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Auteur : Ghysens, François
Promoteur(s) : Kerschen, Gaëtan
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Assessing the robustness of the acceleration surface method

GHYSENS François

Master in Aerospace Engineering
School of Engineering and Computer Science, University of Liège

Supervisor: KERSCHEN Gaëtan

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Nonlinearities are an important aspect to consider in the study of the vibrations of a structure, as they can influence the dynamics of the analysed system, resulting in unexpected behaviours. Nonlinear system identification aims at finding a mathematical model of the structure taking into account the nonlinear forces. One method used in the nonlinear system identification is the acceleration surface method, which helps at determining the functional form of these nonlinear forces by creating stiffness and damping curves. While the method has proven to work well in real-life applications, some artefacts sometimes appear in the stiffness and damping curves, making it more difficult to correctly interpret these curves. The aim of this work is thus to understand their origin and determine how the curves can be improved.

For this purpose, the acceleration surface method is applied to systems composed of 1, 2 and 10 degrees of freedom, whose response to sine sweep excitations is obtained through numerical integration. The nonlinearities consist of a cubic stiffness, a piecewise linear stiffness and Coulomb friction, which are all common types of nonlinearities encountered in real-life structures.

The analysis of the stiffness and damping curves obtained for the different systems reveals that the presence of harmonic components in the response of the system to the excitation can impact the curves, such that the curves can be composed of different lines, which can complicate the determination of the functional form of the nonlinear forces. Such phenomena particularly occur at superharmonic resonances and modal interactions. An effective way to improve the curves in such cases is the use of filters to remove the harmonic components from the response of the system to the excitation. Furthermore, in multiple degree of freedom systems, the linear forces that have been ignored in the equation of the acceleration surface method are responsible for the quality of the stiffness and damping curves. Applying the method to modes for which these forces are small thus yields better results. In particular, modes for which the neighbouring degrees of freedom of the linear connections oscillate in phase with the degree of freedom to which the acceleration surface method is applied have shown to produce better results. The position of the excitation and the extremity of the nonlinear connection to consider in the acceleration surface method also influence the quality of the stiffness and damping curves.

While the identification of the stiffness force can be done successfully in most cases, the functional form of the damping force remains difficult to determine with the acceleration surface method and it can only be found in some specific cases. The artefacts in the stiffness and damping curves can be explained by several phenomena, but are always due to the terms neglected in the equation of the acceleration surface method.