Dynamic response of multibody systems with 3D contact-impact events: influence of the contact force model

M. Machado[*] P. Flores[†]
University of Minho
Guimarães, Portugal

D. Dopico[‡] J. Cuadrado[§]
Universidad de A Coruña
Ferrol, Spain

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Introduction

Contact-impact events can frequently occur in the collision of two or more bodies that can be unconstrained or may belong to a multibody system. In many cases the behavior of the mechanical systems is based on them. As a result of an impact, the values of the system state variables change very fast, eventually looking like discontinuities in the system velocities. The knowledge of the peak forces developed in the impact process is very important for the dynamic analysis of multibody systems and has consequences in the design process. Therefore, the selection of the most adequate contact-impact method used to describe the process correctly is crucial for an accurate design and analysis of these types of systems. The constitutive contact force law utilized to assess contact-impact events plays a key role in predicting the dynamic response of multibody systems and simulation of the engineering applications. Thus, a study on the dynamic response of 3D multibody systems that experience contact-impact events is presented in this paper, where different contact force models are used in order to check how the contact force law affects the dynamic behavior of the whole system.

Contact-impact force models

In the present work, several compliant contact force models are considered to model the contact phenomena developed within the multibody systems, namely those proposed by Hunt and Crossley [1], Lankarani and Nikravesh [2] and Flores et al. [3]. In these models, the local deformations and normal contact forces are treated as continuous events and introduced into the equations of motion of the mechanical system as external generalized forces. The constitutive force laws mentioned above are based on the Hertz law and include a damping term to accommodate the energy loss during the impact. Thus, these three contact force laws can be divided into elastic and dissipative components as

$$F_N = K\delta^n + D\dot{\delta} \tag{1}$$

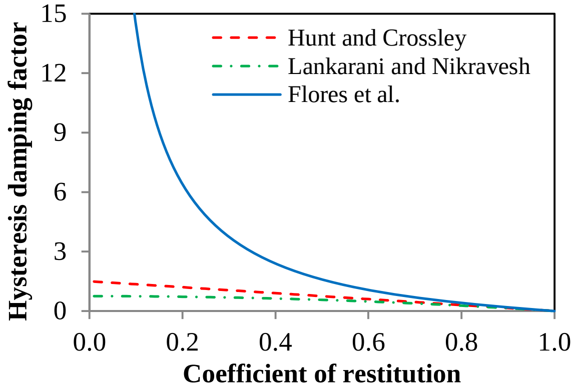
where the first term represents the elastic force and the second term accounts for the energy dissipation. In Eq. (1), K is the generalized stiffness parameter, δ is the relative penetration depth, D is the hysteresis damping coefficient and $\dot{\delta}$ is the relative impact velocity. The exponent n is equal to 3/2 for the case where there is a parabolic distribution of contact stresses. The generalized stiffness parameter K depends on the geometry and physical properties of the contacting surfaces. In turn, the damping term D has different expressions depending on the approach considered, which may be valid for very elastic and/or inelastic contacts. The similarities of and differences among the contact force models are investigated for elastic and inelastic contacts by means of the use of high and low values

[*] margarida@dem.uminho.pt
[†] pflores@dem.uminho.pt
[‡] ddopico@udc.es
[§] javicuad@cdf.udc.es

of the restitution coefficient for the contacting bodies. With the purpose to understand which are the main differences among the dissipative contact force models listed above, the evolution of the hysteresis damping factor for all range of the coefficient of restitution is investigated and shown in Figure 1-a. By observing the plots of Figure 1-a, it can be concluded that all the contact force models exhibit a similar behavior for high values of coefficient of restitution. In contrast, for low values of the coefficient of restitution, the Flores et al. approach is the one in which the hysteresis damping factor increases asymptotically with the decrease of the coefficient of restitution, which can be considered to a be superior model for inelastic contacts. These issues will be object of discussion within this study.

Demonstrative example of application

The demonstrative example is a multibody model of a Liebherr A924 Litronic, a medium-size wheeled excavator (see Figure 1-b). The model interacts with the environment by means of contact forces between its bodies and the surrounding objects and terrain. The normal force models implemented are those explained above, while the frictional model can be found in [4]. The excavator is placed in a working environment, standing on its wheels, and the operator performs two maneuvers: first, the machine is lifted on its legs and blade, and second, the bucket is actuated to hit the surface of a dump truck which is considered as a fixed rigid body. In order to compare the three normal contact models, the time history of the following magnitudes is obtained: position, velocity and acceleration of the chassis center of mass, contact forces, and energy dissipation due to the normal forces.



(a) (b)

Figure 1: (a) Evolution of the hysteresis damping factor as function of the coefficient of restitution for Hunt and Crossley, Lankarani and Nikravesh, and Flores et al. contact force models. (b) Excavator model in its working environment.

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