SOFTWARE TOOLS: FROM MULTIBODY SYSTEM ANALYSIS TO VEHICLE SYSTEM DYNAMICS

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Abstract After successful application to spacecraft and appropriate theoretical examinations, multibody system (MBS) approaches, their formalisms, and software became of interest to the vehicle system dynamicists both for rail and road vehicles. This introductory paper sketches a few important milestones in the MBS general development related to vehicle system dynamics. While at the beginning the absence of system-specific force laws was the major stumbling block, later on the numerical methods and the efficiency of the formalisms became of prime focus. More recently, the transition from system analysis to system design and optimization, as well as the integration into multidisciplinary computer aided engineering (CAE) of vehicle systems, was and still is a challenge.

1. MULTIBODY DYNAMICS—THE BEGINNING

The origin of modern multibody dynamics is closely related to the beginning of the space age in the ’50s and ’60s of the 20th century. The development of such space vehicles as spacecraft and orbiting satellites was essentially based on a computer-aided dynamic analysis, in particular for the rotational behavior, see e.g. [1]. To this end multibody systems were reconsidered from a more algorithmic point of view that took into account the increasing efficiency of computers.
Since then, the term *multibody system* (MBS) has been used more precisely for a system of a finite number of rigid or flexible bodies and their interconnections. It is supposed that the mass of the system is concentrated in the bodies that are connected by such idealized massless elements as joints, springs, dampers, and actuators [2].

The state of an MBS is described by a finite-dimensional vector $q(t)$ of position coordinates and the corresponding velocities $v(t)$. Based on principles of classical mechanics, such as d’Alembert’s principle, the equations of motion are derived in a systematic way [3].

For a single body these equations may be written down straightforwardly, but for complex MBS the derivation becomes technically very complicated and is most conveniently performed by computers using *multibody formalisms*. These formalisms are algorithms to generate the equations of motion for a user-specified MBS in a form that allows an efficient numerical solution.

The multibody system approach, multibody formalisms, and the derived software packages became a powerful basis for the kinematic and dynamic analysis of mechanisms. Shortly after the first applications in space technology and beyond its prime academic appeal, multibody dynamics was found to be useful also in vehicle system dynamics both for rail (including magnetically levitated) and road vehicles.

This introductory paper sketches a few important milestones in the development of multibody dynamics in general, as well as their particular evolution in the vehicle system dynamics area. In the final part of the paper some new challenges are summarized, which result from the concurrent engineering approach to vehicle system dynamics software.

2. MULTIBODY SYSTEMS AND VEHICLE SYSTEM DYNAMICS

Essential contributions to multibody dynamics and to the efficient numerical solution of the equations of motion were made during and after the late 1980s—see §3. Nevertheless, as described by two of the authors in a first survey paper in 1985 [4], the MBS approach had already been used successfully in vehicle system dynamics much earlier. All these early approaches were adapted to the restricted computing power in the early 1980s; they were not designed to handle fully nonlinear spatial MBS models with loop-closing constraints that represent today’s state-of-the-art.

A typical representative of these early attempts is the software package MEDYNA developed at DLR [5]. It is based on kinematically linearized equations of motion, a restriction that was motivated by the applica-