MATEMATIČKI INSTITUT SANU , ODELJENJE ZA MEHANIKU
Mathematical Institute SANU, Belgrade, Department for Mechanics

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Program of Mechanics Colloquium – DECEMBER 2011

Start of each lecture is at each Wednesday at 18,00 h in room 301 F at Mathematical Institute SANU, street Knez Mihailova 36/III.

Sreda (Wednesday), 7 decembar (December 7) 2011 u 18 sati (18h) **Lecture No. 1173**

Prof. dr Aleksandar Obradovic, Department of Mechanics, Faculty of Mechanical Engineering, University of Belgrade

Brachistochronic motion with limited reaction of constraint

The paper considers brachistochronic motion of a particle along a curve y=y(x) in an arbitrary force field in the vertical plane of Cartesian coordinate system. The curve is treated as a bilateral or unilateral constraint that can be smooth or rough. The projection of the reaction force of the curve onto the normal to the curve is confined to the fixed limits. A control variable u is given as the second derivative of the function y(x) relative to the horizontal coordinate x of the particle, i.e., $u = d^2y/dx^2$. Applying Pontryagin's maximum principle and singular optimal control theory, the problem is reduced to numerical solving of the corresponding two-point boundary value problem. The procedure based on the shooting method is used to solve the boundary value problem. Two examples with friction forces of the viscous friction and Coulomb friction type have been solved. Considers the application of this procedure on brachistochronic motion of rigid bodies with Chaplygin's blade, which constraint reaction is limited.

Sreda (Wednesday), 14 decembar (December 14) 2011 u 18 sati (18h) **Lecture No. 1174**

Prof. dr Sreten B. Stojanovic, University of Nis, Faculty of Technology, Leskovac, Serbia

DELAY-DEPENDENT STABILITY AND ROBUST STABILITY ANALYSIS FOR DISCRETE –TIME SYSTEMS WITH TIME VARYING STATE DELAY

The existing stability conditions for time-delay systems can be classified into two types, that is, delay-independent stability conditions and delay-dependent stability conditions. The former do not include any information about the magnitude of the delay, while the latter do employ such information. It is well known that delay-dependent stability conditions are generally less conservative than delay-independent ones, especially when the magnitude of the delay is small. Recently, increasing attention has been devoted to the problem of delay-dependent stability of linear discrete systems with time-varying delay. The key point for deriving the delay-dependent stability criterions is the choice of an appropriate Lyapunov–Krasovskii (L-K) functional. It is known that the general form of this functional leads to a complicated system of equations, yielding high-dimensional linear matrix inequalities (LMIs). That is why many authors have considered special forms of L-K functional and thus have derived simpler, but more conservative, sufficient conditions which can be represented by an appropriate set of linear matrix inequalities (LMIs).

This article presents new delay-dependent stability criteria for time-varying delay discrete systems using a special form of L-K functional and novel techniques to achieve the delay dependence. Stability conditions have been derived in terms of LMIs. By decomposing the delay interval into two no equidistant subintervals by tuning parameter α, choosing different Lyapunov matrices in the decomposed intervals and estimating the upper bound of some cross terms more exactly, a new delay-dependent stability and robust stability criteria are established. The numerical examples show that the obtained result is less conservative than some existing ones in the literature. Moreover, some sufficient delay-dependent stability conditions are derived using an appropriate model transformation of the original system. The derived criteria are dependent on the minimum and maximum delay bounds. It is shown that the stability criteria are approximately the same conservative as the existing ones, but have much simpler mathematical form.

Sreda (Wednesday), 21 decembar (December 21) 2011 u 18 sati (18h) **Lecture No. 1175**

Prof. dr Dragan Milosavljevic, Faculty of Mechanical Engineering, University of Kragujevac

Dynamical behavior of composite plates and laminates

Composite materials consist of at least two constituents one of which is matrix and another fibre usually lay up through layers mutually bonded to make multilayered composite in the forms of laminates. Fibres carry loads giving strength and matrix bonds fibres together play important role in load transfer to fibres and forms outer shape of composite.

If material is reinforced with one family of fibres it has one privileged direction making material locally transversally isotropic in relation to that direction. Fibre direction may be defined as unit vector field $\boldsymbol{a}$ which may vary from point to point. Trajectories of unit vectors $\boldsymbol{a}$ are defined as fibres in relation to which material is locally transversally isotropic. Since fibre direction depends on position here we consider coordinate free formulation of constitutive equations. For given deformation strain energy function depends on both strain $\boldsymbol{\varepsilon}$ and fibre direction $\boldsymbol{a}$. Here is given list of matrix products whose traces make proper orthogonal group basis leading to set of invariants which may be used to form general quadratic form of strain energy function. This may be used to form stress strain relations leading to elasticity tensor for material reinforced by one family of fibres.

Here is also, following Spencer, developed constitutive relation of linear elastic material reinforced by two families of fibres defined by fibre directions say $\boldsymbol{a}$ and $\boldsymbol{b}$. Similarly, as in the case of reinforcement by one family of fibres, strain energy function depends on $\boldsymbol{\varepsilon}$, $\boldsymbol{a}$ and $\boldsymbol{b}$. List of matrix product whose traces form base for proper orthogonal group will be defined. Strain energy function in the most general quadratic form of $\boldsymbol{\varepsilon}$ will be defined, leading to constitutive equation. Elasticity tensor, in that case, has 13 elastic constants which describe material with one plane of symmetry, which is locally tangential to plane containing both families if fibres.

Plates and laminates made of above described materials show some interesting dynamic properties in propagation of elastic waves, which are dispersive. Some results of dynamic behavior when material has strong anisotropy will be displayed.

Lecture by Teaching Assistant dr med. Andjelka Hedrih, is canceled and translated in next period.

Teaching Assistant dr med. Andjelka Hedrih, Department for biomedical science, State University of Novi Pazar, Novi Pazar, Serbia

Modeling oscillations of a zona pelucida before and after fertilization - ENOC Yang Scientist Prize 2011–EuroMech Society

Zona pellucida (ZP), acellular mantel of mammalian oocite, changes its thickness and elastic properties before and after fertilization. To describe changes in mechanical properties of *ZP*, we use the method of discreet continuum and model *ZP* as a discreet spherical net with non-linear elastic and visco-elastic connections. Elements in this discreet spherical net correspond to *ZP* proteins. Oscillatory spherical net Model of mouse *ZP* could explain its' non-linear oscillatory behaviour. A mathematical model of non-linear free and forced vibrations is presented. Before fertilisation discreet ZP net consists of elements that have ideally non-linear-elastic properties and ZP net has ideally non-linear-elastic properties. After fertilisation this model is modified in the following way: material particles (ZP proteins) are interconnected with standard light hereditary elements with visco-non-linear-elastic properties.

Ideally non-linear-elastic spherical ZP net that envelops a non-fertilised oocite has oscillatory properties. It oscillates as a system with 3n degrees of freedom and with 3n eigen circular frequencies. On a distortion caused by spermatozoa, material particles, in general case, each oscillates in a 3n-frequency regime. Mechanical impact of spermatozoa causes distortion of equilibrium state of the ZP elastic network and it starts to oscillate. It can be considered that spermatozoa transfer a part of its kinetic energy to the ZP network that is used for changing its initial state.

To describe oscilatory behaviour of ZP under free and force regime we made three independent sets of coupled non-linear differential equations. First set of the non-linear differential equations contains n independent non-linear differential equations of Georg Duffing type. For solving three independent subsystems of non-linear differential equations we use two methods, Lagranges method of variation constants as well as asymptotic method of Krilov Bogolyubov-Mitropolyskiy for obtaining system of the first approximation for corresponding number of amplitudes and phases.

Material particles in the net move in three orthogonal directions and in each of directions are multifrequency vibrations asynchronous, and resultant of nonlinear dynamics are space trajectory in the form of the generalized Lissajus curves.

Model could explain oscillations of the ZP network in the fertilization process- diameter and consistency change. It is possible that in *ZP* before fertilization appears different type of multifrequency regime of oscillations: from pure periodic to pure chaotic-like regimes. Synchronized regimes of the knot's mass particle motion in the sphere *ZP* net are favorable kinetic states for possible successful penetration of spermatozoid trough *ZP* and fertilization. Chaotic-like motion of *ZP* glycoproteins is an unfavorable kinetic state for spermatozoids penetration of *ZP*.

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Sreda (Wednesday), 28 decembar (December 28) 2011 u 18 sati (18h) **Lecture No. 1176**

Miloš Živanović, PhD student, Faculty of Mechanical Engineering, The University of Belgrade

From decomposition principle to practical stability of mechanical system motion

The decomposition principle, introduced by Evgeniy Serafimovich Pyatnitskiy (1936-2003), is a powerful two-hierarchical control algorithm for control of mechanical systems. It is robust to external disturbances, the change of geometrical and inertial characteristics of the mechanical system, as well as change of the control task for the mechanical system, which makes it a universal control algorithm. The fact that the mathematical model of the mechanical system is not used to determine the control significantly increases applicability of the control algorithm. The decomposition principle involves bringing the mechanical system to the decomposition mode, which is essentially a sliding mode, in which the interactions of the components of the system and action of the external disturbances are completely compensated and do not affect the mechanical system motion in the decomposition mode. Another advantage of the decomposition mode is that motions of the mechanical system in the decomposition mode can be assigned. Establishing the decomposition mode is achieved by the action of discontinuous control force, which is the only drawback of this control algorithm in terms of practical application.

The objective of the mechanical system control is that the mechanical system performs the given task. In order to do that, it must realize the motions by which the task is performed. The set of all such motions is the set of desired motions, so that the objective of the control boils down to realizing a desired motion. Ignorance of the precise mathematical model of the system or not knowing any parameters of the mathematical model at all give no possibility to determine the set of all desired motions. Yet, to be able to prove that the mechanical system can perform the given task, a set of desired motions must be determined in some way. In such the set, a desired motion, for which is considered that the mechanical system will perform the task in best way, is chosen. This motion is called the nominal motion. In practice, the mechanical system cannot realize the nominal motion, but can with certain accuracy. By defining an accuracy of the nominal motion realization, a set of close motions, that is, a set of motions close to the nominal motion is defined. It is clear that the accuracy should be defined such that the set of close motions is a subset of the set of desired motions. If there are a set of initial states of the mechanical system and a continuous bounded control force that ensure that the mechanical system, under the action of the control force and continuous bounded disturbance force, realizes a close motion from any initial state belonging to the set, it is said that the mechanical system nominal motion is practically stable.

In this lecture, how the idea of the decomposition principle may be used to prove the practical stability of the mechanical system nominal motion is presented.

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Предавања ће се одржавати средом са почетком у 18.00 часова, у сали 301 F на трећем спрату зграде Математичког института САНУ, Кнез Михаилова 36/III, (зграда преко пута главне зграде САНУ).

Позив научницима и истраживачима да пријаве сцоја предавања
Пријава потенцијалног предавача треба да садржи апстракт предавања до једне странице на српском језику ћирилицом и превод на енглески jesик, као и CV обима до две странице. Пријаву послати на адресу управника Одељења за механику у виду Word DOC на адресу: khedrih@eunet.rs

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Announcement and Invitation

Start of each lecture is at each Wednesday at 18,00 h in room 301 F at Mathematical Institute SANU, street Knez Mihailova 36/III.

All scientists and researchers in area of Mechanics are invited to contribute to the Program of Mechanics Colloquium of Mathematical Institute of Serbian Academy of Sciences and Arts. One page Abstract of proposed Lecture with short CV is necessary to submit in world doc to Head of Department of Mechanics (address: khedrih@eunet.rs), one month before first day in the next moth.

Катица (Стевановић) Хедрих

Katica R. (Stevanovic) Hedrih
Head of Department of Mechanics