ME – PhD Thesis Colloquium

Experimental and numerical study of mechanics and mechanisms of mode I fracture of a textured magnesium alloy

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ABSTRACT

In recent years, magnesium alloys have gained increasing application in the automotive industry to achieve weight reduction in vehicle components which is crucial for enhancing fuel efficiency and meeting stringent emission requirements. However, it is of primary importance to understand the mechanics and mechanisms of fracture of these alloys since their toughness can be lower than aluminium alloys. Thus, the specific objectives of this thesis are to study the three-dimensional nature of notch tip fields, mechanics of ductile fracture and effects of temperature and loading rate on mode I fracture behaviour of basal-textured magnesium alloys.

Crystal plasticity-based finite element (CPFE) analyses are first performed to analyse the 3D nature of stationary mode I notch tip fields in a four-point bend specimen of a basal-textured magnesium alloy. Two notch orientations (TD-RD and ND-TD) are considered along with the isotropic von Mises material model to bring out the effect of anisotropy exhibited by this alloy. The simulation results agree well with a complimentary experimental study conducted pertaining to the TD-RD orientation. Also, they provide unique insights on the near-tip radial and thickness variations of stresses and plastic variables like slips and twin volume fraction for the two orientations. The mechanics of ductile fracture near a notch tip is investigated through CPFE simulations of an array of circular voids ahead of the notch tip subjected to mode I loading. The two notch orientations, as described above, along with the von Mises material model are considered here as well. It is found that the void growth mechanism depends strongly on notch orientation and initial porosity level. In particular, high hardening triggered by tensile twinning and pyramidal <c+a> slip retards void growth and enhances the crack growth resistance for the ND-TD orientation.

The effect of temperature and loading rate on mode I fracture in a rolled AZ31 Mg alloy, having a near-basal texture, is studied through carefully designed experiments. The high temperature experiments are conducted in the temperature range of 25 to 100 deg C using four-point bend specimens. The experiments at different loading impact speeds (ranging from 9 to 20 m/s) are performed with three-point bend specimens using a Hopkinson pressure bar. In both sets of experiments, in-situ optical images are acquired which are analysed by DIC to map out the displacement and strain fields. Microstructural analysis reveals that the fracture mechanism changes from twin-induced quasi-brittle cracking to ductile void growth and coalescence as temperature is raised from 65 to 100 deg C or as the loading changes from static to dynamic resulting in strong enhancement in the fracture toughness. This corroborates with the decrease in tensile twinning near the tip with loading rate or temperature. Simplified analyses are performed to rationalize the experimental results.

ABOUT THE SPEAKER

Arjun Sreedhar S is a PhD student in the Dept. of Mechanical Engineering, IISc Bangalore. He obtained his B.Tech degree in Mechanical Engineering from Govt. Engineering College, Thrissur in 2012 and M.Tech degree in Mechanical Engineering (Machine Design) from NIT Calicut in 2017. After B.Tech, he worked as senior engineer in L&T Constructions for two years. His research interests are broadly in mechanical behaviour of engineering materials.