Contact Mechanics for Multibody Dynamics

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This talk will focus on the fundamental issues of the modeling and analysis of contact-impact events within the framework of multibody system formulations. Results in terms of the dynamic simulations of several mechanical systems will be presented, which allow for the evaluation of the computational accuracy and efficiency of the methodologies used to handle the contact mechanics in multibody dynamics.

A multibody system can be described as a collection of bodies acted upon by external forces and interconnected by kinematic pairs of different types that constrain their relative motion [1]. The external actions applied on the system components may include gravitational and inertial forces, concentrated forces and state-dependent forces in which contact-impact forces are included. In particular, contact-impact events occur very often in multibody systems [2-4]. As a result of an impact, the state of a system can change quite rapidly, resulting in discontinuities in the system velocities. Overall, the knowledge of the peak forces developed during the impact process is crucial for the dynamic analysis of mechanical systems and has consequences in the design process [5-7]. The subject of contact mechanics and its applications has received a great deal of attention over the last few decades, and still remains an active field of research and development. There is no doubt that contact-impact events are ubiquitous in engineering and research activities, such as in railway dynamics [8], crashworthiness [9], robotics [10], biomechanics [11], mechanisms [12], and sound waves [13], just to mention a few. It is known that contact-impact events can frequently occur in multibody mechanical systems and in many cases the function of mechanical systems is based on them [14]. An impact can be described as a complex physical phenomenon for which the main characteristics are a very short duration, high force levels, rapid energy dissipation and large changes in the velocities of bodies. In turn, contact implies a continuous process, which takes place over a finite time.

The establishment of a general criterion to group the different methods to deal with contact-impact events is not unanimous and simple. A general and broad embracing rule is to group them into contact force based methods (continuous methods) and the approaches based on the geometric constraints (piecewise methods) [15]. In a simple manner, three main features distinguish these two methods: (*i*) the location of the contact points, (*ii*) the relative penetration or indentation between contacting bodies, and (*iii*) the contact forces. In the contact force based methods, commonly referred to as penalty approaches, the location of the contact points does not coincide in both contacting bodies. With these methods a large number of potential contact points exist, in general, being the actual contact points those associated with the maximum indentation [16]. In turn, in the methods based on the geometric constraints, the contact points on both bodies are necessarily coincident due to the contact constraints imposed on the system. In these methods, the relative indentation between the contacting bodies is not permitted as bodies are considered to be entirely rigid at the contact zone [17]. In contrast, with the penalty approaches, relative indentation of bodies is allowed to occur, a reason for which these methods are also usually referred to as elastic approaches [18]. The indentation plays a crucial role as it is utilized to evaluate the contact forces according to an appropriate constitutive law [19, 20].

Thus, this lecture deals with a critical analysis and discussion on the recent developments and challenges when modeling contact-impacts events in the context of dynamics of multibody systems. Several examples of application will be used to show and compared the different models to handle frictional contacts, ranging from simples cases, as the contact between spheres, to complex systems, such as human joints and biomechanical models. Furthermore, future developments and challenging issues will also be object of discussion.

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