Multiscale uncertainty quantification of complex nonlinear dynamic structures with friction interfaces

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Abstract. This work aims to investigate the interest in multi-scale uncertainty quantification for nonlinear dynamic systems with friction interfaces. Indeed, such structures experience uncertainties at different time and space scales due to the friction interface. The focus of this work is to quantify and link the uncertainties from friction interfaces at different scales to the nonlinear dynamic response of the structure. A multi-scale kriging approach is employed to propagate the uncertainty. An industrial test rig for dovetail joints will be used as a test case to demonstrate the proposed methodology.

Context

Large structural assemblies have many friction interfaces that are a major source of non-linearity and uncertainties and can have a significant impact on the dynamic response. Usually, friction interfaces are modelled with a flat surface using a macroscopic friction contact law that depends only on a few parameters. These parameters are usually obtained experimentally, showing a large variability leading to uncertain predictions of the overall dynamic response. Recent works indicate that the current macro-scale contact models are not sufficient to represent the physics at the friction interface and that micro-scale contact models must be taken into consideration. Previous UQ research in friction interfaces considered only macro-scale modelling and proved to be inaccurate in the prediction of the dynamic response due to the lack of consideration of micro-scale phenomena. Therefore, an efficient multi-scale modelling approach of the contact parameters and uncertainties is needed to simulate the micro-scale behaviour and to translate it at the macro-scale for the full nonlinear dynamic response.

Test case and results

The test case for this study is based on a fan blade root test rig setup [1] illustrated in Fig.1(a). The nonlinear normal modes (NNM) of the mechanical system are computed to obtain its nonlinear dynamic behaviour. A two scales numerical solver is used for this. The first scale computes the contact pressure and gap distribution at the different contact surfaces based on micro-scale considerations. The second computes the NNM of the system by considering the real contact pressure and gap distribution. In this work, a single micro-scale uncertain parameter is considered to demonstrate the approach, namely the central bump of the contact surface. The multi-scale approach proposed here, illustrated in Fig.1(b), consists of the creation of a first surrogate model to predict the contact pressure and gap distribution from the central bump, and a second surrogate model to predict the NNM from the contact pressure and gap distribution. From this, it is possible to get the distribution of the random contact pressure and the stochastic NNM of the system. Results show that such an approach allows getting deep insights into the system understanding.

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References

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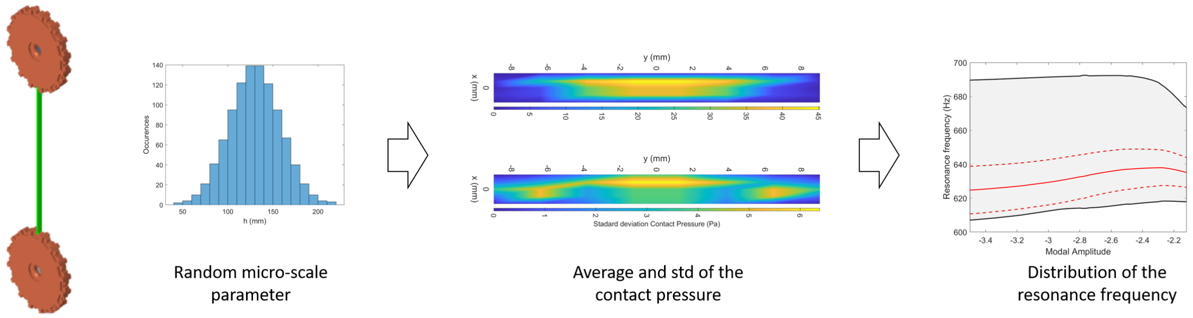

(a) (b)

Figure 1: (a) FE model of the Dogbone rig (b) Multi-scale UQ process illustration