


Fracture of Nano and Engineering Materials and Structures

Proceedings of the 16th European Conference of Fracture, Alexandroupolis, Greece, July 3-7, 2006

Edited by
E.E. Gdoutos

 Springer



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The volume contains the latest research work of renowned experts in the area of failure of engineering materials and structures and is useful for the student, the engineer and the researcher who wants to get an integrated picture of the recent developments in the area of fracture mechanics and fatigue.

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- 1T7. Thin Films
- 1T9. Failure of Nanocomposites

B2: Engineering Materials and Structures

- 2T1. Physical Aspects of Fracture
- 2T2. Brittle Fracture
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1. Fracture and Fatigue at the Micro and Nano Scales (Organized by H.D. Espinosa and I.M.Daniel)
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29. Reliability and Failure Analysis of Electronics and Mechanical Systems (O.S. Lee)
31. Multiscaling in Molecular and Continuum Mechanics – Scaling in Time and Size from Macro to Nano (Organized by G.C. Sih)
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20. Critical Distance Theories of Fracture (Organized by D. Taylor)
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23. Deformation and Fracture of Engineering Materials (Organized by C.T. Liu)
24. Materials Damage Prognosis and Life Cycle Engineering (Organized by R. P. Wei, G. Harlow, A. Ingrassia and J. Larsen)
25. Mixed-Mode Fracture (Organized by M. Gosz)

Invited Lecture

MEASUREMENTS OF DYNAMICAL SYSTEM INTEGRITY AND FRACTURE MECHANICS

K. S. Hedrih

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I. What is the Dynamical System ? Problems in dynamics have been fascinating physical scientists (and mankind in general) for thousands years. Modern dynamical system theory has relatively short history.

It began with Poincaré (1880, 1890, 1899), who revolutionized the study of nonlinear differential equations by introducing the qualitative techniques of geometry and topology rather than strict analytic methods to discuss the global properties of solutions of these systems.

Robert Devaney in his book [1] wrote: "The simple examples of dynamical systems show how dynamical systems occur in the "real world" and how some very simple phenomena from nature yield rather complicated dynamical systems".

The answer is quite simple: take a scientific calculator and input any number whatsoever. Then, start striking one of the function keys over and over again. This iterative procedure is an example of a discrete dynamical system: $x_0, f(x_0), f(f(x_0)), f(f(f(x_0))), \dots, f(f(\dots f(f(x_0))))$.

The basic goal of the theory of Dynamical Systems is to understand the eventual or asymptotic behavior of an iterative process. If the process is a discrete process such as iteration of a function, then the theory hopes to understand the eventual behavior of the points $x, f(x), f^2(x), f^3(x), \dots, f^k(x), \dots, f^n(x)$. Functions which determine dynamical systems are also called mappings, or maps, for short. Mathematical phenomenology and analogy [2] is very useful in the investigation of kinetic properties and processes in the dynamical systems with disparate nature.

A very important notation in the study of dynamical systems is the behavior or persistence of the system under *small changes or perturbations*. This is the *concept of structural stability*.

The notion of structural stability is extremely *important for practical application*.

II. Characterization of a dynamical system:

Material model with material structures (construction with structural elements);

Mathematical description of material structure dynamics (geometry and material of construction, constitutive stress-strain relation depending of material properties [3], time rate changes in the system structures, material coefficients, coefficients of inertia tensor, coefficients of stiffness.....and other material properties; coupled tensor fields properties of material...);

Stress and strain states of dynamical system structure on the boundary surfaces (defined by boundary conditions for free and for loaded system, external surface contour excitations, contour displacements);

Stress and strain states [4] of dynamical system structure at initial time moment or with all history before initial moment on the observation in all material structures and on the boundary surfaces (by initial condition satisfying the boundary conditions for free and for loaded system);

States of dynamical processes in dynamical system;

State of stress and strain in the material, and also state of displacements of structure points and also states of other coupled fields depending on the type of material structure.

III. Types of dynamical system integrity [5,6]

Ideal integrity of dynamical system is when properties of the material structure system and its own kinetic parameters do not change under external excitations;

Partial integrity of dynamical system is when properties of the material structure system or its own kinetic parameters do not change under external excitations.

Modified integrity of dynamical system is when properties of the material structure system or its own kinetic parameters change under external excitations in the proposed intervals.

Rheonomic integrity of dynamical system is when properties of the material structure system and its own kinetic parameters are functions of time and do not change under the external excitations.

Integrity of subprocesses in dynamical systems (In the linear oscillatory system own modes are mutual independent processes and single frequency processes with one own frequency each).

Integrity of the real structure material in dynamical system (Measurements of integrity of the real structure material are defined by development of material sciences and the fracture mechanics theory [7] and [8]. Papers written by the British scientist A. A. Griffith (1920, 1924) are of permanent importance for the early formative period of fracture mechanics. He was the first to consider the energy balance approach to the crack problem, the important aspects of which have been reviewed by Panasyuk (1993) [9].

IV. Chaotic Clock Models: A paradigm for vibrations and noise in machines and integrity of machines. For examining natural clocks [10] of reductors (power transmission), as well as sources of nonlinear vibrations and noise in its dynamics, it is necessary to investigate properties of nonlinear dynamics, and phase portraits, as well as structures of homoclinic orbits, layering and sensitivity of this layering of homoclinic orbits and bifurcation of homoclinic points. The natural clocks of nonlinear dynamics of coupled rotors are studied, as well as integrity of machines with respect to the fatigue of the material structure of power transitions [11].

Key words: Homoclinic orbits and points, separatrix layering, trigger, coupled singularities, bifurcation, vector method, mass moment vectors, phase plane and portrait, couple triggers, the form of number eight or it multiplicand, Chaotic Clock Models, integrity, machines.

V. Single and multifrequency vibration regimes in the sandwich system with discontinuity. By using two examples of free and forced vibrations of the elastically connected multi body systems and corresponding system with a discontinuity in an elastic connection, we show some basic properties and measurements of the integrity of basic dynamical system. The integrity of dynamical subprocesses in the behavior of the whole system and its subsystems or in component processes and as response of the whole system to corresponding system with discontinuity have been studied by using methods of Bernoulli's particular integral and Lagrange's method of constants variation. It is shown that one- and two frequency subprocess regimes change into multi-frequency regimes induced by discontinuity in the system, which represents the loss of integrity of the system structure and marks the appearance of the loss of integrity of basic subprocesses [6]. The presence of multifrequency regimes in one of the modes of vibrations is an indicator of discontinuity in dynamical system and of loss of previous integrity.

VI. Concluding remarks. For the measures of dynamical system integrity it is possible to take one of the sets of kinetic parameters, the changes of which in the critical values range are sources of bifurcation processes or of the appearance of nonprogrammed processes in dynamical system with possible appearance of structure discontinuity.

Acknowledgment

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