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Stress-Strain Behavior of an Aluminum Alloy under Transient Strain Rates

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Mechanics of Materials

Stress-Strain Behavior of an Aluminum Alloy under Transient Strain Rates

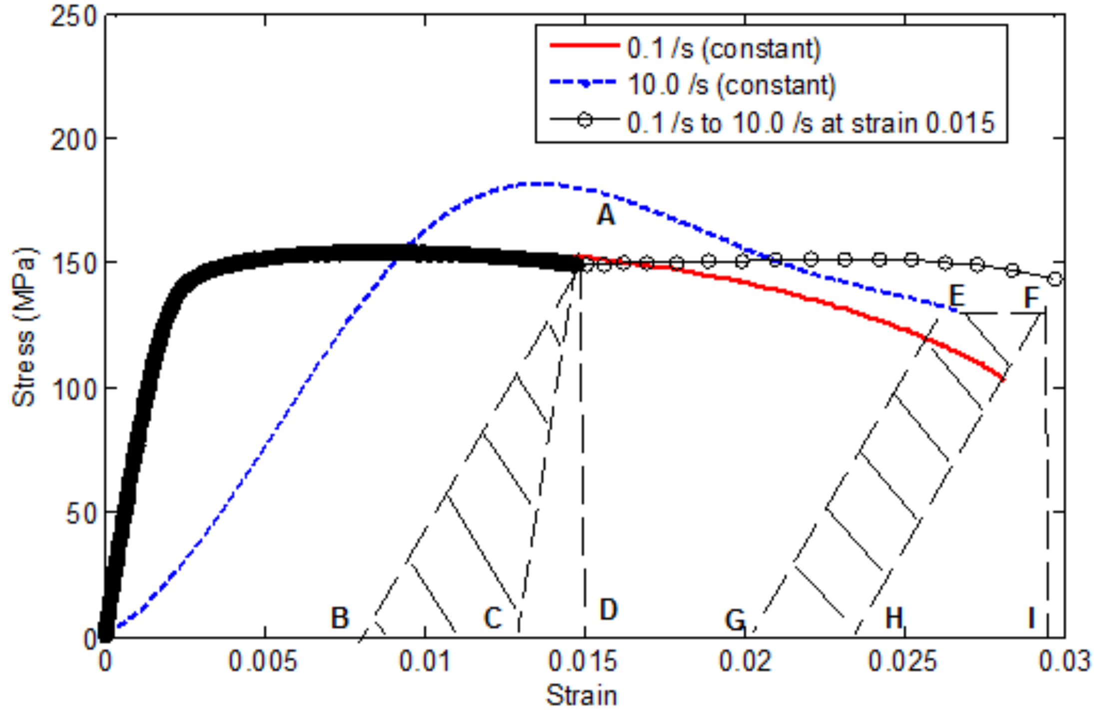
Young W. Kwon and Chanman Park

Overview

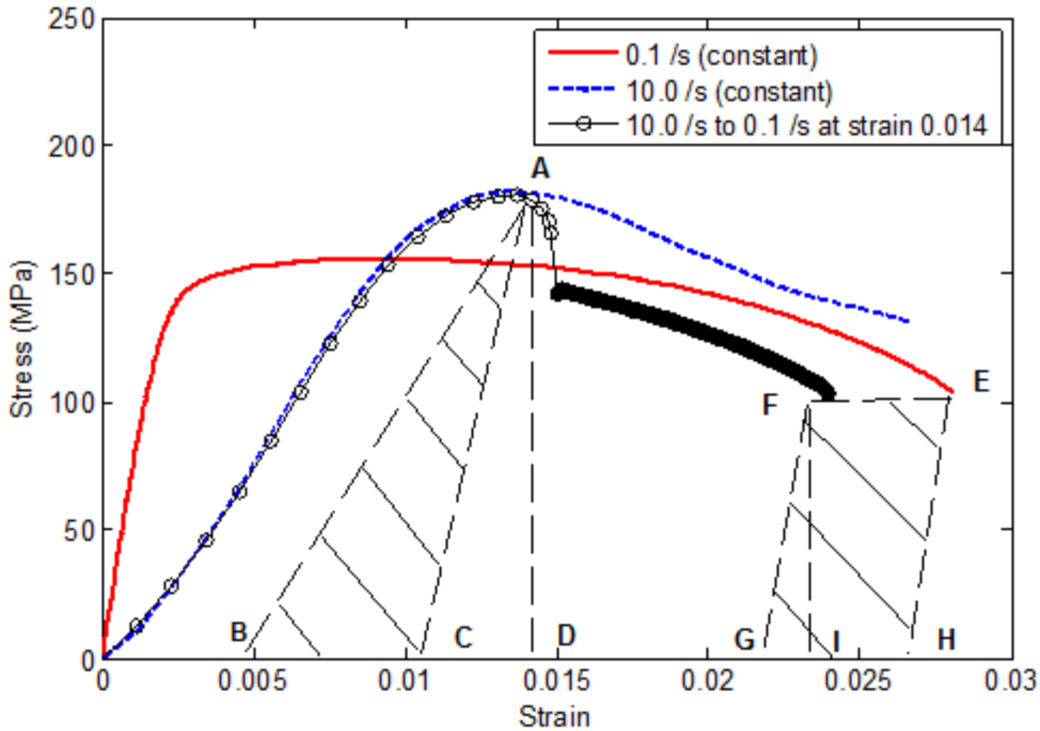
The objective of the study is to investigate the material behavior of aluminum alloy under varying (non-constant) strain rate loading and predict their behavior.

Project Description

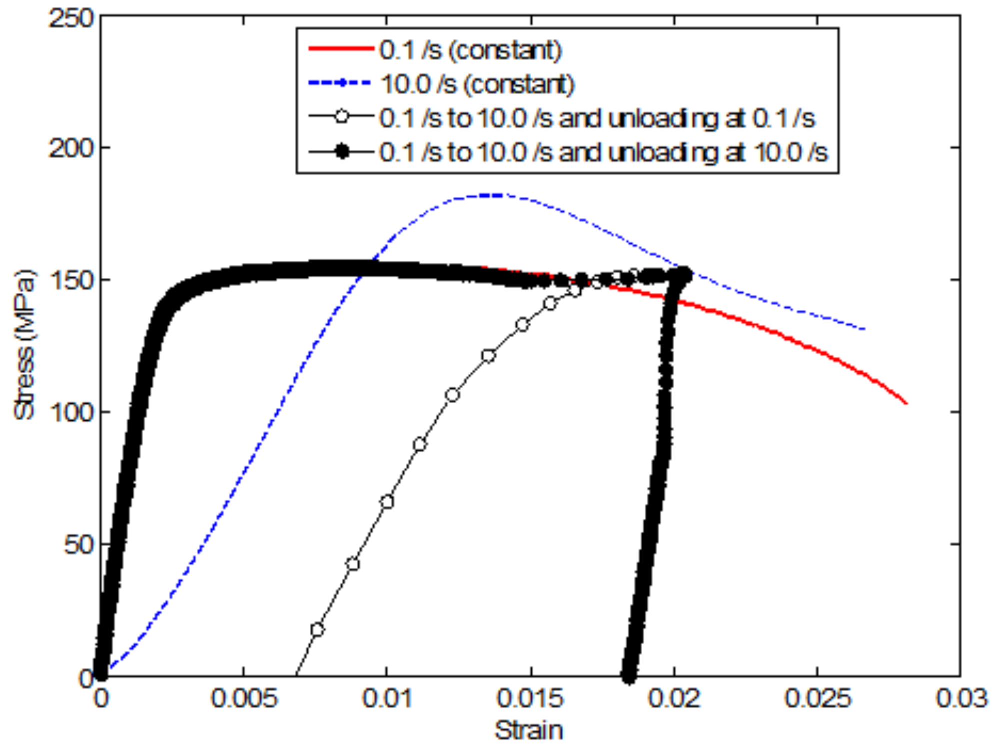
Because most structures are subjected to transient strain-rate loading, an experimental study was conducted to investigate the stress-strain behaviors of an aluminum alloy undergoing varying strain-rate loading. To this end, uniaxial tensile loading was applied to coupons of dog-bone shape such that each coupon underwent two or three different strain rates, i.e. one rate after another. As a basis, a series of single-strain-rate tests was also conducted with strain rates of 0.1 s-1 to 10.0 s-1. When the material experienced multi-strain-rate loading, the stress-strain curves were significantly different from any single-strain-rate stress-strain curve. The strain rate history affected the stress-strain curves under multi-strain-rate loading. As a result, some simple averaging of single-strain-rate curves did not predict the actual multi-strain-rate stress-strain curve properly. Furthermore, the fracture strain under multi-strain-rate loading was significantly different from that under any single-strain-rate case. Depending on the applied strain rates and their sequences, the former was much greater or less than the latter. A technique was proposed based on the residual plastic strain and plastic energy density in order to predict the fracture strain under multi-strain-rate loading. The predicted fracture strains generally agreed well with the experimental data. Another observation that was made was that the unloading stress-strain curve was not affected by the previous strain rate history.



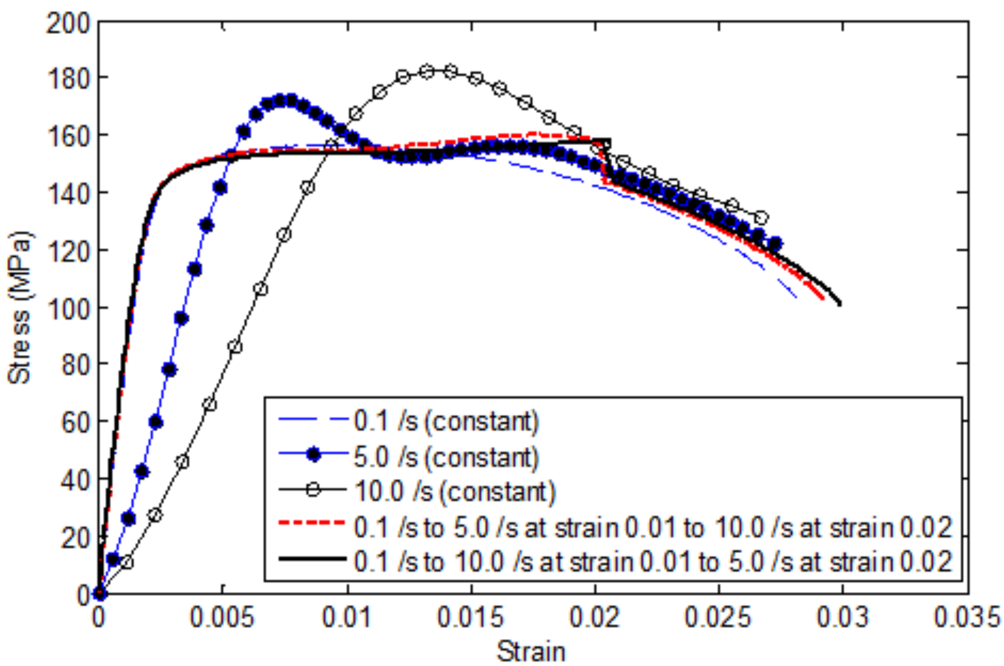
Stress-strain curve under two-strain-rate from 0.1 s^{-1} to 10.0 s^{-1}



Stress-strain curve under two-strain-rate from 10.0 s^{-1} to 0.1 s^{-1}



Stress-strain curves with unloading after applying two different strain rates



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Dynamic Response and Failure of Composite Structures with Fluid-Structure Interaction Under Impact Loading

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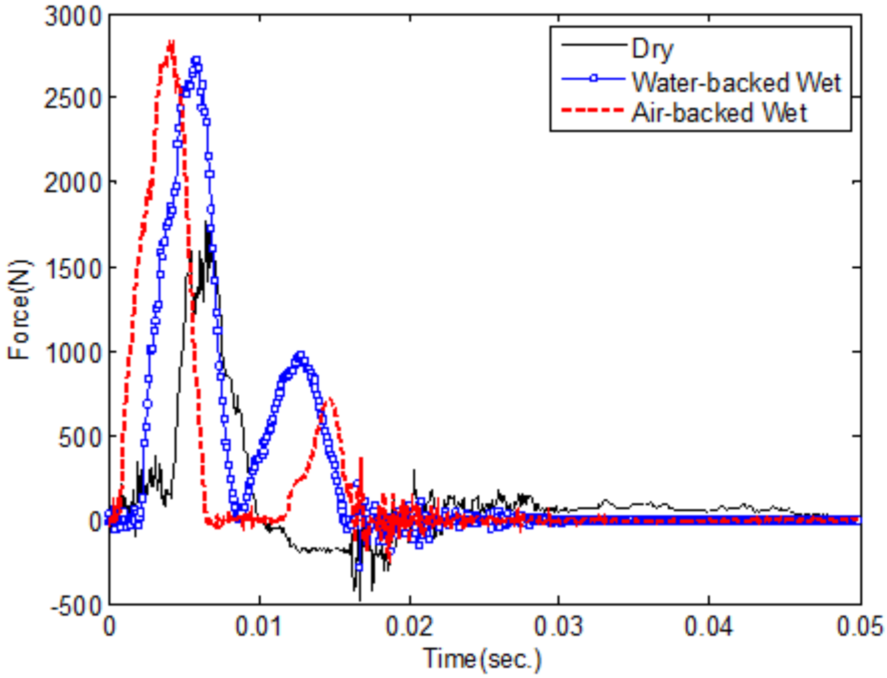
Overview

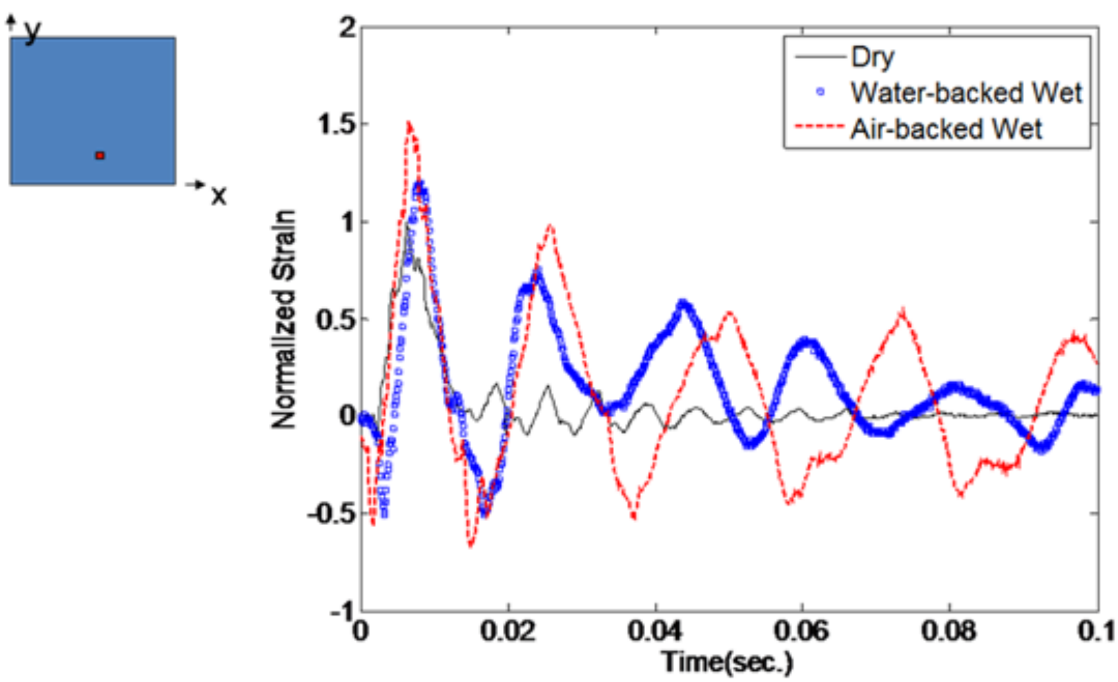
The objective of the study is to investigate the effect of fluid-structure interaction on the dynamic response and failure of composite and sandwich structures under impact loading. Both experimental and numerical studies are undertaken.

Project Description

The transient dynamic response of composite structures under water is affected by Fluid Structure Interaction (FSI), which results in an added mass effect as well as damping. Because the density of composites is comparable to that of water, the added mass effect becomes even more critical to the transient dynamic response of composites in water. In this study, experimental testing set-up was designed and fabricated, and testing was conducted to investigate FSI effects on composite laminate plates immersed in fluid and subjected to impact loading. Square composite laminates made of carbon fiber weave and vinyl ester resin were subjected to impact loading using a specially developed vertical drop-weight testing machine. The composite samples were fitted with gages to provide time-history on strains and impact forces generated during impact. Impact tests were performed on four-side clamped laminate plates in air-backed wet, water-backed wet, and dry environments. The results showed non-uniform effects on transient responses of wet composites with FSI. Generally, wet impacts on composite plates increased both transient impact forces and strains significantly compared to dry impacts under the same impact mass and velocity condition. The findings of this study will provide a better understanding for use of composite materials in underwater structural applications where impact loading is expected. A further study was conducted for failure of sandwich beam structures made of E-glass composites and balsa core. The data from this study showed that submerged samples failed at lower drop heights and lower peak forces with a failure mode dominated by center span skin compression failure. Beams in air were able to withstand higher drop heights and peak forces. Dry sample failure mode was dominated by compression failure at the boundary. The data from this study will increase understanding of cored composite characteristics subjected to underwater impact.



Comparison of impact forces among dry, water-backed and air-backed wet impact cases



Plot of strains along y-axis

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