Book of Abstracts

2020 Online symposium on flexible multibody system dynamics

September 21st, 2020

place: Online (Zoom; backup: Jitsi)

Contents

Introduction 1
- Scientific Committee . . . 1
- Local 'Online' Organizing Committee . . . 1
  - Welcome Address . . . 1
  - Symposium information . . . 2
  - Special Issue . . . 2

Abstracts 3
- On computational aspects of electromechanical coupling in geometrically exact beam dynamics . . . 3
- Formulation of line-to-line contact conditions between flexible beams with circular cross-sections . . . 4
- Comparing Flexible Multibody Impact Simulations Based on Isoparametric and Isogeometric Finite Element Models . . . 4
- Geometrically exact treatment of the deformation measures of flexible components . . . 5
- Dynamics of a Flexible Body: a Two-Field Formulation . . . 6
- A standardized parameterization of rigid and flexible bodies in the multibody code DynManto . . . 6
- Simulation of Elastic Body Dynamics with Large Motion Using Transfer Matrix Method . . . 7
- A matrix-based and implementation-friendly variant of the floating frame of reference formulation . . . 8
- A variational integration approach to the full discretization of a geometrically exact Cosserat beam model in Lie groups . . . 8
- Sensorless force control for a manipulator with flexure joints . . . 9
- Multiscale Modeling of Deformable Terrain for Multibody Off-Road Vehicle Mobility Simulation . . . 10
- Flexible multi-body dynamics of Cosserat rods with IGA formulation . . . 10
- Pendulum-Sloshing Dynamics in Quadrotors Slung Liquid Tanks for Firefighting . . . 11
- Flexible multibody dynamics simulation in Python and C++ . . . 12
- Modeling of Spherical Rigid Bodies With Sliding Friction Effects . . . 12

Author Index 15
- Time Table . . . 16

Introduction

Scientific Committee

- Olivier Brüls, University of Liége
- Johannes Gerstmayr, University of Innsbruck
- Aki Mikkola, Lappeenranta University of Technology

Local 'Online' Organizing Committee

- Johannes Gerstmayr, University of Innsbruck
- Michael Pieber, University of Innsbruck

Welcome Address

In this very challenging year 2020, a part of our scientific life has changed. We are jumping from one to another video conference, however, real conferences, symposia and workshops are mostly canceled. We continue reading journal papers, but no broader discussion on published results is facilitated.

In order to bring together experts of the field of *flexible multibody system dynamics*, to strengthen the collaboration, and to exchange research results, the idea has been born in May 2020 to organize an online symposium.

In the short time, we keep the symposium light-weight and simple – no coffee, no tea, no cookies. The number of participants is kept low by organizing a symposium on a very special topic, which allows to use common online communication tools.

In the end, we are grateful that many colleagues were enthusiastic about this idea. Such a symposium may or may not be continued 'after' the coronavirus pandemic. Nevertheless, it could also help to reduce carbon dioxide emissions and save time for scientists which we otherwise spend travelling.

We hope that we will have a successful meeting in September 2020. Up-to-date scientific results will cross-fertilise each other and perhaps even conference-like small talk may pop up during the breaks.

Symposium information

Symposium on flexible multibody system dynamics:

- date: September 21st, 2020
- place: Online Zoom (backup: Jitsi); Zoom meeting ID: 869 661 4593; Zoom meeting password will be sent out per email by Michael Pieber.
- time: using central European time, but we will try to get some compatible time slots for American and Asian participants
- topic: flexible multibody system dynamics
- single-track, no parallel sessions, 20 minutes per talk
- no participation fees, but also no *liability* that everything will fully work out (internet connection, etc.) – we will do our best to make trial sessions and to see that everything works smoothly.
- homepage: `https://www.uibk.ac.at/mechatronik/mekt/online-symposium.html`

Special Issue

Authors of selected presentations will be invited (after the symposium) for paper submission to a Thematic Issue in the Journal Multibody System Dynamics. The submitted papers will be peer-reviewed. A selection of accepted papers will constitute the Thematic Issue while the remaining papers will appear in regular issues of Multibody System Dynamics.

Abstracts

On computational aspects of electromechanical coupling in geometrically exact beam dynamics

Nr.1
21 Sept
09:25

Dengpeng Huang and Sigrid Leyendecker

Chair of Applied Dynamics, Friedrich-Alexander Universität Erlangen-Nürnberg, Germany

In this work, the Cosserat formulation of geometrically exact beam dynamics is extended by adding the electric potential as an additional degree of freedom to account for the electromechanical coupling. A formulation of the electric potential and electric field for the geometrically exact beam model is proposed to generate complex beam deformations actuated by the electrical forces, such as the contraction, shear, bending and torsion. The electromechanically coupled constitutive model for the beam is derived consistently from continuum electromechanics, which leads to the direct application of the material models in the continuum to the beam model. The electromechanically coupled problem in beam dynamics is first semindiscretized by 1D spatial finite elements and then solved via variational time integration. By applying different electrical boundary conditions to the beam, different deformation modes of the beam are obtained in the numerical examples. To investigate the computational accuracy and efficiency of the electromechanical geometrically exact beam model, the magnitude of deformations as well as the computational cost are compared with results of a 3D finite element model. It can be observed that the deformations in the beam model agrees well with that in the finite element model, however, less degrees of freedom and thus less computational effort are required to resolve the complex deformations in the beam model.

Nr.2
21 Sept
09:50

Formulation of line-to-line contact conditions between flexible beams with circular cross-sections

Armin Bosten[1,2], Joachim Linn[2], Vanessa Dörlich[2], Valentin Sonneville[1], Alejandro Cosimo[1,3] and Olivier Brüls[1]

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[2]Fraunhofer Institute for Industrial Mathematics, Kaiserslautern, Germany
[3]Centro de Investigacion de Metodos Computacionales, Universidad Nacional del Litoral, Santa Fe, Argentina

Flexible slender structures like cables have a variety of applications in high-performance engineering systems. The complex mechanical behaviour of such components, resulting from interactions between individual fibers, cannot be captured by means of global constitutive laws. Mesoscopic models see cables as a collection of fibers, modeled as 1D Cosserat beams, experiencing frictional contact. Beams are described through a space curve augmented by a frame attached to each cross section. The mechanical behaviour of a beam is the result of frame transformations belonging to the Lie group of rigid body motions SE(3). The use of suitable Lie group solvers combined with a discretization consistent with the Lie group framework results in numerical methods with interesting properties. In this contribution the modeling of cables made of elastic fibers with circular cross sections undergoing frictionless contact interactions is addressed. A continuous formulation as Cosserat beams with mortar contact conditions modeled as unilateral constraints is established in SE(3). Constraints are enforced by means of Lagrangian multipliers. Equilibrium equations written in the local frame emerge as a consequence of the left invariant representation of derivatives in the Lie group. They are solved using a semi-smooth Newton method. The spatial discretization is performed using helicoidal shape functions resulting from the geodesic interpolation of elements in SE(3). At the symposium an outline of the problem with its scientific challenges, first numerical results, as well as an outlook on future work will be presented.

Nr.3
21 Sept
10:15

Comparing Flexible Multibody Impact Simulations Based on Isoparametric and Isogeometric Finite Element Models

Tobias Rückwald, Alexander Held, Robert Seifried

Institute of Mechanics and Ocean Engineering, Hamburg University of Technology (TUHH), Eißendorfer Straße 42, room 0516, 21073 Hamburg, Germany

In this talk an efficient and detailed simulation of an impact problem in flexible multibody systems is presented. Thereby the floating frame of reference is used. Usually, impact simulations with flexible bodies are modeled with the finite element analysis (FEA) using isoparametric elements. A precise representation of the geometry is essential for modeling the dynamics of the impact. Since isoparametric finite elements involve the discretization of the geometry, errors occur.

An alternative approach is the isogeometric analysis (IGA). Although the flexible body is still meshed with elements, the exact geometry is preserved. This is achieved by using non-uniform rational B-splines (NURBS). The degrees of freedom of the flexible body are then reduced to save computational time in simulation. To capture precise deformations and stresses in the area of contact, a large number of eigenmodes is required. Therefore, a combination of eigenmodes and static shape functions are used to describe the flexible body. The eigenmodes represent the global deformations and the high eigenfrequencies of the static shape functions capture the effects in the area of contact. Using the IGA is advantageous, since the IGA represents higher modes more accurate than isoparametric FEA.

In this talk, the impact of a tire like structure on a rigid surface is modeled as first testing example. The tire is represented by a hollow cylinder. A penalty method is used to model the frictionless normal contact. As a reference, the tire is modeled with the isoparametric FEA. This method is then compared with the IGA in terms of accuracy and computation time. The standard input data (SID) of the isogeometric model is determined and used in the simulation with the floating frame of reference formulation.

Geometrically exact treatment of the deformation measures of flexible components

Nr.4
21 Sept
11:00

Valentin Sonneville and Olivier Brüls

Department of Aerospace and Mechanical Engineering, University of Liège, Belgium

The comprehensive simulation of flexible multibody systems calls for the ability to model various types of flexible components including concentrated stiffness in kinematic joints, beams, shells, and modal elements. The treatment of these components resorts typically to kinematic assumptions that can be implemented conveniently using moving frames as unknown variables of the governing equations. Such frames are designed to access consistent local deformation measures that can be related to stress measures via constitutive equations. In particular, the objectivity principle must be satisfied, namely the material behavior expressed by the constitutive equations must be independent of the observer that measures the deformations. Because frames belong to the special Euclidean group SE(3), it is convenient to manipulate them in the framework of Lie groups, which provide rigorous mathematical tools to address typical operations such as differentiation/integration, representation/parametrization, and interpolation. In this work we show how the use of basic Lie group concepts leads to a simple yet powerful and consistent treatment of deformation measures which translates into numerical methods featuring improved accuracy and reduced computational burden as compared to traditional approaches.

Nr.5
21 Sept
11:25

Dynamics of a Flexible Body: a Two-Field Formulation

Michel Géradin

Emeritus Professor, University of Liège, Belgium
TUM-IAS Hans Fischer Senior Fellow
Lichtenbergstrasse 2a, D-85748 Garching, Germany

When developing the equations governing the nonlinear dynamics of an elastic body, rigid body motion and elastic deformation can be treated as uncoupled provided that the body CM and principal axes are taken as reference and that the relative deformation field is orthogonal to rigid body modes. The choice (referred to as Tisserand axes) results from the hypothesis that relative kinetic energy due to elastic deformation remains minimum.

The Tisserand formulation is however difficult to implement exactly because of the nonlinear orthogonality conditions on angular rotation. Moreover, even when assuming linearized orthogonality conditions, the kinetic energy expression still involves a deformation dependent tensor of inertia, an effect generally neglected.

The formulation is thus revised as follows:

- A new definition of elastic velocity including the convection velocity due to elastic deformation is adopted.
- The choice of the instantaneous reference axes for the deformed configuration is still made in order to get decoupling of kinetic energy between rigid body motion and elastic deformation, but the orthogonality conditions between rigid body and elastic motions become now linear.
- Displacements and velocities are treated as independent fields, leading thus to a mixed formulation which significant simplifies system dynamics formulation and numerical solution.

Its efficiency in the context of substructuring will be demonstrated in the presentation.

Nr.6
21 Sept
11:50

A standardized parameterization of rigid and flexible bodies in the multibody code DynManto

Alexander Held

Institute of Mechanics and Ocean Engineering, Hamburg University of Technology (TUHH), Eißendorfer Straße 42, room 0516, 21073 Hamburg, Germany

The structural optimization of rigid and flexible multibody systems becomes more and more popular. This is on the one hand due to the adoption of powerful methods from static structural optimization and on the other hand due to the ability to efficiently provide gradients using the semi-analytical adjoint variables method. In order to further improve the optimization process, this work addresses the parameterization of rigid and flexible bodies in the academic multibody simulation program DynManto.

The basic idea is to rely on standard input data files to completely describe both rigid and flexible bodies and augment these files by sensitivity information. In this way a clear separation can be achieved in the optimization process between the body modeling and parameterization on the one side, and the system simulation and sensitivity analysis on the other side.

In this talk the augmented class definitions to define the sensitivity enhanced standard input data are presented and the simplified optimization process is demonstrated using the example of a structural optimization of Chebyshev's lambda mechanism.

Simulation of Elastic Body Dynamics with Large Motion Using Transfer Matrix Method

Nr.7
21 Sept
13:00

Qinbo Zhou[12], Jörg Fehr[1], Dieter Bestle[3] and Xiaoting Rui[2]

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[2]School of Energy and Power Engineering, Nanjing University of Science and Technology, Xiaolingwei 200, 210094 Nanjing, PR China

[3]Engineering Mechanics and Vehicle Dynamics, Brandenburg University of Technology Cottbus, Cottbus 03046, Germany

Efficient formalism is one of the central research topics in multibody system dynamics. The transfer matrix method for multibody systems (MSTMM) is one of those formalisms since it is an order-N strategy, which always keeps order of involved matrices low independently from system degree of freedom (DOF), resulting in fast computational speed. MSTMM has been widely used both in scientific research and practical engineering and is especially suited for real-time applications or use in embedded systems. Generally, the effectiveness of MSTMM is based on two properties: it is possible to (i) set up a library of transfer matrices as building blocks covering various mechanical elements including bodies and hinges; (ii) easily assemble these element transfer equations up to the overall system transfer equation for various system topologies. Up to the present, the later issue has been basically resolved while the former still remains to be extended. Notably, the transfer equation for general three-dimensional elastic bodies with large overall motion does not exist yet in the context of MSTMM. This work aims to bridge the gap by developing the transfer equation of a single elastic body described in the floating frame of reference formulation (FFRF). An articulated manipulator arm robot serves as a demonstrating example throughout the presentation. First, the robot is treated as a rigid multibody system to briefly illustrate the concepts, formalism, and solution procedure of MSTMM. Then, a classical FFRF of flexible body dynamics is shortly explained. Next, the favorable ideas from FFRF are transferred into the MSTMM formulation yielding the transfer equation of an elastic body. These ideas include: (i) splitting the overall motion into a large rigid body motion, and a small elastic deformation, (ii) discretization of the deformation field by using the linear finite element method, (iii) use of a general shape by calculating the standard input data, and (iv) model order reduction (MOR) applied to the linear elastic dynamics part to find the most suitable shape functions. Finally, the robot is considered as a coupled rigid-flexible multibody system. Numerical simulation results obtained with the proposed concept show good agreement with that by a classical Newton-Euler formulation, where results are robust w.r.t different MOR methods.

Nr.8
21 Sept
13:25

A matrix-based and implementation-friendly variant of the floating frame of reference formulation

Andreas Zwölfer[1] and Johannes Gerstmayr[2]

[1]Technical University of Munich, Department of Mechanical Engineering, Chair of Applied Mechanics, Boltzmannstraße 15, 85748 Garching bei München, Germany
[2]University of Innsbruck, Faculty of Engineering Sciences, Department of Mechatronics, Technikerstraße 13, 6020 Innsbruck, Austria

Flexible multibody dynamics systems based on 3D continuum finite elements are important for industrial research but usually require time consuming implementations in research codes. The conventional continuum-mechanics-based floating frame of reference formulation (FFRF) is usually employed for these applications. However, the conventional approach either involves the computation of unhandy inertia shape integrals or is restricted to a lumped mass approximation in order to calculate the so-called FFRF invariants, which are constant ingredients required to set up the equations of motion. This presentation shows the drawbacks of the conventional continuum mechanics FFRF and presents a novel formulation and framework, which are based on discretized (nodal) displacements. In this way, no inertia shape integrals are required, and no lumped mass approximation needs to be performed. The presentation further exploits some examples to show the easiness of the formulation and associated computer implementation.

Nr.9
21 Sept
13:50

A variational integration approach to the full discretization of a geometrically exact Cosserat beam model in Lie groups

Stefan Hante, Denise Tumiotto and Martin Arnold

Institute of Mathematics, Martin Luther University Halle-Wittenberg, 06099 Halle (Saale), Germany

In this paper we will consider a geometrically exact Cosserat beam model taking industrial challenges into account. The beam model is based on [1] and the framed curve is parametrized in the configuration space $\mathbb{S}^3 \ltimes \mathbb{R}^3$ with semidirect product Lie group structure, see [2]. Unit quaternions $\mathbb{S}^3$ are used to represent orientation and velocities as well as angular velocities are measured with respect to the body-fixed frame.

The Cosserat beam will be constrained to an extensible Kirchhoff beam model, where the rigid cross sections have to remain perpendicular to the center line. We apply the approach of variational integrators [3], which has already been used on unconstrained beam models and beam models with different configuration space, see

e.g. [4]. To do so, we consider the potential and kinetic energies of the continuous beam and construct an augmented Lagrangian, taking the Kirchhoff constraints into account. Then, we apply Hamilton's principle and subsequently discretize the space of admissible functions leading to the fully discretized equations of motion after approximating some of the integrals. Here, it is notable that we allow the Lagrange multipliers to be discontinuous in time in order to respect the derivatives of the constraint equations, also known as hidden constraints.

In the last part, we will test our numerical scheme on a benchmark problem and analyze how the amount of grid points in arc-length and time influences the errors and computing time.

[1] Lang, Linn, Arnold. Multibody Syst. Dyn. 25.3 (2011): 285-312.

[2] Hante, Arnold. PAMM 17.1 (2017): 151-152.

[3] Marsden, West. Acta Numer. 10.1 (2001): 357-514.

[4] Demoures, Gay-Balmaz, Leyendecker, Ober-Blöbaum, Ratiu, Weinand. Numer. Math. 130.1 (2015): 73-123.

Sensorless force control for a manipulator with flexure joints

Nr.10
21 Sept
14:15

Ronald G.K.M. Aarts

University of Twente, Applied Mechanics & Data Analysis, 7500 Enschede, Netherlands

Sensorless force control aims at controlling the force or torque applied by a manipulator on its environment without the need of including a dedicated force or torque sensor. To enable this control concept the dynamic relation between drives and interaction with the environment needs to be established accurately. From that perspective manipulators with flexure joints may offer advantages. In these manipulators the relative rotation of links is enabled by elastic deformations of flexible elements in the joints which results in reproducible behaviour due to the low amount of friction and hysteresis.

In this paper the development of such force control is addressed. It depends heavily on a simulation that evaluates the non-linear dynamic behaviour of the manipulator to estimate the end-effector forces from the actuator torques in real-time. Main ingredients of the model are the finite compliance of the flexure joints and the mass properties of the rigid links. Next to setting up the model structure the involved mass and stiffness parameters need to be determined from experimental identification of the system.

The concept is demonstrated for a manipulator with two degrees of freedom. For a limited range of motion the compliance can be described by a (constant) stiffness matrix. For larger displacements non-linear behaviour is observed which can be modelled with polynomial fits of the actuator torques as functions of the displacement. It is assumed that the mass properties can be captured with a (constant) mass matrix and velocity dependent inertia terms. Currently, the control concept has mainly been evaluated in simulations, but it is expected that preliminary experimental data can be presented during the online symposium.

Nr.11
21 Sept
15:00

Multiscale Modeling of Deformable Terrain for Multibody Off-Road Vehicle Simulation

Hiroyuki Sugiyama[1], Hiroki Yamashita[1], Guanchu Chen[1], Yeefeng Ruan[2] and Paramsothy Jayakumar[1]

[1]University of Iowa, Iowa City, Iowa, U.S.
[2]U.S. Army CCDC GVSC, U.S.

This talk presents a high-fidelity hierarchical multiscale off-road mobility simulation capability to address limitations of existing computational deformable terrain models, including phenomenological constitutive assumptions in finite element (FE) models as well as high computational intensity in discrete element (DE) models. In the multiscale deformable terrain model, soil deformation is modeled as a continuum with FE meshes, while phenomenological constitutive assumptions in FE models are eliminated by introducing the grain-scale DE representative volume element to predict stress responses of granular soil materials. Such a scale separation facilitates cross-scale understanding of granular terrain behavior for vehicle-terrain interaction problems, for which small size particles can be used for RVEs to accurately describe grain-scale soil material behavior without increasing the computational cost. For full-scale off-road vehicle simulations, on the other hand, computational complexities associated with the large dimensionality of multibody vehicle equations, involving rigid vehicle components, nonlinear FE tires and multiscale terrain models, need to be addressed. Therefore, a scalable parallel computing scheme for the multiscale off-road mobility model is developed and used for the full-scale vehicle validation conducted against test data.

Nr.12
21 Sept
15:25

Flexible multi-body dynamics of Cosserat rods with IGA formulation

Alessandro Tasora, Simone Benatti and Dario Mangoni

Department of Engineering and Architecture, University of Parma, Italy

The Cosserat rod theory is at the basis of formulations for geometrically exact beams. On the ground of this approach, beams can be subject to arbitrarily large displacements and rotations, and very generic constitutive relations can be introduced to compute a sectional six-dimensional wrench from information of shear, extension, curvature and torsion of the centerline. We develop a Cosserat rod model based on the Isogeometric Analysis (IGA) theory, where spans of B-Spline NURBS are used as finite elements; in our formulation quaternions are used as rotational coordinates. The IGA approach leads to some benefits, for example high continuity between elements and ease of conversion from CAD systems. We implemented the model in the ProjectChrono open-source multibody simulation software and we developed a

system that allows a modular definition of complex sections, including cases with eccentric mass, non-uniform elasticity, structural damping and plasticity. Moreover, beams can have initial curvature and variable section. The aforementioned features make the model suitable for simulating aeroelastic problems like rotor blades in helicopters and wind turbines. We provide benchmarks where the IGA Cosserat rod model is used in conjunction with constraints, rigid bodies, user-defined loads and motors, and we compare it with other models.

Pendulum-Sloshing Dynamics in Quadrotors Slung Liquid Tanks for Firefighting

Nr.13
21 Sept
15:50

Kuo Zhu[1], Jie Huang[1], Sergey Gnezdilov[2]

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[2]Department of Lifting - Transport Systems, Bauman Moscow State Technical University, Moscow, 105005, Russia.

Water tanks suspended below quadrotors may be used for fire-fighting services. Unfortunately, both cable-suspended tank and liquid sloshing are flexible multibody systems. Undoubtedly, motions of the aerial vehicle cause unwanted cable pendulum and liquid sloshing, which degrade effectiveness and safety of the flight operation. The pendulum-sloshing dynamics in a quadrotor moving a liquid tank exhibit complex coupling behavior among quadrotor's attitude, load swing, and liquid sloshing. However, little attention has been focused on the coupled pendulum-sloshing dynamics in this type of aerial cranes. A novel nonlinear model of a quadrotor moving a liquid tank having pendulum-sloshing dynamics is given. The pendulum model derived by Kane's equation includes load swing and slope, and interaction with fluid forces. Meanwhile, the sloshing model including infinite vibrational modes and interaction with cable swing is developed by the Euler's fluid dynamics equation. Resulting from the model, the dynamic analyses are also developed. Then a novel control method is proposed to control oscillations of pendulum-sloshing dynamics. Numerous simulations performed on the nonlinear model demonstrate that the method can suppress the undesirable oscillations of quadrotor's attitude, load swing, and liquid sloshing simultaneously. The theoretical findings may also extend to helicopters or tiltrotors slung liquid containers.

Nr.14
21 Sept
16:15

Flexible multibody dynamics simulation in Python and C++

Johannes Gerstmayr

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The computational approach to flexible multibody systems is often based on redundant coordinates, index 3 constraints, treatment of larger number of unknowns by sparse matrix methods, introduction of specific joint and contact formulations, and model order reduction. Due to the complexity of the sum of these methods, research projects are often solved with small, customized in-house codes, which only partly meet the above mentioned criteria and therefore are not helpful for other projects. Furthermore, many formulations for flexible multibody systems are published, but the reproduction is time consuming and often impossible without having these original in-house codes. Open source codes can help to boost the community's achievements, in providing a framework for easier development of new computational methods. Therefore, the open source research code EXUDYN has been developed, which is based on C++ (C++14) and Python (versions 3.6 and 3.7). The code is intended as a follow-up of the previously developed code HOTINT, which is now outdated regarding computational methods, coding standards, code redundancy, and maintainability. Besides efficient implementation of core equations, being prepared for parallelization and automatic differentiation, EXUDYN offers the simple extension by Python user functions that allow easy extension and application for research. Automatized up-to-date documentation and a larger test suite improve maintainability. In the presentation, the setup of simple multibody models will be shown. Advanced flexible multibody dynamics examples including highly flexible bodies, model order reduction, user elements and time integration shall demonstrate the potential of this approach.

Nr.15
21 Sept
16:40

Modeling of Spherical Rigid Bodies With Sliding Friction Effects

F.J. Cavalieri[1], E. Sanchez[1], A. Cosimo[2], O. Brüls[2] and A. Cardona[1]

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This work investigates the dynamics of spherical rigid bodies under the effects of sliding friction. The equations of motion are integrated using a nonsmooth generalized-α time integration scheme valid for flexible and rigid bodies. Then, the frictional contact problem is formulated using a mixed dual approach based on an augmented Lagrangian technique and a Coulomb friction law. The spherical rigid element presented in this work could be used in more general applications as in ball bearing joints, which can be modeled by a flexible cage and rigid balls. The robustness and the performance of the proposed algorithm are shown by solving the motion of two spheres in contact with a rigid plane and where their mutual impact is also considered. Additionally, the contact between two spheres linked with a flexible spring is presented to show the applicability of this methodology to mechanisms composed by flexible and rigid elements.

Author Index

Aarts Ronald G.K.M., 10
Arnold Martin, 9

Benatti Simone, 11
Bestle Dieter, 8
Bosten Armin, 4
Brüls Olivier, 4, 5, 13

Cardona Alberto, 13
Cavalieri Federico J., 13
Chen Guanchu, 10
Cosimo Alejandro, 4, 13

Dörlich Vanessa, 4

Fehr Jörg, 8

Géradin Michel, 6
Gerstmayr Johannes, 8, 12
Gnezdilov Sergey, 11

Hante Stefan, 9
Held Alexander, 5, 7
Huang Dengpeng, 3
Huang Jie, 11

Jayakumar Paramsothy, 10

Leyendecker Sigrid, 3
Linn Joachim, 4

Mangoni Dario, 11

Ruan Yeefeng, 10
Rui Xiaoting, 8
Rückwald Tobias, 5

Sanchez E., 13
Seifried Robert, 5
Sonneville Valentin, 4, 5
Sugiyama Hiroyuki, 10

Tasora Alessandro, 11
Tumiotto Denise, 9

Yamashita Hiroki, 10

Zhou Qinbo, 8
Zhu Kuo, 11
Zwölfer Andreas, 8

Time Table

Nr.	Date	CEST	Name	Title
1	21 Sept	09:25	Dengpeng Huang and Sigrid Leyendecker	On computational aspects of electromechanical coupling in geometrically exact beam dynamics
2	21 Sept	09:50	Armin Bosten, Joachim Linn, Vanessa Dörlich, Valentin Sonneville, Alejandro Cosimo and Olivier Brüls	Formulation of line-to-line contact conditions between flexible beams with circular cross-sections
3	21 Sept	10:15	Tobias Rückwald, Alexander Held, Robert Seifried	Comparing Flexible Multibody Impact Simulations Based on Isoparametric and Isogeometric Finite Element Models
4	21 Sept	11:00	Valentin Sonneville and Olivier Brüls	Geometrically exact treatment of the deformation measures of flexible components
5	21 Sept	11:25	Michel Géradin	Dynamics of a Flexible Body: a Two-Field Formulation
6	21 Sept	11:50	Alexander Held	A standardized parameterization of rigid and flexible bodies in the multibody code DynManto
7	21 Sept	13:00	Qinbo Zhou, Jörg Fehr, Dieter Bestle and Xiaoting Rui	Simulation of Elastic Body Dynamics with Large Motion Using Transfer Matrix Method
8	21 Sept	13:25	Andreas Zwölfer and Johannes Gerstmayr	A matrix-based and implementation-friendly variant of the floating frame of reference formulation
9	21 Sept	13:50	Stefan Hante, Denise Tumiotto and Martin Arnold	A variational integration approach to the full discretization of a geometrically exact Cosserat beam model in Lie groups
10	21 Sept	14:15	Ronald G.K.M. Aarts	Sensorless force control for a manipulator with flexure joints
11	21 Sept	15:00	Hiroyuki Sugiyama, Hiroki Yamashita, Guanchu Chen, Yeefeng Ruan and Paramsothy Jayakumar	Multiscale Modeling of Deformable Terrain for Multibody Off-Road Vehicle Mobility Simulation
12	21 Sept	15:25	Alessandro Tasora, Simone Benatti and Dario Mangoni	Flexible multi-body dynamics of Cosserat rods with IGA formulation
13	21 Sept	15:50	Kuo Zhu, Jie Huang, Sergey Gnezdilov	Pendulum-Sloshing Dynamics in Quadrotors Slung Liquid Tanks for Firefighting
14	21 Sept	16:15	Johannes Gerstmayr	Flexible multibody dynamics simulation in Python and C++
15	21 Sept	16:40	F.J. Cavalieri, E. Sanchez, A. Cosimo, O. Brüls and A. Cardona	Modeling of Spherical Rigid Bodies With Sliding Friction Effects