

# TAM 674

## Applied Multibody Dynamics

### A How-To Course

Spring Term 2003, Mon & Wed 10:10-11:00, 202 Thurston Hall, 3 credits

instructor:

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## Introduction

In this course we will cover a systematic approach to the generation and solution of equations of motion for mechanical systems consisting of multiple interconnected rigid bodies, the so-called multibody systems. This course differs from “advanced dynamics”, which mostly covers theoretical results about classes of idealized systems (e.g. Hamiltonian systems), in that the goal here is to find the motions of relatively realistic models of systems (including, for example, motors, dissipation and contact constraints).

By the end of the course you will be competent at finding the motions of linked rigid body systems in two and three dimensions including systems with various kinematic constraints (sliding, hinges and rolling, closed kinematic chains). Collisional interactions will be considered in a unified manner for all the different ways of formulating the equations of motion.

There will be weekly homework assignments and a final project. In doing the homework I encourage you to work together and to use computer software like MATLAB, MAPLE, ADAMS, WORKING MODEL etc.

## Course topics

- Newton-Euler equations of motion for a simple planar system, free body diagrams, constraint equations and constraint forces, uniqueness of the solution.
- Systematic approach for a system of interconnected rigid bodies, virtual power method and Lagrangian multipliers.
- Transformation of the equations of motion in terms of generalized independent coordinates, and Lagrange equations.
- Non-holonomic constraints as in rolling without slipping, degrees of freedom and kinematic coordinates.
- Unilateral constraints as in contact problems.
- Numerical integration of the equations of motion, stability and accuracy of the applied methods.
- Numerical integration of a coupled differential and algebraic system of equations (DAE's), Baumgarte stabilisation, projection method and independent coordinates.
- Newton-Euler equations of motion for a rigid three-dimensional body, the need to describe orientation in space, Euler angles, Cardan angles, Euler parameters and Quaternions.
- Equations of motion for flexible multibody systems, introduction to Finite Element Method approach, Linearised equations of motion.

Upon request and if time and ability of the instructor allows, related topics are open for discussion.

## Literature

There are no lecture notes for this course. On the other hand there is a vast amount of literature in the field of Multibody System Dynamics. Most books can be found in the library.

### Dynamics, general

1. H. Goldstein, Classical mechanics, 2nd edition, Addison-Wesley, Reading, 1980.
2. C. Lanczos, The variational principles of mechanics, 4th edition, University of Toronto Press, Toronto, 1970.
3. L.A. Pars, A treatise on analytical dynamics, Heinemann, London, 1965.
4. G. Hamel, Theoretische Mechanik, Springer-Verlag, Berlin, 1949.
5. A. Sommerfeld, Vorlesungen ueber theoretische Physik, Band I: Mechanik, Klemm, Wiesbaden, 1949.
6. E.T. Whittaker, A treatise on the analytical dynamics of particles and rigid bodies, 4th edition, Cambridge University Press, Cambridge, 1937.

### Linear Algebra

1. G. Strang, Linear algebra and its applications, 3rd edition, Harcourt Brace Jovanovich, San Diego, 1988.
2. G. Strang, Introduction to applied mathematics, Wellesley-Cambridge press, Wellesley, 1986.

### Multibody System Dynamics

1. A.A. Shabana, Computational Dynamics, Wiley, New York, 2001.
2. M. Géradin, A. Cardona, Flexible Multibody Dynamics: A Finite Element Approach, Wiley, Chichester, 2001.
3. R. von Schwerin, Multibody System Simulation: Numerical Methods, Algorithms, and Software, Springer-Verlag, 1999.
4. H. Baruh, Analytical Dynamics, McGraw Hill, 1999.
5. A.A. Shabana, Dynamics of multibody systems, Wiley, New York, 1998.
6. F.C. Moon, Applied Dynamics, Wiley, New York, 1998.
7. M. Géradin, D. Rixen, Mechanical Vibrations, Theory and Application to Structural Dynamics, Wiley, New York, 1994
8. R.L. Huston, Multibody dynamics, Butterworth-Heinemann, Stoneham, 1990.
9. W.O. Schiehlen (ed), Multibody systems handbook, Springer-Verlag, Berlin, 1990.
10. E.J. Haug, Computer aided kinematics and dynamics of mechanical systems, Volume I: Basic methods, Allyn and Bacon, Boston, 1989.
11. P.E. Nikravesh, Computer-aided analysis of mechanical systems, Prentice-Hall, Englewood Cliffs, 1988.
12. R.E. Roberson, R. Schwertassek, Dynamics of multibody systems, Springer-Verlag, Berlin, 1986.
13. J. Wittenburg, Dynamics of systems of rigid bodies, Teubner, Stuttgart, 1977.

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