Nonlinear System Identification of an F-16 Aircraft Using The Acceleration Surface Method

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1 Framework

In most mechanical engineering applications, the purpose of nonlinear system identification is to upgrade and update a linear finite element (FE) model. Nonlinear elements, whose parameters are found during the identification procedure, are locally added to this linear model to better reproduce the experimental results.

The following nonlinear system identification method takes place in this framework, where a linear FE model of the structure is assumed to be available. A nonlinearity characterization step is first performed using qualitative nonlinear stiffness curves computed with the Acceleration Surface Method (ASM). This step enables to determine the location and the mathematical form of the nonlinear elements to add in the FE model. The parameters of those nonlinear elements are then identified by optimization, using the error between the ASM curves from the experiments and the numerical model as a cost function.

The case of an F-16 aircraft exhibiting nonlinearities at the wing-to-payload mounting interfaces [1] is considered and a FE model of the right wing and its connected payload is used as a starting point.

2 The Acceleration Surface Method

The ASM provides a quick visualization tool of the nonlinearity [2] as it only requires the acceleration, velocity and displacement signals measured on two degrees-of-freedom (DOF) across the studied nonlinear connection and under a sine sweep excitation. Its main assumption consists in approximating the restoring forces acting on a DOF by the opposite of its acceleration. Therefore, acceleration versus relative displacement (resp. velocity) curves yield a qualitative estimation of the stiffness (resp. damping) nonlinearities.

Regarding the F-16 aircraft, Figure 1(a) clearly reveals the presence of a piecewise linear behavior in the connection. Moreover, the discontinuity locations can be directly extracted from the qualitative stiffness curve.

3 Finite Element Model Updating Using the ASM and Optimization

As only qualitative estimation of the nonlinearities can be carried out using the ASM, the FE model is used to compute the actual nonlinear parameters, namely the slopes of the different linear regions in the stiffness curve. Simulations on the FE model with the added nonlinear elements are performed. The ASM is then applied to the simulated results (Figure 1(b)) to produce a qualitative stiffness curve similar to the experimental one. The error between those two stiffness curves is finally used as a cost function for an optimization procedure to identify the real parameters of the nonlinear elements.

References

[1] J.P. Noël and M. Schoukens, F-16 aircraft benchmark based on ground vibration test data, *2017 Workshop on Nonlinear System Identification Benchmarks*, Brussels, Belgium, April 24-26, 2017.

[2] T. Dossogne et al., Nonlinear Ground Vibration Identification of an F-16 Aircraft: Part II Understanding Nonlinear Behaviour in Aerospace Structures Using Sine-sweep Testing, *Proceeding of the International Forum on Aeroelasticity and Structural Dynamics*, St Petersburg, Russia, June 2015.

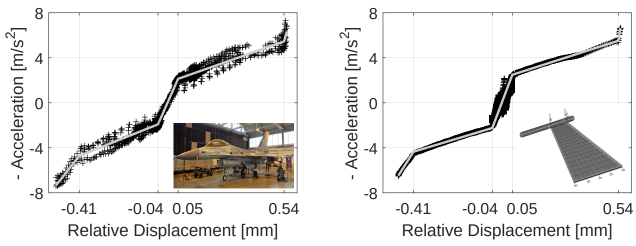

Figure 1: Qualitative stiffness curves computed by the ASM on (a) experimental results and (b) simulation results