Fracture Control and Structural Integrity (FRACSI) Education and Research

Ashok Saxena
University of Arkansas, Fayetteville, AR 72701
asaxena@uark.edu
479-466-4301

Abstract

Fracture control and structural integrity (FRACSI) analyses aim to achieve safe operation of engineering components and structures and in the process engage several disciplines in science and engineering. The analyses focus on the assessment and quantification of the margin between safe operation and failure that is sometimes considered in a probabilistic frame-work and expressed as probability of failure. This discipline has evolved as a field at the interface of Mechanical, Materials, Aerospace, Engineering Mechanics, and Civil Engineering, Physics, Chemistry and Mathematical and Computational Sciences and is now also touching Biomedical Engineering, Biology, and Geology thru faults in Earth's crust. The field has continued to prosper over the past six decades while continuously expanding its capabilities to address new classes of deformation, fracture and crack initiation and growth problems. Past thirteen ICF conferences have contributed immensely to keep the field in the fore-front of science and engineering research since 1965.

The past five decades have seen significant progress in equipment capabilities for materials characterization, characterization techniques, molecular and atomistic scale computational modelling, nondestructive inspection techniques and capabilities, scientific understanding of the fracture phenomenon within the crack tip process zone, finite element analysis as well as new developments and better understanding of the limitations of single parameter linear and nonlinear fracture mechanics. Similarly, there has been progress in understanding of crack initiation phenomena related to fatigue, creep and environmental effects and their synergistic effects. However, a question arises that deserves in-depth probing. Have we maximized the potential of these developments in the design of next generation, highly efficient structural components? For example, we can now estimate the concentration of hydrogen in the crack tip region in ferritic and austenitic stainless steels because of progress in molecular dynamics and atomic scale ab initio calculations, but, can we then use it to quantitatively estimate what that means to damage tolerance of a pressure vessel that is designed to store hydrogen at high pressures?

We are also at the cross-roads where few may even believe that the field has now matured and does not need the same level of attention in research resource allocations. Conversely, it can be argued that there is greater than ever need for various disciplines within the umbrella of FRACSI to coalesce more effectively to deliver easily implementable methods and analyses that can be inserted in the **direct-path of design of future engineering systems and accelerate the design process** by minimizing the number of iterations

needed. Examples of these include economical ways of energy storage via compressed combustible gases, future transportation and propulsion systems, next generation energy conversion systems, solving biomedical engineering problems or in predicting the location and intensity of future eartquakes. These are among the commonly identified grand challenges for a sustainable world that is committed to a high quality of life and we are fortunate that our field is in a position to contribute toward those challenges. The future of the field is tied to delivering very tangible value in the front-end of these major projects and not just be relegated as part of reliability analyses to be conducted at the back end or only after discovering that certain components of the system have failed.

Some relevant questions must be raised about how we should educate our young scientists and engineers of the future, and also how FRACSI professionals should be organized in industry and in research laboratories to be prepared to address the challenges described above. In both instances, we can say that the current effort is fragmented and therefore not fully effective. The groups lack integrative skills that are needed to connect atomic scale phenomena that cause material degradation to parameters that can be used to ensure structural integrity during service. Bridging of length scales in the context of fracture problems has been talked about but there are few tangible examples of successes. This presentation addresses some ideas on what changes are needed, both in educational institutions and in research laboratories that will likely produce professionals that are well positioned to become integrators of FRACSI expertise and can add value in the front end of the design of future systems. Examples of the design of advanced power plant equipment that operate at higher temperatures, and systems for storage of hydrogen at pressures of 1000 bars safely in urban areas will be used. Both have important fracture control and structural integrity issues to be resolved for the benefit of society and quality of life.

The evolution of a discipline often follows the sequence of first being a multi-disciplinary program in which experts in different disciplines come together to solve a complex engineering problem, of which fracture is a prime example. Often with time it evolves into an interdisciplinary program in the form of a research center that eventually evolves into a discipline in itself with a variety of embedded sub-disciplines. FRACSI, it can be argued, has not quite made the last jump. So, how can and should that be facilitated? Even if FRACSI can be made ready to become a technical discipline by itself, it may for other more practical reasons such as lack of new resources, not be possible everywhere. For example, a very high performing and reliable but expensive automobile may be considered a technical marvel but is expected to be present only in few garages. Similarly, there may be reasons to have FRACSI as a discipline in certain companies, universities and laboratories that can afford it and reap the benefits, but may not suitable for all institutions.

In the new paradigm, design, materials selection, and specification of inspection techniques, criteria and intervals as part of good maintenance practices, must be concurrently addressed such that suboptimal designs that are either too bulky and expensive or may carry a higher than necessary risk of fracture, can be avoided. This need must be addressed with a systematic approach to educating fracture control and structural integrity engineers that can think within a “cradle to grave” and/or “life cycle engineering” frame-work. ICF14 is a good venue for such discussions to begin that can be continued at future ICFs.

Biographical Sketch

Dr. Ashok Saxena currently serves as the Provost and Vice-Chancellor of Academic Affairs and Distinguished Professor at the University of Arkansas. Previously, he served as the Department Head of Biomedical Engineering, Distinguished Professor and the George and Boyce Billingsley Endowed Chair from May 2014-June 2015 and as the Dean of Engineering and the Raymond and Irma Giffels' Chair from 2003-2012. During 2012-2014, he served as the Vice-Chancellor of Galgotias University in Greater Noida, India while on leave from the University of Arkansas. Dr. Saxena also held various academic positions at Georgia Tech between 1985 and 2003 where he last held the position of Regents' Professor and Chair of the School of Materials Science and Engineering. Prior to joining Georgia Tech in 1985, he was a Fellow Scientist at the Westinghouse Research and Development Center in Pittsburgh, PA.

Dr. Saxena received his MS and PhD degrees from University of Cincinnati in 1972 and 1974, respectively in Materials Science and Metallurgical Engineering and his B. Tech degree in Mechanical Engineering from the Indian Institute of Technology, Kanpur in 1970. Dr. Saxena has made seminal contributions in linear and nonlinear fracture mechanics and its application to life prediction, reliability and risk assessment of structural components and in testing of structural steels. He is the author of over 250 research papers and reference books and two text books and has given invited lectures at numerous international conferences. He is a Fellow of ASTM (1994-), a Fellow of ASM International (1996-) and a Fellow of International Congress on Fracture (2009-) and a winner of numerous research excellence awards including the George Irwin Medal from ASTM (1992), Georgia Tech Outstanding Research Author Awards (1993), ASTM Fracture Mechanics Medal (2009), and the Wöhler Fatigue Medal from the European Structural Integrity Society (2010). In ICF, he has served as member of the Board of Directors (2001-2005, 2013-2017), Vice President (2009-2013), and Chair of the Awards Committee (2005-2013).