicopter Blade at Large Static Deflection[J]. AIAA Journal, 1993, 31(5): 938~946.
[4] P.F.Pai, T.J.Anderson, E.A.Wheater. Large-deformation tests and total-Lagrange finite -element analyses of flexible beams[J]. International Journal of Solids and Structures，2000, 37(21) : 2951-2980.