Preface to the Special Issue on the Sandia Fracture Challenge

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Published online: 11 February 2014
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Despite many advances in fracture mechanics and computational analysis methods over the past several decades, there are still certain classes of problems in failure of structural materials that are difficult to predict. One such class of problems can be generally categorized as ductile tearing of metals and alloys. Ductile tearing has been an enduring challenge in the metal forming industry, where certain rubrics like forming limit diagrams provide utilitarian solutions, but are limited in applicability. The 2012 Sandia Fracture Challenge was pursued as a means to evaluate the ‘state-of-the-art’ in prediction of ductile tearing.

As a precursor to the Sandia Fracture Challenge, a series of internal blind prediction assessments were performed at Sandia National Laboratories. These efforts, some of which were documented in a 2011 report [Report number SAND2011-6801], demonstrated the difficulty in accurate computational prediction of ductile tearing failures. Several deficiencies were highlighted: (a) the need for an accurate assessment of finite deformation as a prerequisite for accurate failure modeling, (b) the limitations of a tensile test as the sole

means to calibrate against an arbitrary failure mode, (c) the lack of consensus on a constitutive model for tearing. The issue of inadequacy of tensile data has been addressed in the sheet metal forming industry, where deep drawing over a mandrel or punch provides additional multiaxial data for the forming limit diagrams; yet there is no consensus that extends beyond sheet form factors.

The Sandia Fracture Challenge was designed to assess the ability of the mechanics community at large to address problems in the area of ductile failure of structural metals, beyond the scope of sheet metal forming. The idea was to issue a rather straightforward challenge to the community: predict the forces and displacements necessary to cause failure in a geometrically simple but mechanically complex structure. The geometry had never been seen or tested before, and the challenge was generally beyond the limits of intuition. Detailed tensile and fracture toughness test data were provided for the material of interest, consistent with data that is often available from metal suppliers. This challenge was offered to the mechanics community through two routes: (1) an open invitation on imechanica.org, and (2) targeted solicitation of specific active researchers in the field. No direct funding was provided to any of the participants. In this way, the Sandia Fracture Challenge depended entirely on volunteer contributions.

It is this spirit of volunteer community cooperation that is particularly remarkable. Without a broad sampling of a spectrum of state-of-the-art approaches to

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy’s National Nuclear Security Administration under contract DE-AC04-94AL85000.

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ductile fracture modeling, the exercise would have had less impact. There were over 50 volunteer participants involved in the Sandia Fracture Challenge, representing over 20 different institutions. Many of these participants used their evenings and weekends to not only perform their initial engineering prediction, but also to author this entire compendium of manuscripts. Moreover, these participants each risked the uncomfortable possibility that their model would perform poorly, and that the outcome might render personal judgment on their engineering prowess. While there was an offer extended to participants that their prediction could be anonymous, it is outstanding that all of the participants chose to maintain affiliation with their results. In this way, the mechanics community can have an open and honest discussion about what is and is not working for this class of problems in the current state. As a community, we can learn from these difficulties and implement improvements over time to make this class of problems more accessible. My sincere gratitude goes out to the participants of this challenge for their selfless dedication in the pursuit of community-based learning and growth.

I want to specifically thank several colleagues who have helped facilitate this exercise. Dr. Eliot Fang, a manager in computational mechanics at Sandia, encouraged me to engage the external community on this problem, rather than leaving it as an insular Sandia assessment. He also brought several contacts from the external mechanics community to help spawn broad interest in the project. Dr. Tom Moyer at the Naval Surface Warfare Center Carderock Division and Dr. Marty Dunn, then a program manager at the National Science Foundation, both were highly encouraging of this sort of exercise. Dr. K. Ravi-Chandar, was not only a willing participant, but his undying inquisition helped to drive some of the ‘discoveries’ that resulted from this challenge. As Editor-in-Chief of this Journal, he also paved the way to publish this Special Issue. And last but certainly not least, Dr. Charlotte Kramer, who as a new staff member at Sandia, tackled the bulk of the experimental validation testing, and was relentlessly dedicated to ensuring the accuracy of the test data.

The lead article for this Special Issue can serve as a stand-alone document for the outcome of this Sandia Fracture Challenge. It contains details regarding the motivation, approach, experimental observations, and a brief description of each of the 13 different modeling

methods employed. Most importantly, it contains a discussion regarding the observed deficiencies in current methods, guidance on the execution of similar challenges in the future, and some key areas where further exploration is needed. The lead article was written by 51 co-authors, a feat that may not be unusual for particle physicists, but truly a rare event for engineering mechanics. To facilitate gathering input from all participants, Sandia hosted a 2-day on-site writing workshop where much of the text was fleshed out by a group of authors. After the on-site workshop, several drafts of the manuscript were distributed among the participants to further hone the message, and ensure a document that did not represent one interpretation, but rather a group consensus. In addition to the lead article, all teams were offered the option to submit a full-length manuscript for inclusion in the Special Issue with more detail on their team’s approach and findings. Eight of the teams seized this opportunity, and those papers are included in this Special Issue. Finally, supplementary data for the Sandia Fracture Challenge, including videos of the failure process, can be found through the Journal’s website for the lead article and other articles.

I have been asked numerous times, “who was the winner of the Sandia Fracture Challenge”? Albeit a bit cliché, the real winner was the mechanics community as a whole, who can use the findings published in this Special Issue as (1) evidence that fracture is not a ‘solved problem’, (2) documentation on the state-of-the-art, and (3) motivation for the development of improved mechanistic understanding and improved computational methods. Within the papers published in this Special Issue, and especially within the lead article, you can make your own assessments of who was successful in the Sandia Fracture Challenge. But also I must make an important disclaimer: the findings here only illustrate the current state-of-the-art for the particular participants, their time limitations, and the current state of maturity for the techniques. Only by repeating this assessment numerous times with different materials, different challenge scenarios, different participants, and different prediction techniques, will we develop a comprehensive understanding of the current capabilities for predicting ductile failure of structural metals. There are many important facets to be explored such as dynamic fracture, complex load histories, high-temperature rupture, interfacial fracture, etc. It is with this imperative that I announce the second Sandia Fracture Challenge, tentatively scheduled to be

issued on May 15th, 2014 on imechanica.org. If you would also like to receive an e-mail invitation, please

notify me and Dr. Eliot Fang: blboyce@sandia.gov and hefang@sandia.gov.