# Experimental study of dislocation avalanches during unstable plastic deformation

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The plasticity of crystalline materials is a collective phenomenon which results from the motion and interaction of defects of the crystal structure, particulary dislocations and solute atoms. Jerky flow of dilute alloys, also referred to as the Portevin-Le Chatelier (PLC) effect, is a spectacular example of the self-organization of nonlinear dynamical systems. Statistical and dynamical analyses of serrated stress-time series revealed such complex phenomena as self-organized criticality and deterministic chaos [1]. These dynamical regimes are characterized by power laws reflecting the property of scale invariance. Independently, power-law statistics were found for bursts of acoustic emission (AE) and local strain rate recorded during deformation of pure crystalline solids [2], which bears evidence to an intermittent, avalanche-like character of plastic activity, although at a macroscopic scale, the deformation process is viewed as being regular and homogeneous. These observations suggest that self-organization phenomena are of a general nature in dislocation ensembles, and may become apparent at various plastic event scales.

So far, the mesoscopic scale remains unexplored in the studies of jerky flow. Such experimental investigation is realized in the present work on an AlMg alloy - a classical material exhibiting the PLC effect. The multiscale character of the experimental approach is warranted by the application of a variety of techniques, including the measurement of stress-strain curves, the accompanying AE, and the local strain field through high-resolution extensometry. Correlation, statistical, and multifractal analyses are applied to these signals, each reflecting a specific aspect of the deformation processes, in order to characterize the organization of the dislocation dynamics during the PLC effect. The results show that the intermittency of plasticity in these conditions is not solely related to the macroscopic stress serrations, but manifests itself at a mesoscopic scale throughout the deformation. A particular accent is put on the statistical distributions of AE. It is found that AE is characterized by power-law statistics in all experimental conditions. In contrast, depending on the applied strain rate, the stress serrations display various types of statistical distributions, including power-law, peaked, and bimodal histograms. The observed behavior is discussed in terms of self-organized criticality and synchronization in extended dynamical systems.

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2. Weiss, J., T. Richeton, F. Louchet, et. al., Phys. Rev. B, 76, 224110, 2007.