HIGH-STRAIN-RATE EXPANDING RING TEST

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Ever since the inspiring work of Mott [1] on the explosive fragmentation of shells, the expanding ring test has been used as an effective tool for evaluating the dynamic constitutive and failure behavior of materials at strain rates of about 10^4 s^{-1}. Due to the complexity of the experimental configuration used in the expanding ring test, very few experimental results are available in the literature. A large database collected by Grady and Benson [2], which shows that the ring fails by generating a large number of localized necking deformation and a number of fractures at the neck points, has served as the main benchmark for analytical and numerical investigators. Two different points of view are prevalent in the literature, one is based on a statistical approach following on Mott and the other based on the growth of perturbations that localize deformation into necks (see for example, Guduru and Freund, [3]). Both approaches provide realistic predictions of the statistics of the fragmentation and its dependence on the rate of loading; hence additional experimental investigations that are instrumented to identify the appropriate necking and fragmentation mechanisms at these strain rates to are essential.

In this paper, we report on electromagnetically driven high-strain-rate expanding ring tests conducted on aluminum rings; this experiment is a recreation of the pioneering work of Niordsen [4]. With our experimental setup, these rings can be accelerated to 200 m/s expanding velocity corresponding to a strain rate of 10^4 s^{-1}. The main innovation in these experiments is the use of high-speed and high-resolution photography to study the dynamic necking and failure behaviors of the rings. The effects of expanding velocity, ring radius, and on the fragmentation of the ring were examined based on image analysis of high speed photographs and statistical analysis of ring fragments. Our results show that for the aluminum rings, almost all necks occur simultaneously without much communication between each other during the ring expansion; the fragmentation process – from the onset of the first fracture to the total fragmentation of the ring – is complete within about 10 μs. Since the complete time sequence of the strain evolution in the ring, the sequence of appearance of necks and fracture points is identified in the experiment, numerical simulations of any particular experiment, with the appropriate comparison to the measured kinematic quantities, can be performed to infer the constitutive and failure properties of the ring material. A comparison of the experimental results with numerical examinations based on an assumed elastic-plastic constitutive response for the material will be presented.

References

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