The Damage- Fracture-Fatigue Evolution Law and some Prospect in Failure Mechanics

by

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How to link the solid medium from damage to fracture and fatigue, How to deduce the evolution-law for these inter-disciplinary problems, That is important problem in the fracture and failure analysis, The evolution law can be developed in the longitudinal dimension in macro-meso-micro scale and lateral dimension covered the quasi-brittle materials and intelligent materials such as shape memory alloy, structural ceramics, piezo-electic materials and bone. The methodology of derivation for evolution law in different damaged medium are formulated and discussed. Four problems of the methodology for derivation of the evolution laws developed by author and his collaborators are formulated and analyzed as following: (1)-- Quasi-brittle damage of solids by domain micro-crack growth (DMG) model; The concept of the domain of micro-crack growth (DMG) is defined as damage evolution characteristics and used to describe the damage state and the anisotropic properties of brittle materials under anisotropic damage and non-monotonic loading condition; (2)—A micromechanics constitutive model of transformation plasticity with shear and dilatation effects to describe the plastic, pseudo-elastic and shape memory behaviors of structural ceramics during transformation under different temperature. Thus the constitutive law with evolution of volume fraction f can also be used to describe the pseudo-elastic and shape memory behavior which is typical of thermo-elastic martensitic transformations; (3)-- The evolution law of volume-fraction f in the domain switching of ferro-electric materials under electrical-mechanical loading by observation of meso-materials testing is proposed, the butterfly and reversed butterfly curves of ferro-electric ceramics due to electric fatigue have been formulated based on a constitutive model by considering the fact that domain switching is a progressive process.. The smoothness of butterfly curves close to experimental results is attributed to the incorporation of gradual domain switching. The asymmetric tendency of reversed butterfly loops has the same position-dependency as the butterfly loops.; (4)--The non-monotonic evolution laws for damage and healing of bone under mechanical-electrical-magnetic loading combined with observation and identification methods. Bone, as a living tissue, it can repair itself. This renewing process is performed by bone remodeling, so the bone damage behavior can be easily influenced by many factors as long as these factors can affect bone remodeling or damage accumulation. Besides mechanical loadings, electromagnetic fields and hormones also play an important role in bone functional remodeling process. A mechanism-based damage model to rationalize the damage evolution law of bone under simultaneously applied mechanical and electromagnetic fields are established. Some crucial physical and biological mechanisms underlying the sophisticated damage, remodeling and healing

process of bone tissues have been incorporated in the model. Especially, an evolutionary law of bone damage and the corresponding modeling methodology are presented to analyze the complicated damage-repair behavior of bone under multi-fields. Then the numerical examples are considered to verify the theoretical model and the influence of those mechanical and non-mechanical factors on the bone damage and healing are simulated based on the new damage model. Those factors include mechanical overload, electromagnetic field, mechanical disuse, estrogen deficiency and bisphosphonate. The results of simulation with the new evolution law of damage and healing are qualitatively coincided with the tendency from hospital experiences. But further experimental verification and parameters identification are obviously required before the proposed model can be applied to the medical clinical practice. Finally, the prospect on the derivation and methodology of the evolution laws under different coupling mechanics problems relating the failure mechanics such as damage-fracture-fatigue mechanics are discussed

Biographical Sketch

Professor Shouwen Yu is a Professor of Engineering Mechanics at Tsinghua University, Beijing, China. He was with the Institute of Mechanics, Technische Hochschule Darmstadt, Germany in 1985-1987 as Visiting Research Fellow under an Alexander von Humboldt Fellowship. Yu is President of the International Congress of Fracture (ICF, 2013-2017) and was elected as Honor Fellow of ICF in 2005. He is Vice President of China Engineering Education Accreditation Association Accreditation (CEEAA) and a member of Advisory Board of International Institute for Developing Engineering Academics (IIDEA). He was former Vice President of International Federation of Engineering Education Societies (IFEES ,2008-2012) and former Vice-President of Tsinghua University from 1992 to 1999. He has worked in the field of fracture mechanics and macro -meso /micro mechanics and management for higher engineering education in last several decades. Professor Yu authored and

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