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Analysis of the non linear dynamic behaviour of an assembly. Determination of the friction-induced damping.

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ABSTRACT

The objective of the work presented here is to calculate the damping generated by the friction in the joints of an assembled structure. The vibrations of assembled structures are characterized by a non classical damping dependent on the amplitude of solicitations. Although several mechanisms allow a loss of energy in the interfaces of a structure, the friction is considered as one of the preponderant mechanisms.

Among the previous studies, some authors have proposed some 3D finite element analysis [4] with or without sub structuring [1], [6]. Some approaches have launched high frequency vibrations [2]. Our work and some others [5], [6], are concerned with the low frequency vibrations. Considering that the knowledge is very poor to characterize the contact parameters, some authors have used stochastic methods in order to modelize the unknown parameters, [3]. Take into account the friction in the joints during the analysis of dynamic systems remains a difficulty. That is why we propose an analytical study on a quite simple structure. We therefore consider a beam type structure. It is built in three parts of length L/4, L/2 and L/4 linked by an interface contact and the friction. The three parts remain linked with the help of an axial load N. The beam is loaded by a simple transverse force T applied in the middle of the second beam. The proposed method is first to calculate the modal motion of the all structure. After that, we focus on the energy loss in a joint, calculating the friction stresses at the interface during the harmonic motion on a single mode of vibration. This allows to watch the influence of different parameters as the amplitude of excitement, the friction coefficient, the clamping force, the frequency of vibration. The paper is organized in four sections.

First, we present the analytical resolution of the problem of beam with perfect links without any sliding in the clamp. Assuming that the solution of the problem with friction is not so far from the perfect model, we calculate the real shear stresses in the joints. Particular attention is given to the shear stresses in the interface located at L/4 for which, constraints related to bending are void. This section has allowed us to determine the distribution of shear stresses in the section for several amplitudes of excitement and several pre-load values.

We can demonstrate that the shear stresses distribution can be assumed to have a

parabolic form in the section of a mono-block beam. By taking into account the Coulomb model of sliding, one can show that the ratio of the shear stresses and the normal stresses is bounded by the friction coefficient. As the previous results show, there are three phases: sticking, mezzo-sliding, which corresponds to a sliding located on the central party of interface, and complete sliding. This mezzo-sliding comes without any relative motion between the parts of the structure. Our model is based on the parabolic distribution form model of stresses in the section; it considers the continuity of the material, and the model of Coulomb to define the border of sliding. One determines analytically a new distribution of the stresses. The results highlight precisely the two phenomenon in the interface: a sliding zone and two areas of adhesion.

The second section presents a semi-analytical model to define the sliding motion in the interface. We start off with an assumption of sliding in the middle of the section, a parabolic distribution of the stresses without sliding on the edges of the beam. One analyses a section subjected to a tangential stress and defines the main parameters of the structure which have an influence on the maximum value of this displacement. The resolution of the problem of elasticity associated with the finite element method shows that the maximum sliding varies linearly as a function of the size of the sliding zone. It allows to define a coefficient determined numerically, which provides a distribution of displacement in the area of sliding.

In the third part, and now that the distribution of stresses and displacements is defined everywhere in the section, we calculate the energy dissipated by friction in the interface on a loading cycle. Also by calculating the energy of the first mode of the beam, one can get a rate of equivalent damping. A parametric study of the influence of geometry, the normal load, the excitement, is used to determine damping in these different conditions. These results are discussed and compared qualitatively with other results represented in literature.

Finally in the fourth section, we present the numerical resolution of the entire problem in the computation code ABAQUS. Acquired results and their confrontation with analytical results allow match up to the analytical results.

This analytic work is the first step to the study of more realistic links from a technological point of view. It has helped to fix the orders of magnitude of energy dissipated in contacts for different values of structural parameters.As perspectives, we introduce the beginning of experimental work intended to reinforce our models on a real structure similar to that which has been modeled. We also introduce tracks in order to generalize this work, on the one hand to the study of multi-mode vibration and to the study of geometrically complex links.

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