MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

T a g u n g s b e r i c h t 42/1991

Nonlinear and Random Vibrations

22.9. bis 28.9.1991

Die Tagung fand unter der Leitung der Herren L. Arnold, Bremen, W. Schiehlen, Stuttgart, und W. Wedig, Karsruhe, statt. Von den 35 Teilnehmern kamen 12 aus Deutschland, die übrigen aus Australien, England, Frankreich, Italien, Kanada, den Niederlanden, Österreich, Polen, der Schweiz, den USA, der UdSSR und aus Vietnam. Wegen dieser starken internationalen Beteiligung wurden alle Tagungsvorträge in englischer Sprache gehalten.

Mit dem Thema "Nonlinear and Random Vibrations" wurden Vertreter der Mathematik und der Mechanik angesprochen. Von besonderem Interesse waren dabei die nichtlinearen deterministischen Schwingungen und die stochastischen, häufig auch nichtlinearen Systeme. Einen wichtigen Aspekt bildeten die Verzweigungen, welche in der Deterministik und der Stochastik nichtlinearer Systeme auftreten. Dabei hat sich eine starke Verwandtschaft der mathematischen Methoden gezeigt. So werden z.B. Lyapunov-Exponenten sowohl zur Charakterisierung chaotischer Bewegungen als auch zur Stabilitätsuntersuchung stochastischer Systeme herangezogen.

Die einzelnen Vorträge können den folgenden Problemgruppen zugeordnet werden:

Normalformen nichtlinearer Systeme,
Nichtlineare Schwingungen von Balken und Platten,
Verallgemeinerte Zellabbildung,
Chaotische Bewegungen mit zufälligen Parametern,
Statistische Linearisierung komplexer Systeme,
Verzweigungen in nichtlinearen und stochastischen Systemen,
Stabilisierung mit Zufallsschwingungen,
Numerische Methoden für stochastische Systeme,
Regelung von dynamischen Systemen,
Stabilität durchströmter Rohre,
Beiträge zu Couette-Taylor-Strömungen,
Zuverlässigkeit von Strukturen,
Dynamik periodischer Strukturen.

An jeden Vortrag schloß sich eine lebhafte Diskussion an. Alle Teilnehmer, die Mathematiker und die Ingenieure, schätzten diese einzigartige Gelegenheit zu einem intensiven Gedankenaustausch über Theorie und Anwendung außerordentlich hoch ein.

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Y.K. Lin

Disordered Periodic Structure

An ideal periodic structure is composed of identical units which are connected end-to-end to form a spatially periodic array. However, such an ideal periodic structure does not exist in reality, due to material, geometrical and manufacturing variabilities. The departure from exact periodicity is known as disorder which has significant effects on its dynamical behavior. In this presentation, two effects of disorder are discussed. One is the attenuation of wave propagation even if the frequency is within a so-called wave-passage frequency band and the structure is undamped. This effect is characterized by a localization factor which is the average exponential decaying rate per cell-unit, or negative Lyapunov exponent in space. Another effect is possible higher structural response near where an excitation is applied.

It is shown that the localization factor depends on the level of disorder, cell-to-cell coupling parameter, and the position of frequency in a wave-passage frequency band. The number of cells in a disordered chain and the level of disorder play a similar role in spreading the frequency response distribution. The mean and the standard deviation of frequency response magnitude are increased with increasing disorder, while they are both decreased with increasing material damping of the structure.

N. Sri Namachchivaya

Nonlinear Stochastic Systems

First part of this paper presents a perturbation approach to calculate the asymptotic growth rate of stochastically excited two-degree-of-freedom systems of the type $\ddot{q}_i + \omega_i^2 q_i + \epsilon\, 2\varrho\omega_i\, \dot{q}_i + \epsilon^{1/2} k_{ij}\, q_j\, \xi(t) = 0,\ i,j = 1,2$. The noise is assumed to be white and of small intensity in order to calculate the explicit formulas for maximal Lyapunov exponents.

Second part of this paper presents the method of stochastic normal forms. Similar to the deterministic normal forms, the crucial step in the normal form computations is to find the so-called resonant terms which cannot be eliminated through a nonlinear change of variables. Subsequent to the reduction of dimensionality, the associated stochastic normal form is obtained using Markovian approximation.

Finally, a new scheme of stochastic averaging using elliptic functions is presented. The second order nonlinear differential equation that is examined in this work can be expressed as $\ddot{q} + c_1 q + c_3 q^3 + \epsilon\, f(q,\dot{q}) + \epsilon^{1/2} g(q,\dot{q},\xi(t)) = 0$ where c_1 and c_3 are given constants of order one, $\xi(t)$ is a stationary stochastic process with zero mean and $\epsilon \ll 1$.

W. Szemplinska-Stupnicka

Some Remarks on Mode Shapes of Vibrations in Continuous Nonlinear Systems

A continuous nonlinear dissipative system under harmonic load is considered in the light of the problem of "active modes" and the Galerkin projection procedure. First, some critical comments are made on the commonly used assumption of spatial structure of the system involved in the Galerkin method. Then, the attention is focused on effects and consequences of using linear normal modes in an analysis of large amplitude nonlinear vibrations. The concept of approximate, amplitude dependent "nonlinear normal modes" is presented and the role the concept plays in the analysis of resonant oscillations is discussed. A suggestion is made that the controversial term "nonlinear normal oscillations/modes" might be replaced by, say, "POAC" term (Periodic Oscillations in Autonomous Conservative Systems). This would allow us to cover a wider class of nonlinear functions than those defined by R.M. Rosenberg (e.g. we might include "quadratic nonlinearities") and, what is not less important, would reduce criticisms raised by some mathematicians.

Then, the question of mode shape of chaotic vibrations of a buckled beam is examined in the light of the experimental results available so far, and of the theoretical analysis based on an approximate mathematical model. It is pointed out that there is a need of further experimental measurements of chaotic response of the beam and of the study of spatiotemporal chaos in the solid mechanics problems.

N.D. Anh

Nonlinear Oscillations of a System with Delay

We consider a system with delay, i.e. $\dot{x} + ax(t-\Delta) = \epsilon f(x(t), \dot{x}(t), x(t-\Delta_1), \dot{x}(t-\Delta_1))$. The following oscillations are observed (or of interest): free oscillations, harmonic oscillations, subharmonic oscillations, and chaotic and random oscillations.

It is obtained that even very small delay can result in large deviations from the corresponding system without delay. For example, take the system $\dot{x} + ax(t-\Delta) = 0$, $a = 500\pi$, $\Delta = 0.001$. This system has periodic solutions $x(t) = a\cos(at + \theta)$, $a, \theta = const$. However, for the corresponding system without delay, i.e. $\dot{x} + ax(t) = 0$, $a = 500\pi$, the equilibrium point $x = 0$, $\dot{x} = 0$ is asymptotically stable. Analogously, for the system with harmonic excitation, i.e. $\dot{x} + ax(t-\Delta) = P\cos\nu t$, $a = 500\pi$, $\Delta = 0.001$, there is an infinite resonance when $\nu = 500\pi$. This infinite resonance can not be observed from the corresponding system without delay: $\dot{x} + ax(t) = P\cos\nu t$.

H. Troger (co-authored by A. Steindl)

Three-dimensional Dynamics of Fluid-conveying Tubes with the Symmetry of the Square

Making use of Kirchhoff's theory of slender rods a geometrically fully nonlinear but physically linear (Kelvin-Voigt viscoelastic law) system of governing equations for a tube carrying incompressible fluid flow are derived. The rotationally symmetric tube is elastically supported by four springs which introduce D_4–symmetry. Considering the flow velocity as bifurcation parameter we study the loss of stability of the trivial equilibrium position and the postcritical behavior. For various amounts of the stiffness of the support divergent, flutter, and coupled divergent and flutter instabilities occur.

D.H. van Campen (co–authored by R.H.B. Fey and A. de Kraker)

Dynamic Behavior of a Damped Non–linear Beam–spring System Under Harmonic Excitation

This investigation is part of a somewhat broader research with respect to the dynamic behaviour of mechanical systems consisting of linear components and local nonlinearities. For the linear components spatially discretized models are used as an idealization of continuous models. The behaviour in space and time of such models is described by a finite number of degrees of freedom. Component mode synthesis methods are used to reduce the number of degrees of freedom of the linear components. The local nonlinearities are taken into account by coupling them to the linear components.

Periodic steady–states are computed by solving a two–point boundary value problem. The local stability of these steady–states is evaluated by Floquet multipliers. This approach also offers the possibility to follow branches of solutions when a design variable is varied. On these branches local bifurcation points can be detected.

As an example the steady–state dynamic behaviour is considered of a discretized continuous beam supported at both edges by frictionless hinges and supported halfway its length by a linear damper and two non–linear springs. One of these springs is of the Duffing type, whereas the other one is linear, but only acts in the compressive direction. The beam is subjected to harmonic excitation halfway its length. The excitation frequency is taken as a design variable.

First, a main branch with harmonic periodic solutions has been computed by means of a combination of a time discretization method and an arc continuation method. Next, the bifurcation points on this branch have been traced and analyzed, followed by investigation of the side branches. In some frequency intervals no stable periodic solutions have been computed through time integration. The creation of a chaotic motion via an intermittency transition has been observed.

F.L. Chernousko

Control of Oscillating Systems

Some problems of control for linear and nonlinear dynamic systems containing oscillating parts are considered. The following requirements are imposed: the control is bounded; the terminal state is prescribed; the time of control is finite. Thus, we do not consider stabilization control which leads to infinite time of motion. Some exact optimal control solutions are presented for linear systems. These optimal time control problems are simulated by control of cranes carrying swinging loads. However, explicit optimal time controls can be obtained for rather simple systems. More general results are obtained for linear time–dependent systems: it is shown that the well–known Kalman's approach (for control of linear systems) can be applied in the case of bounded control under some additional conditions. Using these results, we obtain explicit control for a system of n different oscillators.

Feedback control for nonlinear dynamic systems governed by Lagrange equations is suggested. It is assumed that there is a separate bounded control force for each degree of freedom. Under some general conditions for kinetic energy of the system and non-controlled forces, the explicit feedback law for control is suggested which is robust with respect to parameter variations and disturbances.

L. Arnold

Bifurcation in Random Systems: A Survey

Stochastic bifurcation theory studies "qualitative changes" in the behavior of parametrized families of stochastic dynamical systems. This can be formalized in (at least) two different ways:

(i) "Probabilist's approach": On the level of solutions of the Fokker–Planck equation (Zeeman 1988)

(ii) "Dynamical systems approach": On the level of invariant measures of the corresponding dynamical system and its Lyapunov exponents.

It has been observed quite often that near a bifurcation of type (ii) we have a bifurcation of type (i) on the bifurcated branch. We explain this by large deviations theory and recent results of Baxendale.

K. Xu (co-authored by L. Arnold)

Normal Forms for Random Differential Systems

Given a dynamical system $(\Omega, \mathcal{F}, \mathbf{P}, (\theta_t)_{t\in\mathbf{R}})$ and a random differential equation $\dot{x} = f(\theta_t\omega, x)$. The normal form problem is to construct a smooth near identity nonlinear random coordinate transformation $h(\omega)$ to make the random differential equation $\dot{y} = g(\theta_t\omega, y)$ "as simple as possible", preferably linear, where $g(y) = (Dh(y))^{-1}(f(h(y)) - \dot{h})$. The linearized equation $\dot{x} = A(\theta_t\omega)x$ generates a matrix co-cycle for which the multiplicative ergodic theorem holds, providing us with stochastic analogues of eigenvalues (Lyapunov exponents) and eigenspaces. Now the development runs pretty much parallel to the deterministic one, the difference being that the appearance of θ turns all problems into infinite-dimensional ones. In particular, the range of the homological operator is in general not closed, making the concept of ϵ-normal form necessary. The stochastic versions of resonance and averaging are developed. The case of simple Lyapunov spectrum is treated in detail.

V. Wihstutz

A Stochastic Averaging Principle and Stabilization by Random Vibration

Given the control system $\dot{x} = Ax + Bu$ in $\mathbf{R}^d$ one wants to find a zero-mean stochastic feedback control $u = \sigma \sum_{i=1}^{m} C_i \xi^i x$ ($\xi^i, i = 1,\dots,m$, independent sources of real or white noise) such that the exponential growth rate of the solution $x^\sigma(t, x_0)$ becomes as small as possible, and hopefully even negative. If A is of companion form, there is only one dimension which can be controlled in a physically realizable way, and the known procedures for stabilization fail.

With help of a stochastic averaging principle one can show that the system $\dot{x} = Ax$, A of companion form, is not stabilizable if one uses white noise or non-degenerate real noise, even if it is speeded up. But this system can be stabilized if a proper combination of white and real noise is used, or with help of types of degenerate noise.

W. Kliemann (co-authored by F. Colonius)

On Two Perturbation Lemmas for Ordinary Differential Equations

We consider an ordinary differential equation $\dot{x} = X(x)$ with a perturbation term $\sum u_i(t) X_i(x)$, where $(u_i)_{i=1\dots m} = u \in \mathcal{U} = \{u : \mathbf{R} \to U,\ \textit{local integrable}\}$ and $U \subset \mathbf{R}^m$ compact. On $\mathcal{U}$ we use the weak topology. Generically (on an open and dense set $\mathcal{U} \times M$, M the state space) all trajectories of the perturbed equation will enter the interior of invariant control sets in finite time, describing the possible location of the ω limit sets. For $U^\epsilon = \epsilon\, U$ one finds that for ϵ small enough the control sets of the perturbed equation develop around the Morse sets of $\dot{x} = X(x)$, with invariant control sets corresponding exactly to the maximal Morse sets (=attractors). These results allow the study of invariant measures under Markovian disturbances, of control of chaos, of robust feedback stabilization at unstable reference trajectories ...

R. Seydel

Remarks on Detecting Stationary Bifurcation Points

We consider a system of *n* nonlinear equations $f(y, \lambda) = 0$, with a real parameter λ, and ask how to detect stationary bifurcation points. The standard means is to check the sign of a "bifurcation test function" $\tau(f, y, \lambda)$. The usual choice is the determinant of the Jacobian matrix. The determinant has bad scaling properties, reflected by $\tau(sf, y, \lambda) = s^n \tau(f, y, \lambda)$. An alternative that was proposed in Numer. Math. 33, p. 339–352, is investigated. For this alternative test function we prove reasonable scaling in the sense $\tau(sf, y, \lambda) = s\tau(f, y, \lambda)$, and show that three candidates for τ can be calculated with together 6 operations. The choice of the candidates is based on the results of the pivoting of a factorization of the Jacobian. The approach provides piecewise local test functions.

E. Platen

Numerical Methods for Stochastic Differential Equations

The talk gives a survey on numerical methods for stochastic differential equations, based on the book of Kloeden, P.E. and Platen, E.: The Numerical Solution of Stochastic Differential Equations, Springer, 1991. Especially the numerical investigation of stiff stochastic differential equations by implicit schemes is discussed. Further, the numerical stability of explicit and implicit schemes is considered. Finally, the visualization of paths of the Duffing–Van der Pol Oscillator is given as an example.

L. Faravelli

Stochastic Equivalent Linearization for Complex Structural Systems

The dynamical behaviour of hysteretic frames under stochastic excitation is studied. Stochastic equivalent linearization is used. The equations of motion of a multi-degree-of-freedom shear structure, coupled with a linearized form of constitutive law of the hysteretic stiffness elements, are rearranged in the state vector form and solved by a complex modal analysis. The complex structure is also discretized into elastic elements interconnected at potential plastic hinges where the whole inelastic deformation concentrates. The Bouc–Wen endochronic model is adapted to describe the hysteretic behaviour of the critical sections. The variation of the eigenproperties of the structure is studied in order to define a "criterion" for ignoring the contribution of some eigenvalues and to estimate an "a priori" error.

F. Casciati (co-authored by F. Bontempi)

Chaotic Behaviour and Probabilistic Measure

Attention is focused on the chaotic behaviour of dynamical systems under stochastic excitation. Characterization techniques associated with Poincaré Sections, Lyapunov exponents, capacity and information dimensions, power spectra and probability densities are used for a nonlinear SDOF system.

It is shown that it is virtually impossible to distinguish between chaotic and non-chaotic stochastic motion when relatively high intensity of the external random excitation is involved. While looking for a transition criterion, the Fokker–Planck equation is regarded as a unifying model between stochastic and chaotic motion.

C.S. Hsu

Certain Nonlinear Problems Studied by the Generalized Cell Mapping Method

Two problems of nonlinear systems studied recently by the cell mapping method are reported here.

The first problem concerns the effects of uncertainties on systems which possess multiple long term asymptotically stable solutions, some of which could be strange attractors. If a strange attractor does exist with other periodic solutions, would the presence of random uncertainties make the chaotic response represented by the strange attractor more dominant. The answer is "not always" or "not necessarily". Each attractor is protected by the domain of attraction. When the uncertainties cause the attractor to pierce the protection layer, then that attractor will be lost.

The second problem concerns the use of generalized cell mapping to study random vibration problems. When generalized cell mapping is used for this purpose, the evaluation of the transition probability matrix is computationally intensitive. Here it is proposed that a short-time Gaussian approximation be used for the purpose of evaluating the transition matrix, resulting in a drastic reduction of computation. Once the transition matrix has been determined, the methodology of generalized cell mapping will yield all statistical information one may wish to have.

J. Brindley

Noisy Periodicity and Nonchaotic Strange Attractors in Forced Nonlinear Oscillators

Nonlinear oscillators, forced at a single frequency, have been the subject of much research, and the occurrence of strange attractors for certain parameter ranges is well known. Much less well known or understood is the behaviour of nonlinear oscillators forced quasi-periodically. A common feature of such systems is the occurrence of "nonchaotic strange attractors", that is, attractors whose structure is not simple, but near and on which neighbouring trajectories do not display exponential divergence. Such behaviour has a characteristic spectral signature and is robust not only to changes in parameter values or initial conditions but also to structural perturbations of the equations. It has strong implications for predictability. Some examples of this behaviour are presented, and in addition the occurrence of noisy periodicity in quasi-periodically forced systems is demonstrated and discussed. In particular the effect of adding a second frequency of forcing, or of adding a random multifrequency forcing, to simple forced oscillator models for the occurrence of ice ages or "El Nino" like events is presented. Preliminary results are encouraging, and motivate further systematic numerical experiments.

S. Ariaratnam

Stochastic Stability and Bifurcations

The concept of stochastic bifurcation is illustrated through some simple one- and two-dimensional examples. The role of the Lyapunov exponent in determining the point of bifurcation and the almost sure stability of the bifurcating solution is shown. This concept is different from that adopted in some of the literature, particularly in Physics, where stochastic bifurcation is regarded as implying a change in the nature of the response probability distribution, e.g. from uni-modal to bi-modal. The possibility of error in randomizing parameters in the deterministic normal form of a dynamical system rather than in the original system is illustrated through an example. Finally, the evaluation of the Lyapunov exponent of a two-dimensional system with visco-elastic (i.e. hereditary) damping under deterministic and stochastic parametric excitation is illustrated in a unified way using Khasminskii's approach.

W. Wedig

Lyapunov Exponents and Invariant Measures of Dynamic Systems

For stability investigations of linear systems with parameter fluctuations we follow Khasminskii's concept by introducing a projection on a unit hypersphere which separates all stationary solutions from one instationary part. The projection processes are simulated by a simple algorithm which avoids geometrical singularities and satisfies exactly the hypersphere condition.

This algorithm is explained in details by the two-dimensional stability problem of oscillators with multiplicative white noise. The obtained results are invariant measures and Lyapunov exponents which can be controlled solving the associated Fokker-Planck equations. In a second example, two coupled oscillators with harmonic parameter excitations are considered. Here, the obtained Lyapunov exponents can be compared with corresponding results of the Floquet theory.

D. Talay

Approximation of Lyapunov Exponents of Linear and Nonlinear Stochastic Differential Systems

The numerical approximation of Lyapunov exponents of linear and nonlinear systems is investigated. Efficient algorithms are presented, with the theoretical analysis of the rates of convergence.

For linear systems in $\mathbf{R}^d$ (whose solution is denoted by (X_t)) the algorithm is based upon an approximation of the process $(X_t/|x_t|)$ constructed by a time-discretization of the linear system combined with a projection operation at each step (this avoids numerical instabilities). Under a strong ellipticity condition, it can be shown that the invariant measures of $(X_t/|\overline{X}_t|)$ and its approximation, denoted by μ and $\overline{\mu}^h$, respectively, (h being the discretization step-size) satisfy: for any φ smooth on S^{d-1}: $\left| \int_{S^{d-1}} \varphi(s)\, d\mu(s) - \int_{S^{d-1}} \varphi(s)\, d\overline{\mu}^h(s) \right| = O(h)$. This permits to show that the order of convergence of the computed Lyapunov exponent is h.

For the nonlinear case, the algorithm and the analysis of the error are extended via a discretization of the linearized system on the tangent bundle of the state space (constrained to be $\mathbf{R}^d$ or a compact connected C^∞ manifold).

D. Flockerzi

Applications of Invariant Manifolds in Nonlinear Control Theory

By studying some problems of nonlocal stabilization for nonlinear affine control systems we show how the theory of invariant manifolds for regularly and also singularly perturbed ordinary differential equations can be successfully employed in attacking control theoretical tasks.

K. Popp

Nonlinear Behavior of Structures due to Dry Friction

Two subjects are presented: Firstly, the detection of nonlinearities from input–output measurements and, secondly, the utilization of the nonlinear effect of dry friction.

In the first part, Hilbert transform techniques and the isochrone function are applied as nonlinearity tests to answer the questions: Is a given system linear or not, and if not, what type of nonlinearity occurs?

In the second part, a SDOF–oscillator with dry friction and beam structures with friction interfaces are investigated and optimized with respect to maximum energy dissipation. As applications the effect of optimal friction damping is shown for a frame structure and turbine blades with friction elements, respectively.

W. Schiehlen (co–authored by M. Kleczka)

Ergodicity and Chaotic Behaviour of an Oscillator with Backlash

The concept of ergodicity is very useful for measurements on stochastic systems replacing the ensemble average by a time average. Ergodic processes can be analysed by consideration of one realization only. An oscillator with backlash under random initial conditions is investigated with respect to the ergodicity of the responses. First, the Lyapunov exponents and the corresponding Lyapunov dimension is computed. It turns out from the Kolmogorov–Sinai entropy that the information on the initial conditions is lost after a well–defined period. Then, it is shown that the ergodicity of the resulting chaotic motions depends on the region of the initial conditions chosen. The responses may be ergodic up to the fifth order moments or they are not ergodic even in the mean, respectively. Thus, the ergodicity can be used as a test criterion for the sensitivity of chaotic motions with respect to initial conditions.

G.I. Schueller

Efficient Computational Procedures for Reliability Estimates of MDOF–Systems

A new numerical code for determining the reliability of multi–degree–of–freedom (MDOF)–systems (linear or nonlinear) exposed to stochastic excitation is presented. The procedure is based on the response surface method and hence allows the utilization of any of the currently available multi purpose finite element computer codes. The method is discussed in context with the issue of accuracy and computational efficiency. In particular it is compared with Monte Carlo simulation procedures as well as non–Gaussian equivalent linearization.

Z. Kotulski

On the Moment Equations for Stochastic Differential Equations in Hilbert Spaces

For stochastic multiplicative differential equations $dU/dt = AU + BU\xi(t)$ in Hilbert space we obtain the complete sets of moment equations in the case: $\xi(t)$ – H-valued white noise, and $\xi(t)$ – random telegraphic process. We use the obtained equations for investigation of the moment stability of the randomly excited column.

A.D. de Pater

Investigations in the Field of Railway Vehicle System Dynamics

The paper gives a survey of author's activities in the field of railway vehicle system dynamics during the last years. In synthetic activities, viz. when designing a vehicle in such a way that both a good curving behaviour and a sufficient stability can be achieved, he used linear methods whenever possible. But in many cases non-linear effects have to be taken into account and analytic activities are necessary. In performing analytical investigations one has to consider the geometrical contact track–wheelset, the physical contact track–wheelset, and the dynamics of wheelsets and other vehicle parts. In the present paper mainly the geometrical contact is considered; the physical contact has been investigated by Kalker thoroughly, whereas, recently, author's collaborator Yang Gu–ang has paid much attention to the integration of the dynamical equations of motion of simple wheelsets and complete vehicles.

J. Wallaschek

Nonlinear Dynamics of Railway Vehicles with Independent Wheels

Recently, a new generation of light rail vehicles for urban traffic has been developed. They have low floors and thus offer much comfort to the passengers. This design only was possible because new suspensions were developed. Basically, there are two competing designs: classical bogies with independent wheels and single wheel units with independent steerable wheels. Combined with independent electric drivers, active guidance systems for railway vehicles can be realized which possibly allow to improve the traction and guidance performance considerably. In this lecture, some first results concerning the dynamics of railway vehicles with independent wheels are discussed.

J. Scheurle

Quasiperiodic Drift Solutions in the Couette–Taylor Problem

The Couette–Taylor problem deals with the flow of an incompressible viscous fluid between two coaxial rotating cylinders. Depending on the angular velocities of the cylinders different flow patterns are observed in experiments. The transitions between different flow patterns are described by instabilities and bifurcations of certain solutions of the corresponding Navier–Stokes equations. In this talk a sequence of three successive bifurcations which occur in this problem for certain parameter values is described. It starts with the classical bifurcation of Görtler–Taylor vertices from the Couette flow and finally leads to quasiperiodic solutions, where the vertices slowly drift in the direction of the axis of the cylinders.

G.-D. Kersting

How Much Noise is Sufficient to Disturb a Dynamical System

Consider the diffusion process in $\mathbb{R}^d$, solving the Ito-equation $dX_t = b(X_t)\, dt + \sigma(X_t)\, dW_t$, as a random disturbance of the dynamical system $dy = b(y)\, dt$. When do both processes behave differently? We approach this problem (as is explained in more detail in the lecture) by the construction of harmonic coordinates $u : \mathbb{R}^d \to \mathbb{R}^d$ (which means that $Lu = 0$, where L is the infinitesimal generator) such that $|u(x) - x| = o(|x|)$, as $|x| \to \infty$.

J. Szopa

The Multi-degree-of-freedom Chaotic Systems and Stochastic Chaotic Systems

The two-degree-of-freedom system is analyzed. It is a system which connects the Duffing and the linear oscillator. The Duffing oscillator shows for some parameters and initial conditions chaotic motion. The influence of chaotic vibrations of the Duffing part of this system on the linear part is investigated. The characteristics of chaos which are used in the investigations are the following: a) nonregular displacement, b) non-existence of limit cycles in the phase plane, c) shape of Poincaré map, d) wide spectrum, e) shape of the auto-covariance function, f) Lyapunov exponents. For this system there exist many interesting phenomena. In the neighborhood of chaos there exist regular and quasi-periodic solutions. The following conclusions are obtained: the linear part of the system vibrates much more regularly than the non-linear part, for other systems it is observed that by choosing special values for stiffness or damping parameters chaos disappears.

The Duffing equation with random excitation is also analyzed. The amplitude of the excitation is a random number. It can be seen that the mean values of chaos characteristics are more regular than for the deterministic Duffing equation.

F. Ziegler (co-authored by R. Heuer and H. Irschik)

Nonlinear Vibrations of Plates

Shear deformable (orthotropic or composite) plates under the action of a thermal prestress are considered in free and forced vibrations. In the case of simply supported straight edges (and for general polygonal planforms) the nonlinear set of partial differential equations of sixth order can be reduced to fourth order with effective parameters of a Kirchhoff plate including the proper boundary conditions. The Berger (hydrostatic) approximation of the membrane forces is understood. The Galerkin procedure is applied with shape functions according to the two sets of (linear) eigenfunctions of two corresponding membranes. Unifying dimensionless representations of backbone and resonance curves are calculated. Randomly forced vibrations are considered by means of the FPK-equation. The latter has a closed form stationary solution due to the potential type of the coupled restoring forces in the case of independent white noise excitations with proper intensities. For the latter see Proc. of IUTAM-Symp. in Torino, July 1991, publ. by Springer.

Berichterstatter: D. Bestle

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