A full-field approach to characterizing acoustoplasticity

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Introduction and backbround

The plastic deformation of metals is key in many industrial forming processes, from forging critical aerospace components to deep-drawing aluminium cans. 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 increase in process speed and reduction in demand on energy resources. The effect, which was first observed in the 1950's [1], is known as acoustoplasticity. To date, research has been focused on simple test-piece configurations that apply ultrasonic excitation during standard test-machine deformation, such that the fundamental physics of acoustoplasticity has not been exposed [2]. New experimental mechanics techniques, using ultra-high-speed imaging systems, present an opportunity for new methodologies to investigate further the link between fully characterised ultrasonic excitation inputs and resulting alteration of microstructure.

Developing a compatible full-field approach

Building on previous work [3, 4], 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 maximise the potential for 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 timed to coincide with the same point in the oscillation cycle. In addition, a thermal camera measured the temperature field to identify and verify regions undergoing high dynamic strain. Following the ultrasonic tensile test, the microstructural response was evaluated. A Scanning Electron Microscope (SEM) was used to examine the microtexture, comparing samples which had been subjected to ultrasound with one which had not. This was repeated for cross-sections at intervals along the length of the specimen to complement the full-field strain map. Characterisation of the microstructure was carried out using Electron Back-Scattering Diffraction (EBSD) to map misorientation of the metal grains, which is an indicator of the movement of dislocations, a key component of acoustoplasticity [5-7].

Conclusion

A new approach is presented for understanding the effects of ultrasonic excitation of metal forming processes, by recording the full-field strain evolution. This technique provides accurate quantitative measurement of the strain field on the specimen surface, showing where ultrasonic excitation enables greater plastic deformation. Further characterisations of the microstructural response at selected cross-sections of the specimens corroborated the DIC findings, identifying the influence ultrasonic excitation has on the alteration of grain shape and orientation.

References

[1] F. Blaha, and B. Langenecker, *Dehnung Von Zink-Kristallen Unter Ultraschalleinwirkung.* Naturwissenschaften, 1955. 42(20):556-556.

[2] A. Cardoni, A. Gachagan, and M. Lucas, *Research applications and opportunities in power ultrasonics.* Proc. Inst. Mech. C, 2009. 223(12):2949-2965.

[3] Y. Daud, M. Lucas, and Z. Huang, *Modelling the effects of superimposed ultrasonic vibrations on tension and compression tests of aluminium.* J. Mater. Process. Technol., 2007. 186(1-3):179-190.

[4] S.A. Aziz and M. Lucas, *Characterising the acoustoplastic effect in an ultrasonically assisted metal forming process.* IOP Conf. Ser.: Mater. Sci. Eng., 2012. 42:012017.

[5] V. Randle and O. Engler, *Introduction to texture analysis : macrotexture, microtexture and orientation mapping*. 2000, Amsterdam: Gordon & Breach.

[6] G.E. Nevill and F.R. Brotzen, *The Effect of Vibrations on the Static Yield Strength of a Low-carbon Steel.* Proc.- Am. Soc. Test. Mater., 1957, PRO1957-57: p. pp. 751 - 754 (or Pages: 8 (751 - 758)).

[7] R.K. Dutta, *et al*., *The effect of tensile deformation by in situ ultrasonic treatment on the microstructure of low-carbon steel.* Acta Mater., 2013. 61(5):1592-1602.