World Tribology Congress 2013
Torino, Italy, September 8 – 13, 2013

Modelling friction contacts in nonlinear vibration of bladed disks

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The dynamic response of assembled structures, such as bladed-disk interfaces of aero engines, can be strongly influenced by the friction behaviour in the contact joint. The interface can change the stiffness of the assembled structure, leading to a shift in resonance response frequency, and add damping to the system due to energy dissipation. In addition the friction in the joint can also lead to wear, which on the one hand reduces the cycle life of the component, and on the other hand can significantly affect the global dynamic response of the structure over time [1].

An analysis of the nonlinear dynamic behaviour of an assembled structure can be based on a simplified nonlinear model that represents the entire contact problem implicitly with a single element (eg. an underplatform damper element). Alternatively the contact surface can be explicitly modelled with great detail, where a large number of nonlinear elements are spread over the contact area to capture the underlying nonlinear mechanism. The latter approach allows a much more accurate representation of the contact condition, since areas of high and low contact load can be predefined, and the stuck-slip-separation condition can be calculated locally over the contact area instead of globally. It is therefore the preferred method of analysis, and the focus of the presented research.

With advances in linear finite element modelling the demands for the nonlinear dynamic analysis are increasing as well. This leads to large nonlinear models for an accurate representation of the contact interface, which in turn pose a significant challenge to the solution process of the nonlinear problem. Explicit approaches have been developed [2] for the simulation of the non-linear vibration response. Component mode synthesis methods are being used to reduce the size of the nonlinear system before solving them with a multi harmonic balance solver. With the current transition to more detailed nonlinear models, two major problems arise: (i) the available model reduction methods are not efficient enough, leading to very long calculations times and memory allocation problems, and (ii) a very accurate knowledge of the static normal contact load is required to take advantage of the detailed representation of the contact interface.

To address these issues, a new approach is being presented that combines model reduction and normal load calculations for an improved nonlinear analysis of large systems. Initially the main features of two available component mode synthesis methods (fixed interfaces [4] and free-interface [2]) are discussed. A combination of both approaches is then presented to increase the efficiency of the model reduction for large problems.

The calculation of the nonlinear static forces and the dynamic response are combined into a single solution step for a further increase in the accuracy of the nonlinear dynamic response. For this purpose the static nodal normal forces are projected onto the improved reduced model and the static and dynamic problem is then solved simultaneously during multiharmonic balancing. Results obtained with this new approach include changes to the mean position of the contact surface due to preloads and vibration levels. In this way settling and realignment of the contacting structures, such as an underplatform damper movement against the blade surface, can be included in the analysis, and a future simulation of dynamic fretting wear and its influence on the dynamic response will be facilitated [1] as well.

The developed approach is being demonstrated with a numerical study of a bladed-disk and its performance evaluated against the more traditional methods.

Acknowledgements

The authors are grateful to Rolls-Royce plc. for providing the financial support and for giving permission to publish this work.

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