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Methods of Simulation for Dynamic Systems with Friction

In this paper the contact/impact between two bodies is accentuated by simulations using the ANSYS code. In the present study has been selected the ANSYS/LS-DYNA code because it is used in the simulation of contact/impact. This computer code performs nonlinear transient dynamic analysis of three-dimensional structures.

Keywords: *friction, contact, impact, mathematical model*

1. Introduction

Friction between two slippery surfaces plays an important role in the dynamic behavior for a large number of mechanical systems. Various aspects such as complex dynamic sliding movement, auto-excitation and chaotic oscillations are also identified in the presence of friction in joints and contact surfaces.

The study of dynamic systems with friction has a long and rich history. Except some cases, the effects of friction lead to the incorrect operation of several systems and require the introduction of effects - control devices to compensate for friction phenomena.

The dry friction model of Coulomb is used for most engineering calculations of the roughness, but it is difficult to be used for complex applications because this model neglects the microscopic degrees of freedom of contract that have a very important role in various applications. For example, in the case of mechatronic systems, speed and interval length of movement become comparable to the length and the time involved in the microscopic degrees of freedom of contract. This aspect has led to the development of new models for phenomenology modeling of friction and different techniques to compensate for the unwanted effects of friction.

Modern literature is rich in many mathematical models of friction. Each of these models is relevant to one or several operational areas and phenomenology, depending on interest. To solve a particular case, a friction model has to be selected, a model close to reality which is very important.

Depending on the time scale and the length, friction models in specialized research can be classified into two categories, which are called macroscopic models, respectively microscopic models.

The mathematical model of a mechanical system with one degree of freedom and with friction is presented below where the body of a slide mass m moving on a surface with friction and is coupled by a spring of elastic constant k which is able to produce variations in time of the control velocity with the following form $v_m + v_a(t)$.

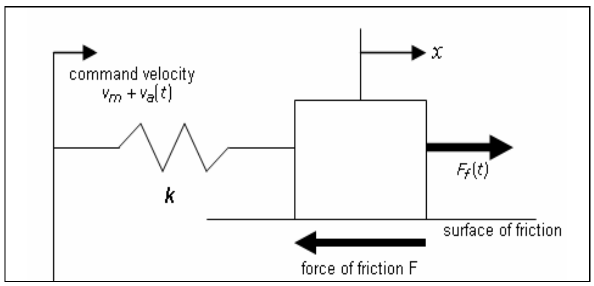

Figure 1. Mathematical model of the system considered

This system is in agreement with the dynamic friction model of LuGre. The system is excited by a high frequency disturbance. Excitation frequency is very large compared to the natural frequency or frequency of variation of the velocity of command. Non-dimensional equation of motion of the system is given by the following equation:

$$\ddot{X} + X + \tilde{F} = \tilde{f}_f(\tau, T_0) + \tilde{f}_s(\tau) + v_m^* \tau$$

$$\frac{dZ}{d\tau} = \dot{X} - \frac{\sigma_0^* |\dot{X}| Z}{g^*(\dot{X})}$$

and

$$\tilde{F} = \sigma_0^* Z + \sigma_1^*(\dot{X}) \frac{dZ}{d\tau} + \sigma_2^* \dot{X} \quad (1)$$

where as you can see the non-dimensional sizes are set out below: $\tau = t\omega_n$ non-dimensional time, $T_0 (<< 1)$ is the non-dimensional time of excitation fast.

$\tilde{f}_f(\tau, T_0) = \frac{F_f}{m\omega_n^2 L}$ and $\tilde{f}_s(\tau) = \frac{k \int_0^\tau v_a(s) ds}{m\omega_n^2 L}$ are fast and slow signals of superposition (oscillations of small corrective amplitude) respectively excitations.

$$\omega_n = \sqrt{\frac{k}{m}}$$

$$X = \frac{x}{L},\ \dot{X} = \frac{x}{\omega_n L},\ \ddot{X} = \frac{x}{\omega_n^2 L}$$

$$Z = \frac{z}{L}$$

with L a length of arbitrary size.

$$\sigma_0^* = \frac{\sigma_0}{k},\ \sigma_1^*(\dot{X}) = \hat{\sigma}_1^* e^{-\left(\frac{\dot{X}}{v_d^*}\right)^2},\ \hat{\sigma}_1^* = \frac{\hat{\sigma}_1}{m\omega_n}$$

$$v_d^* = \frac{v_d}{\omega_n L},\ \sigma_2^* = \frac{\sigma_2}{m\omega_n}$$

and

$$g^*(\dot{X}) = f_c + (f_s - f_c) e^{-\left(\frac{\dot{X}}{v_s^*}\right)^2}$$

where

$$f_c = \frac{F_c}{m\omega_n^2 L},\ f_s = \frac{F_s}{m\omega_n^2 L},\ v_m^* = \frac{v_m}{\omega_m L},\ v_s^* = \frac{v_s}{\omega_n L}.$$

In the above model X is the structural macroscopic degree of freedom and Z is the microscopic degree of freedom of the interface of friction. These two degrees of freedom are coupled by the force of friction. The equation of motion (1) without fast excitation describe the dynamics in two disparate time scales, unrelated, Z is rapidly variable. When the time scale of the fast excitation is different from the time scales of X and Z, can be the three disparate time scales.

2. Numerical example

The experimental study of a model is named and simulation and is favorite in the situations in which the study on analytic path is impossible or too laborious. The model studies is named model of simulation and is, in most happy case, a mathematical model. Simulation offers always the possibility for the study of the model, when the analytic study is not applicable.

FEM is an efficient method; from this reason the numerical simulation tends to replace the experiment from most as the simple cases to the simulation of the complex attempts. In the ANSYS cod are available 7 types for structural analyzed: static analyze; the modal analyze is use from obtain the natural frequency and the deformation mod of structures. In the modal analyze is use the ANSYS WORKBENCH cod; harmonic analyze; dynamic transient analyze; spectral analyze;

analyze of flambé; explicit dynamic analyze In the explicit dynamic analyze is use the ANSYS LS-DYNA program whence is an explicit dynamic program; it assures the simulation of problems of non linear analysis, rapid dynamics, with applications in the simulation of technological processes of cupping, smiting, lamination, etc., simulations with impact.

Use the ANSYS LS-DYNA cod is realized the simulation for the problem: the rigid body 2 coupled by an elastic spring with the constant k, as in Figure 2, can move on the surface 1.

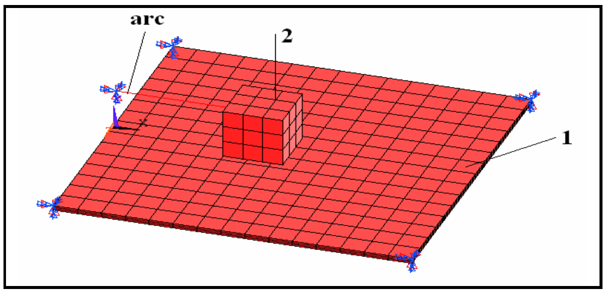

Figure 2. The problem studied

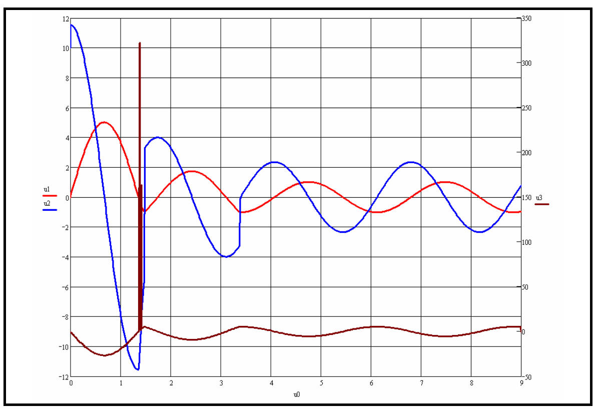

Figure 3. Graphical representation of displacement u1, speed u2 and acceleration u3, the X axis, according to the time u0

The following the simulation of a particular node of the rigid body 2 which is graphically represented by the displacement u1, speed u2 and acceleration u3, where X-axis, depends on the time u0 as in Figure 3

In Figure 3 is represent the displacement, the speed and the acceleration of rigid body 2 whence can move on the horizontal surface 1. The acceleration have a jump at t=1.38[s] what is constituted the moment of modification the slip direction. Since this moment begin the stik-slip movement then it is amortize.

From the results obtained from this simulation "von Mises stress" can be obtained selecting some of these variables at different moments of time as can be seen in Figure 4 ... Figure 13.

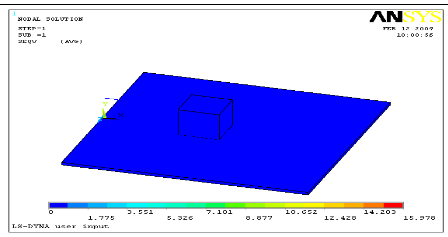

Figure 4. Initial position

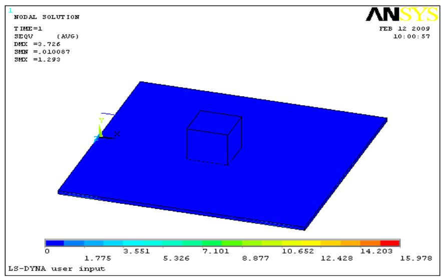

Figure 5. t=1[s]

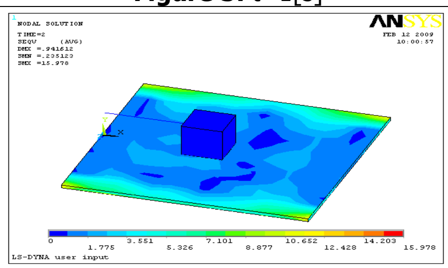

Figure 6. t=2[s]

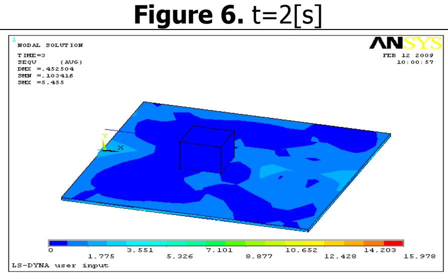

Figure 7. t=3[s]

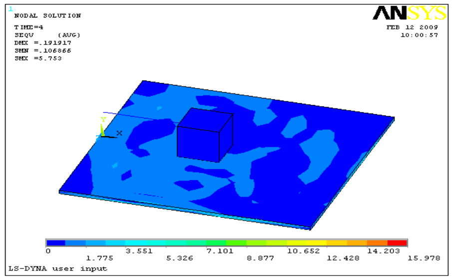

Figure 8. t=3[s]

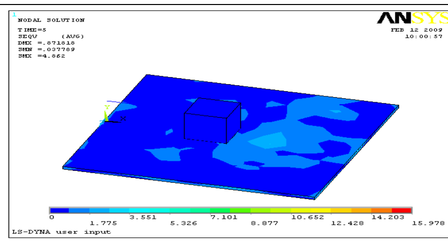

Figure 9. t=5[s]

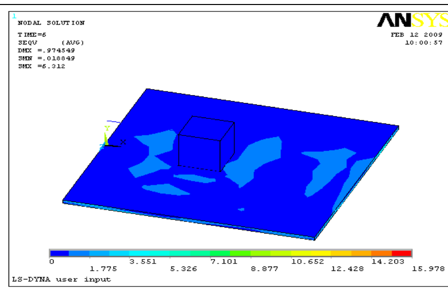

Figure 10. t=6[s]

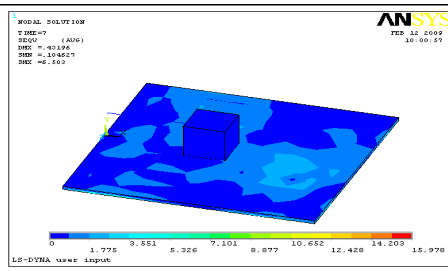

Figure 11. t=7[s]

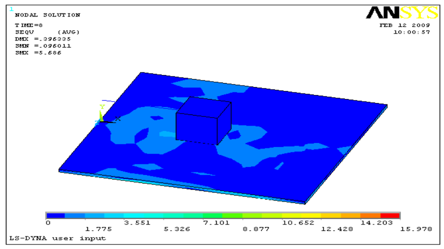

Figure 12. t=8[s]

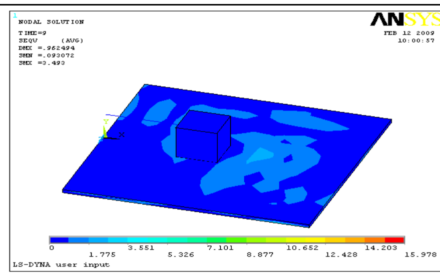

Figure 13. t=9[s]

3. Conclusions

The efficiency of the Finite Element Method in the numerical simulation, in general, substitutes the experiment, in many cases and in complex tests.

The choosing of ANSYS LS-DYNA program is due to the fact that it is the most suitable for the contact/impact problems of elastic bodies. The analyzed in this study has a theoretical character.

The long duration of stick and slip phases are broken down to short duration of stick and slip phases and the total relative time of short time sticking phase increases with the control velocity.

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