SAND2019-1999C

Study the deformation of solid cylindrical specimens under torsion using 360^o DIC

H. Jin, W.Y. Lu, Jay Foulk, Jakob Ostien

Sandia National Laboratories, P.O. Box 969, Livermore, CA, 94551, USA

ABSTRACT

In this work, the plastic deformation and ductile failure of solid Al 6061-T6 and 304L tube specimens under torsion loading was investigated using a new developed 360^o DIC system. The tube specimens of both ductile metals can exhibit very large rotation under torsion loading, which makes it very difficult to experimentally measure the deformation at failure. In our earlier work, 3D DIC system composed of one pair of cameras was applied to investigate the local deformation. The DIC system with one pair of cameras was only able to track the area of interest within a rotation angle of 90 degree or smaller. However, the specimens failed at rotation angles larger than 240^o. The DIC system with one pair of cameras was difficult to obtain the critical strain data at large rotation. In this work, a new 360^o DIC system which consists of four pairs of cameras was designed and incorporated into the experiment so that the whole surface can be imaged during the rotation. The new DIC system was able to track the area of interest and measure the deformation till the specimen failure. Shear strain at failure location can be measured and related to the global loading condition.

Keywords: Digital image correlation, shear loading, large deformation

INTRODUCTION

Fracture and failure in ductile metals is a complex issue, especially under shear dominated loading. There are numbers of efforts in numerical analysis and modeling of ductile fracture and failure, but very few experimental efforts. We have previously studied the ductile failure of Al 6061 under various combination of tension and torsion using thin wall tubular specimens. In this work, we conducted torsion experiments of solid cylinder specimens to introduce very large shear deformation. The traditional 3D-DIC technique with one pair of cameras was initially applied to measure the localized deformation at the shear band, but it faces difficulty of tracking the same area of interest due to large rotation angle. A new 360^o DIC system which consists of four pairs of cameras was designed for the torsion experiments to measure the deformation around the whole cylinder specimen and track the initiation of failure. This paper will discuss the multiple challenges facing the new DIC system.

SPECIMEN AND EXPERIMENT

Two types of materials are of interest in this work – Al 6061 and stainless steel 304L. The experiment was conducted using MTS table top Bionix system with both torsion and tension/compression capabilities. The specimens were gripped using the hydraulic grip at both ends. During the experiment, the axial force and displacement, as well as the rotation angle and torque were monitored. The specimen was maintained under zero axial force. The specimen was painted with black and white paint to generate speckle patterns for the DIC technique to measure the full-field deformation. Figure 1 shows the experimental setup with cylinder specimen in the middle and four pairs of cameras facing the specimen. Each pair of cameras have their own LED light facing the specimen. Each pair of cameras were able to capture 90 degrees of the specimen surface and four pairs of cameras captured the whole circumference of the specimen. Each pair of cameras need to be calibrated separately first to have accurate measurement in their own field of view. They are firmly mounted to the tripod to avoid relative motion between two cameras once they were calibrated. Meanwhile, all four pairs of cameras need to be secured tightly to avoid relative motion among each pair once they were set up and calibrated.

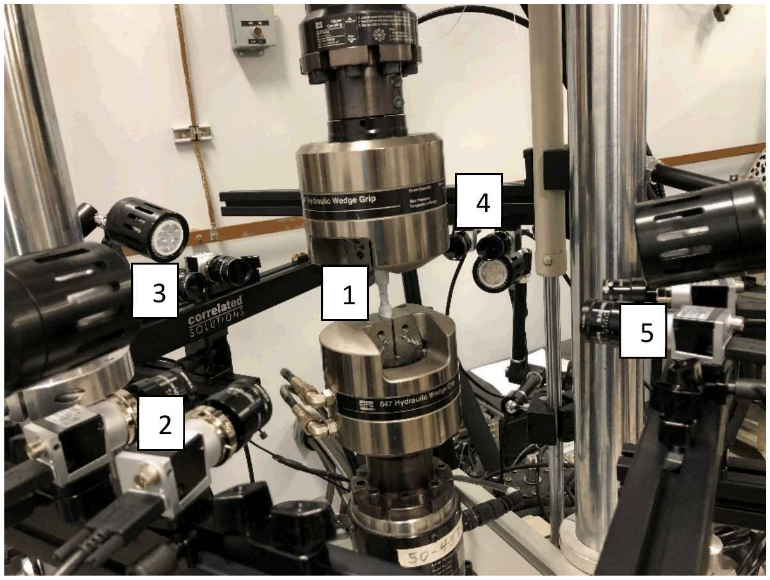

Figure 1 Torsion experiment setup with cylinder specimen in the middle and four pairs of cameras facing the specimen. 1- specimen, 2-5 DIC camera pairs and LED lights

ANALYSIS

To obtain the full-field displacement and strain from the DIC technique, two challenges need to be overcome: (1) Multi-View registration for the four pairs of DIC systems. (2) Tracking the same area in different DIC systems as the specimen underwent large rotation. As shown in Figure 2(a), the full-field deformation was first calculated from each individual DIC system in its own coordinate system. Then one system was selected as the reference system. The other systems were transformed to the reference system using the transformation tensor that was calculated from a common set of rigid body motion. The cylindrical view of the specimen can then be obtained based on the same coordinate system. Figure 2(b) shows the cylindrical whole field view after coordinate transformation.

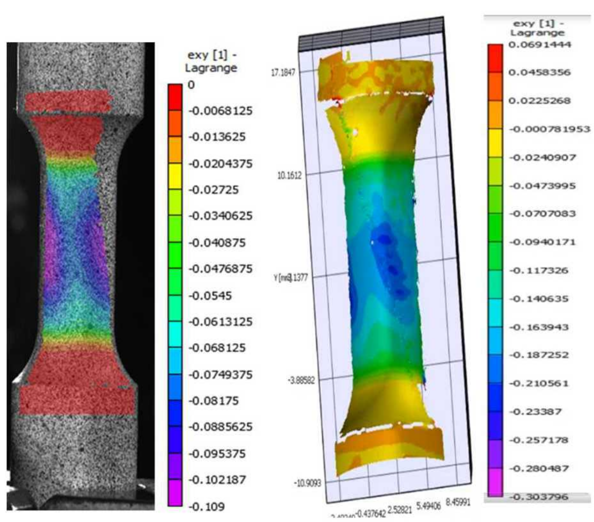

Figure 2: (a) DIC results from one system; (2) Combined DIC results from multi-systems after transformation

CONCLUSIONS

The new 360° DIC system was a powerful tool to obtain the full-field deformation around the whole cylindrical view of the specimen. It enabled us to understand the initiation of the ductile fracture and failure when the specimens underwent large shear deformation. However, challenges remained ahead as we aimed to obtain the deformation when the specimens rotated through views of multiple DIC systems.

Acknowledgement

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA-0003525.