18th International Conference
ENGINEERING MECHANICS 2012
Svratka, Czech Republic, May 14 – 17, 2012

pp. 2–3
Paper **#36**

APPLICATION OF CHAOTIC DYNAMICS IN NATURAL AND TECHNICAL SCIENCES

C. Kratochvíl*, P. Švéda, M. Hortel, A. Škuderová, M. Houfek**

Abstract*:* *During the entire 20th century there was a gradual transformation of scientific research, which has produced in science and technology especially in the extraordinary interest in complex dynamic systems. They are non-linear systems, operating environments and the irreversible complexity in their name means they have complex structures, relations and interactions (often of different physical nature). It turned out that an inherent attribute of these complex systems and chaos (deterministic and stochastic). The article will focus on some aspects of the manifestations of chaos, its spread, as well as identification, suppression and control. We will mention also other important phenomena - the possible emergence of a new order out of chaos.*

Keywords: ***Dynamical systems, bifurcation, chaotic attractors.***

1. Introduction

Our objects of interest are dynamic systems, describing changes in their status over time. There is a vector situated in the state space, describing system's state in arbitrary point on timeline. Dynamical systems describe the system of nonlinear differential equations. Changes in the system are determined by the solution of these equations and their waveforms are displayed as trajectories in state space.

The emergence of chaos in these systems can lead to extreme amplification of certain disorders. Systems also function as a filter, some disturbances intensify, suppress others. These failure processes are initially linear, but with increasing time nonlinearities are manifested precisely which systems to bring unstable chaotic state due to their sensitivity to character disorders, sensitivity to changes in initial conditions, or even change some system parameters. The result is the unpredictability of their future behavior. However, this orderability and identifiability can then emerge a new order, following the signs of chaos and conflict of chaos and order. And that is becoming one of the major themes of chaos in the current study of scientific knowledge not only in technology and natural sciences but also in other fields (economics, philosophy, etc.).

2. Open dynamical systems

According to Prigogine (1998) isolated the dynamical systems (in which no exchange of energy with the surroundings) usually evolve to chaos, i.e. towards disorder. Their future is only in the direction of entropy increase to its maximum. The increase in entropy becomes "indicator for the development of systems" in a figurative sense "arrow of time" - unless we admit, "... that time here is forgetting the initial conditions, growth and development of the uniformity towards disorder" (Heczko 2003). Current systems are systems to exchange energy, matter and information with others. They are open systems that evolve from simple to complex, from less organized structures to structures more structured. In other words, from the systems' structures "indistinguishable" to so-called "better organized". A certain level of complexity of the system is also subject to certain internal irreversibility of the processes inside the system and raises the volatility and instability. And the volatility and instability may be a source of new order and new order, and can create a "new order from chaos" *(Ordo ab Chaos).*

* Prof. Ing. Ctirad Kratochvíl, DrSc., Ing. Martin Houfek, Ph.D., Mgr. Petr Švéda: Institute of Solid Mechanics, Mechatronics and Biomechanics, Department of Mechatronics, Faculty of Mechanical Engineering, Brno University of Technology; Technická 2896/2, 616 69 Brno; CZ, e-mail kratochvil@fme.vutbr.cz

** Ing. Milan Hortel, DrSc., Ing. Alena Škuderová, Ph.D.: Department D3 - Dynamics and Vibrations, Institute of Thermomechanics AS CR, v. v. i.; Dolejškova 1402/5, 182 00 Praha 8; CZ

It is in this context to define the term deterministic chaos, which is self-conceived team deterministic nonlinear open systems, where due to extreme sensitivity to initial conditions, failure (or some system parameters) leads to unpredictable behavior and the possible emergence of chaos (locally unstable and globally stable). Chaos often plays a creative role; as a result synergic effect leads to a certain self-regulation of systems. The result is that the structurally distributed energy entirely concentrated on certain symptoms - strange or chaotic tractors, representing the final states of the system.

3. The chaos is characterized by

- The chaotic structure is characterized by alternating states of irregular instability and dissipativity. These irregularities are the essence of the transition of different types of generators of chaos;

- Images show typical Poincare “infinitely” structured point set, consisting of clusters of points with relatively smooth transitions;

- In view of the phase plane (or in the state space), we see tractors strange (strange attractors), which are globally bounded but locally unstable display of complex non-periodic oscillations;

- Tin phase plane is often encountered with the distribution of state trajectories around more centers (usually two), symmetrically spaced around the origin;

- Frequency spectra of chaotic signals represent a significant set of isolated frequencies, among which are “dense areas” of local noise.

4. Conclusions

Here we mention “only” about some aspects of chaos. The paper will discuss the other factors, characterizing chaos: in particular the role of bifurcations that characterize extremely unstable states of open systems. Bifurcation can occur both due to external (accidental?) Effect and increase the influence of disorder in the system. We will mention the classification of chaos, his identity, get acquainted with the important class of chaotic attractors derived from Chu electronic circuits and we will reflect on ways to limit and control the chaos.

Questions unpredictable behavior of chaotic systems and the possibility of a new order will also be the subject of our discussion. Recall “just finding” a startling workers dealing with chaos. Chaotic systems can be put into an unstable state of external intervention, but it subsides after the systems “self” will return to its original condition. If cease interference occurs for systems to “break the original set of rules” and “restructuring”. For the system will apply the new rules, although built on the basis of the original, but adapted to new circumstances. What does this mean? Chaotic systems are capable of spontaneous and independent of any outside influence self-organization!

The history of human knowledge continues to move toward discovering new patterns. However, each new law and the notion that it occurs, has a limited scope and duration. There is no reason to believe that the current instruments - differential equations - are still the best tool. I answer the question whether our world is deterministic or random chaotic is in fact uncertain. The answer is “only” that the world exists, evolves, and we observe it, and we are part of it. Our ideas about it - models can be deterministic or chaotic - but they are only approximate models (Pokorný, 2008).

References

Heczko, S. (2003) Teorie chaosu a chování otevřených systémů. *Marathon,* 4. Available on-line http://www.valencik.cz/marathon/03/mar030400.htm

Pokorný, P. (2008) Deterministický chaos-plod počítačové fyziky, *Čs. čas. pro fyziku*, 58.

Prigogine, I. (1998) *Modern Thermodynamics*, J. Willey and Sons, Chicester.