

Wave Structure for Elastic-Plastic Flow and Entropy Anomalies

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Elastic-plastic flow is modeled by the Euler equations augmented by a rate equation for plastic strain. The plastic strain rate serves to relax the shear stress to the yield surface. The yield surface is analogous to a phase boundary across which the sound speed is discontinuous. The sound speed inside the yield surface (elastic region) is larger than the equilibrium sound speed outside the yield surface (plastic region). The elastic-plastic transition causes a compressive wave to split into a shock-like elastic precursor followed by a dispersed plastic wave. The plastic wave profile is determined by the dissipation from the plastic work. Due to the wave profile, transients when waves form or interact result in localized entropy anomalies. The entropy anomalies are similar to numerical ‘glitches’ that occur in fluid flow simulations using shock capturing algorithms, as exemplified by the Noh problem. For fluid simulations the glitches are artifacts or numerical errors. In contrast, the entropy anomalies in plastic flow are contained in the solution to the PDEs.

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Elastic-Plastic Flow

- One-Dimensional

- Isotropic material

- PDEs

- Constitutive model

- Plastic model

Wave Analysis

- Characteristics
- Equilibrium acoustic waves
- Elastic-Plastic transition
- Equilibrium Hugoniot locus

Canonical Wave Types

- Elastic wave
- Split wave
- Fully-dispersed wave
- Partly-dispersed wave
- Smooth profile

Entropy Anomalies

Piston driven fully-dispersed wave

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-

Entropy anomaly

Due to transient response whenever

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- (shock through material interface)

Fluid flow

Shock capturing algorithm displays similar anomalies

Example: Noh problem (“excess wall heating”)

Artifact (numerical error) due to numerical shock width

Effect of artificial length scale mimics physical phenomena

Transient Response

Impulsively started piston

Driving split elastic-plastic wave

Decay of elastic precursor

- Slow relaxation
- Rate increases with plastic strain
- Inverse problem