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Dynamic Analysis of Fretting-wear in 3D Structures in Contact with Friction

L. Salles[1,2,3], L. Blanc[1], F. Thouverez[1], A.M. Gouskov [2], P. Jean[3]

[1] *Laboratoire de Tribologie et Dynamique des Systèmes, UMR CNRS 5513 École Centrale de Lyon, Écully, France, {loic.salles,laurent.blanc,fabrice.thouverez}@ec-lyon.fr*
[2] *Moscow state technical university named after N.E. Bauman, Russia, gouskov_am@mail.ru*
[3] *Snecma Groupe Safran, France, pierrick.jean@snecma.fr*

Many assembled systems have contact interfaces with dry friction. In some applications, for example turbomachinery, dry friction is the most important source of mechanical damping. This is the positive aspect of dry friction. On the other hand damping in contact interfaces is due to micro-sliding under high pressure, which can involve fretting-wear. Fretting-wear is a surface degradation process in which removal of material is induced by small amplitude oscillatory movement between contacting components. The main parameters affecting fretting wear are reported to be normal load, slip amplitude, frequency, contact geometry, surface roughness, temperature in the contact and material properties. Fretting-wear has already been experimentally and numerically studied, but only for quasi-static loading. Studies taking into account vibration and fretting-wear are rare.

In this work assembled bladed disks are studied. Because of relative displacements at interfaces in roots (Fig. 1), fretting-wear can occur, which shortens the life expectancy of the structure. Moreover, vibrations that occur in bladed-disks can increase this fretting-wear phenomenon. A new approach for multi-scale modelling of fretting-wear under dynamical loading is proposed. It is based on multiple temporal scale analysis[1] with a finite element description of the structure. Wear is a very slow phenomenon and the depth of wear is very small compared with the dimension of the structures in contact, for this reason the modifications of the mass and stiffness matrices due to wear are neglected. A Component Mode Synthesis (CMS) is performed to reduce the size of the system. Methods with free interface or fixed interface are tested to reduce system. Wear parameter is introduced in the penalty term of the augmented Lagrangian formulation that is used. This approach allows not to remesh structures after fretting cycles. The proposed methodology is based on the hypothesis of local periodicity in the time domain (dynamic phenomena). This approach can be compared with homogenisation theories of space periodic structure. In the temporal homogenization proposed, both the applied loads and the response fields are assumed to depend on a slow time coordinate (slow modification of contact interfaces due to fretting-wear), as well as on the fast time coordinate (due to locally periodic dynamical loading). Wear appears here as a permanent normal displacement of the interface at the scale of one period in the response of the system. On the fast time scale the response of the structure is still periodic and consequently on one period Fourier series can describe displacements and contact forces. On a long duration Fourier coefficients will evolve as functions of a slow time variable linked with the fretting-wear phenomenon.

A method based on HBM (harmonic balance method) with AFT procedure (Alternating Frequency Time) is employed to solve the dynamical contact problem on the fast scale time. This method, called the DLFT, uses dynamic Lagrangians [2, 3]. In this method Lagrangian multipliers representing contact forces are obtained in time domain and introduce in frequency domain by a prediction/correction approach. Displacements and velocities are calculated in the frequency domain and transformed into the time domain using an inverse DFT procedure (iDFT). In the time domain, contact forces are evaluated by correcting the contact forces predicted in the frequency domain to respect the contact conditions asso-

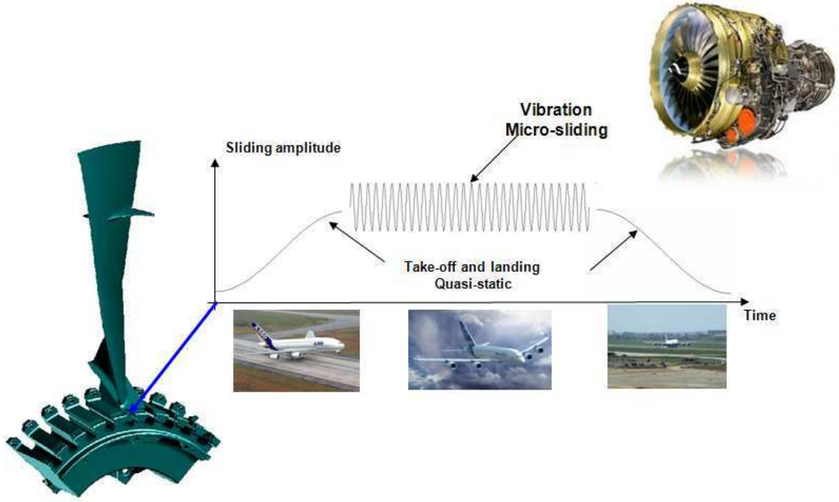

Figure 1: Sliding amplitudes in bladed-disk roots during flight

ciated with Coulomb's friction model. The problem on slow scale, linked with tribological phenomena, is solved by numerical integration. Explicit and implicit schemes can both be used, nevertheless implicit schemes are more reliable and stable. Implicit schemes and non-linear solver (Hybrid Powell) of HBM system require calculation of Jacobian matrix. In DLFT method Jacobian matrix can be calculated semi-analytically in the same way as in the method proposed by Petrov [4]. An ad hoc prediction-correction method is used in both schemes to accelerate the convergence of the non-linear solver.

Numerical investigations illustrate the performances of this method and show the coupling between dynamical and tribological phenomena [5].

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