Collisions of Rigid Bodies – An Open Problem

The problem of the determination of the velocities after collisions and the impulses which appear during the collisions is an old but still open one. All authors agree the following hypotheses: a) only the impulses are considered during the collisions; b) neglect of the rigid displacements; c) the impulses satisfy the principle of action and reaction.

The previous researches focused on a few main directions.

From the point of view of the existence of friction during the collision the authors deal with collisions without and with friction. Usually, the friction between the collided rigid bodies is considered to be a Coulombian one. Three coefficients of restitution are defined: Newton, Poisson and energetic one. For the case of the collision without friction it is proved that the three coefficients of restitution are equal, and they have positive values between zero and one. In the case of the collisions with friction the three coefficients of restitution are not longer equal. The open problems refer to:

– existence of some cases in which one may a priori establish an order of magnitude for the three coefficients of restitution. All existed studies highlight the idea that this order does not exist for the considered situations, but a general demonstration is absent;

– which coefficient of restitution is the most consistent with the initial data. The authors highlight the situations in which the Newton and Poisson coefficients of restitution may lead to inconsistent models. For this reason, the energetic coefficient of restitution is the most used one. There still exist some particular cases in which the experiments do not agree with the theory and the researchers consider new coefficients of restitution that may be applied in those cases;

– the appearance of the jamb phenomenon during the collision. There is not a criterion by using of which one may state the existence or the absence of this phenomenon, even in very simple cases;

– definition of the situations for which one or more coefficients of restitution may have values greater than one. The possibility of supra-unitary coefficients of restitution is proved even for simple situations;

– the mathematical equivalence of the three coefficients of restitution, that is, knowing the value of one of them we may predict some intervals for the other two.

From the point of view of the existence of simultaneous multi-collisions we have:

– single collision. For the collisions without friction this problem is solved. The modern theory of collisions appeals to the definition of inertances, resulting in simple matrix expressions for the impulse, velocities after collisions and the lost of energy. The case of collisions with friction is a more difficult one because of the complex phenomena which may appear;

– simultaneous multi-collisions. The general theory for the case of collisions without friction was developed using the notion of inertance. For simultaneous multi-collisions with friction the discussion is more difficult because of the complex phenomenon which may appear. A general theory is not developed yet, but some discussions concerning simple cases may be found in the literature.

From the point of view of the existence of excitations we discuss about:

– systems with no excitation;

– systems with excitations. Only collisions without frictions are considered. The majority of the literature contains examples of harmonic excitations. The elastic elements are in the most cases linear ones, while only a few articles deal with non-linear ones (polynomials, up to the third order). The case of non-polynomial elastic elements is not considered. The damper is also described by polynomial functions. The dynamics of these systems is a complex one leading to periodic or non-periodic motions. Some cases offer examples of chaotic motions.

The rigid bodies which collide are generally considered to be free, that is, no constraint act upon them. If at least one of these rigid body has a constrained motion, then only collisions without friction are considered and the theory is more complicated and the problems are solved using screw-coordinates. Using the notion of inertance one may also determined the constrained impulses. The case of constrained rigid bodies which collide with friction is not discussed in the literature.

The problem of the existence of collision between two rigid bodies, or between a rigid body and a surface with arbitrary shapes requires very complicate algorithms.

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