A full-field method for characterising acoustoplasticity

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Background, Motivation and Objective

The plastic deformation of metals is key in many industrial forming processes. High-power ultrasonics has been demonstrated to reduce the force required to cause and maintain yielding during plastic deformation of metals, offering opportunities for significant improvements in process speed and energy demand. The effect, which was first observed in the 1950's, is known as acoustoplasticity. To date, research has been focused on simple test-piece configurations that apply ultrasonic excitation during standard tension or compression tests, with force and displacement measured at the cross-head. However, this is not appropriate as ultrasonic vibration imposes an oscillatory loading which varies spatially and temporally within the specimen. New experimental mechanics techniques, using synchronised imaging systems and experimentally refined simulation, present an opportunity to explore the material stress-strain relationship throughout the specimen as a basis for better characterisation of acoustoplasticity.

Statement of Contribution/Methods

Digital Image Correlation (DIC) was used to derive the evolving strain field during a tensile test with ultrasonic vibrations superimposed on the quasi-static loading. The specimens were of a soft 1000 series alloy to ensure the excitation of observable acoustoplasticity. To capture images of a quality sufficient for accurate DIC, a system was developed which captured images of very short exposure at intervals triggered at the same point in the oscillation cycle.

Using a Laser Doppler Vibrometer (LDV), the vibration velocity response was measured from a grid across the surface of the vibrating structure to create an Operational Deflection Shape (ODS). The ODS was not used to predict stress directly, but used to refine a numerical model in Finite Element Analysis (FEA) which in turn was used to predict stress and force at any location.

Results/Discussion

DIC produced a series of strain maps, e.g. Fig.1(a). The LDV velocity measurement, in Fig.1(b), was used to calibrate the FEA model, Fig.1(c). The next step used the model and the strain maps to derive the stress-strain relationship at discrete cross-sections through the specimen, enabling identification of acoustoplasticity and improved characterisation of this phenomenon.

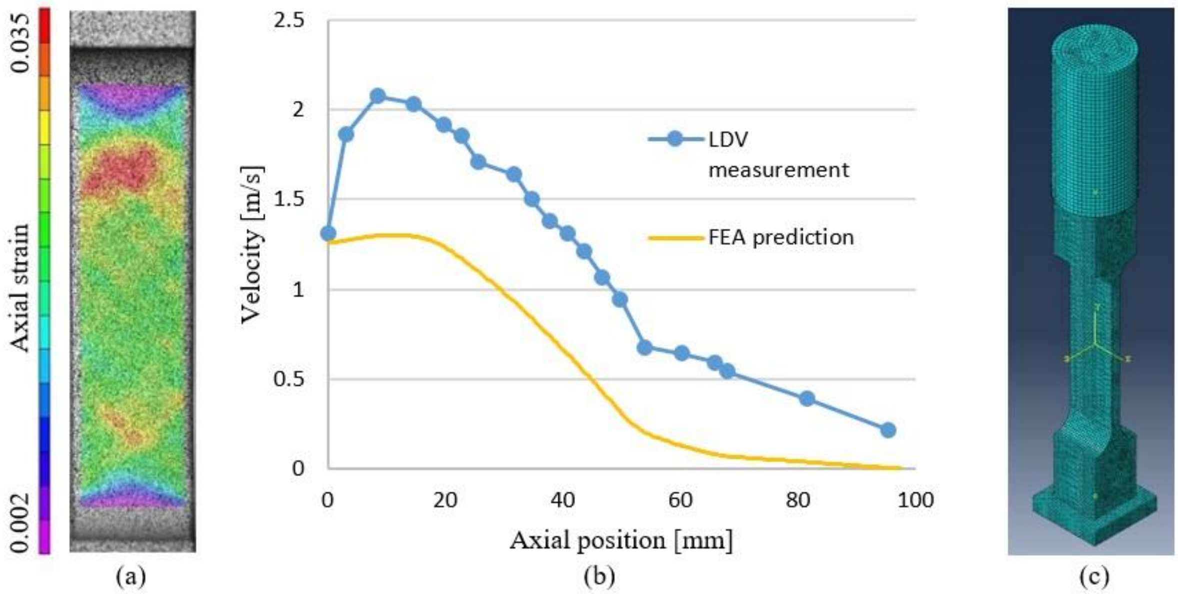

Fig.1 – (a) Typical strain map; (b) Velocity – experiment against simulation; (c) FEA model