Digital Imaging Analysis of Dynamic Deformation of Materials

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Introduction

During the design of certain engineering products, it is necessary to determine how materials will react when subjected to high strain rates. It is known that the strain rate at which a material is loaded largely affects its mechanical properties. In dynamic loading, the rate of change in the applied force is very large, having strain rates on the order of 10^3-10^5 s^{-1}. Therefore, it is essential to understand events that take place during ballistic impacts or high-speed mechanical processes such as vehicle accidents or machining processes. The objective of this research was to analyze the response of two different materials to a dynamic compression test conducted on a Split-Hopkinson pressure bar. The analysis will help develop stress-strain relations and verify which material will exhibit the ability to withstand the most stress under dynamic loading.

Approach

The experiment will be run 5 times for each of the two materials: 1045 steel and 6061 aluminum. Air pressure will be varied from 60 to 120 psi in 20 psi increments. The specimen is placed between the incident and transmitter bars. The air gun is filled with air at an indicated pressure, and then quickly released. The released air propels the incident bar towards the transmitter bar compressing the specimen. Strain gages measure the impulses of the waves and send this data to the oscilloscope to be analyzed later. The wave impulses from the oscilloscope signal an internal trigger in the Imacon 200 digital camera to record the deformation process.

Results and Discussion

Upon completion of the impact, still frames of various time steps during the dynamic loading event were analyzed, and the mode of deformation was determined. The frames are shown in Figure 1 and Figure 2 for 6061 Aluminum and 1045 Steel, respectively. Each frame was recorded at 25 nanosecond intervals. The set pressure was 80 psi.

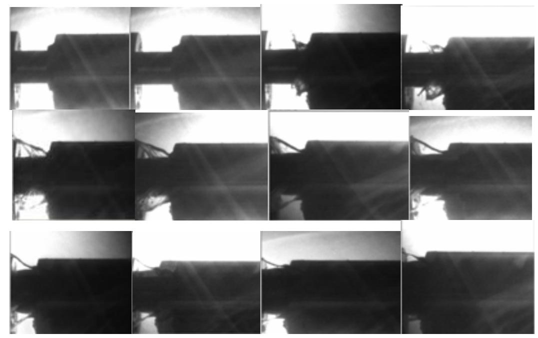

Figure 1: 6061 Aluminum

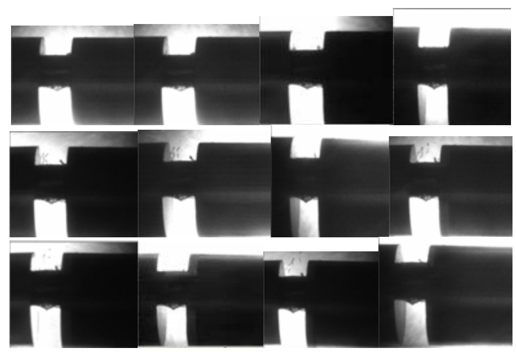

Figure 2: 1045 Steel

From the frames in Figure 1, aluminum showed a homogenous compression mode of deformation with no friction on contact surfaces. In Figure 2, initial impact produced no noticeable deformation in steel. However, as the frames progressed, steel exhibited a slight barreling mode of deformation with little friction on contact surfaces.

Future Work

In order to determine how each material responded to the dynamic stresses, the next step is to gather data recorded from the oscilloscope and transfer it to a Matlab program. The Matlab program utilizes wave propagation theory and the recorded voltages to display stress-strain curves of the tested material. Strain values can be found by integrating the strain rate. With the stress and strain values known, a stress-strain curve can be generated to determine which material can withstand the most stress.

References

1. Meyers, M.A., *Dynamic Behavior of Materials*. 1994, New York: John Wiley & Sons, Inc. p.23-25.