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SENSITIVITY OF LIMIT CYCLE AMPLITUDES AND FREQUENCIES OF SELF-EXCITED VIBRATIONS FOR STRUCTURES WITH NONLINEAR CONTACT INTERFACES

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There are two major sources of vibration excitation in machinery structures: (i) excitation by time-varied external forces and (ii) self-excitation, which can occur even in absence of the external excitation.

For the first type, vibration are excited by time-varying external forces. These forces can be considered as independent of the motion of a structure. When the excitation forces are periodic in time, as happens in many practical applications, the steady-state forced vibrations are often also periodic (although for nonlinear structures quasi-periodic or stochastic responses are also possible). The period of forced response is determined by the period of excitation: (i) for linear structures the period of vibration coincides with the excitation period; and (ii) for nonlinear structures the vibration period can be equal to a product of the excitation period and some integer number.

The second type, self-excited vibrations are caused by a non-periodic source of energy. The energy is transferred into structural vibrations by forces which are dependent on the motion of a structure and the vibration period and the vibration amplitude levels are defined by dynamic properties of a structure, the energy source and the feedback mechanism of interaction between the energy source and a structure. Important practical examples of self-excited vibrations are flutter in bladed discs of gas-turbine engines and friction-excited vibrations due to rubbing contacts, such as squeal in automotive of aircraft braking systems.

In this paper, an effective method is presented for the high-fidelity analysis of sensitivity of limit-cycle amplitudes and frequency of the self-excited vibrations for jointed structures with nonlinear contact interfaces. Major types of nonlinearities occurring in jointed machinery structures are considered: friction contacts, cubic spring nonlinearity and gap nonlinearity. The limit-cycles considered here are formed by nonlinear contact forces which limit the exponential amplitude growth of the self-excited vibrations. The method allows highly accurate and fast determination of the sensitivity coefficients to the variation of contact interface parameters (such as friction and contact stiffness coefficients, gap values, etc.) and intensity of the excitation. The sensitivity coefficients are calculated together with the determination of the limit-cycle amplitudes and frequencies. Realistic large-scale finite element models of structures and the contact interfaces are used in the analysis. The analysis of the periodic limit-cycle vibration is performed in the frequency domain using mutliharmonic representation of the structure vibrations.

The accuracy and high efficiency of the method is demonstrated on a set of studies for cases including a model of a compressor bladed disc. An example of the analysis of limit-cycle vibrations induced by fluttering modes for a bladed disc is given in Fig.1, where the dependency of the limit cycle amplitudes and frequencies on the friction coefficient value at the contact interface is shown together with calculated sensitivity coefficients with respected to variation of the contact interface parameters: friction coefficient, μ , contact stiffness coefficient, k_t , and characteristics of the fluttering first mode: modal damping factor, η_1 , and natural frequency, f_1 .

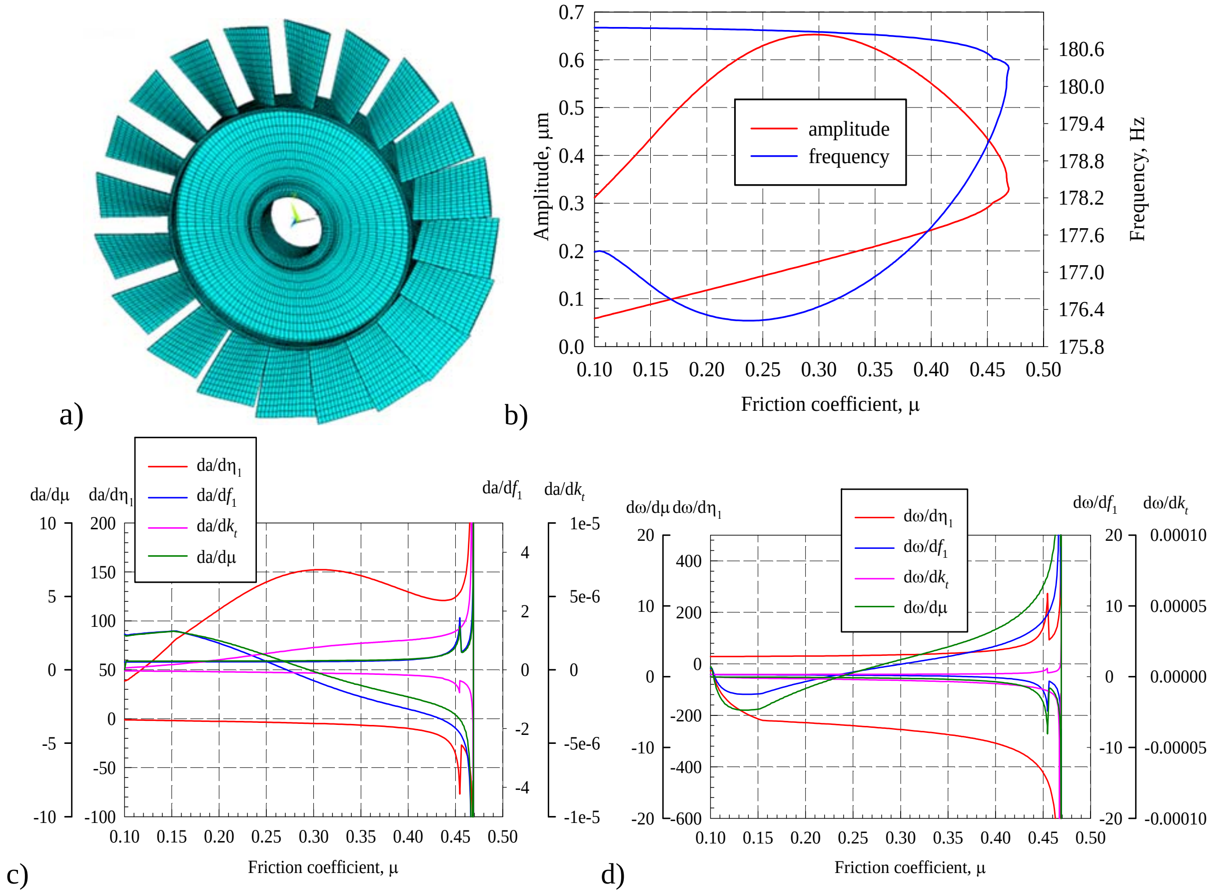

Fig.1 Finite element model of a bladed disc (a), limit cycle amplitude and frequency (b), sensitivity coeffiicents with respect to contact interface parameters and fluttering mode characterstics

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