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Author: Dr. Mark McElroy
National Aeronautics and Space Administration (NASA), United States

Mr. Raymond Patin
NASA, United States
Ms. Sarah Luna
NASA, United States

FRACTURE CONTROL FOR ADDITIVELY MANUFACTURED SPACECRAFT STRUCTURES

Abstract

This paper describes how the intent of current NASA fracture control requirements may be applied to "fracture critical" additively manufactured spacecraft hardware. Fracture control is a multi-discipline design and certification methodology that is applied in order to mitigate catastrophic failure of structures resulting from growth of an undetected crack-like defect. The methodology is defined in existing NASA standards and is required on all human-rated space structures. As legacy spacecraft structures have been built using primarily metallic and composite materials manufactured using well established methods, guidance for application of fracture control to parts composed of these material types has been established and is documented in several NASA requirements. Additive manufactured structures offer advantages in design flexibility and manufacturing efficiency and as a result are expected to continue to be used more and more in the future. Recently, relevant guidance has been published by NASA to define materials and processes requirements for certain additive manufactured hardware, but procedures for fracture control are not addressed yet in any requirements or guidance document.

While use of additive manufactured parts in non-critical scenarios may be of relatively low concern in current structural certification processes, there is a need for new fracture control guidance in order to use and certify additively manufacture hardware that is "fracture critical" where failure of the part may result in loss of life or loss of vehicle. Assurance of damage tolerance, i.e., that as-built flaws in a given part either do not exist or will not grow to become catastrophic, is of particular interest to the fracture control community. This poses a challenge due to the fact that damage tolerance behavior is not well understood in additive manufactured parts compared to legacy material types and manufacturing techniques.

The discussion contained herein is necessary at this time as new guidance in this area should be founded collaboratively by the technical community at large. Different hardware types (e.g., pressure vessel, structural member) are described to highlight specific challenges and solutions for each. The discussion concludes with considering specific disciplines within fracture control (non-destructive evaluation, materials processes, fracture mechanics, and structural certification) in a proposed extension of existing fracture control requirements to additive manufactured parts.