Compression experiments lead to shocking results

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Using acceleration 1 trillion times faster than a jet fighter in a maximum turn, researchers have gained new insight into dynamic compression of aluminum at ultrahigh strain rates.

Controlled shock compression has been used for decades to examine the behavior of materials under extreme conditions of pressure and temperature.

Using an ultrafast spectroscopic technique (used to track shocks on a time scale of ten trillionths of a second), Lawrence Livermore National Laboratory scientists Jonathan Crowhurst, Michael Armstrong, Kim Knight, Joseph Zaug and Elaine Behymer measured breakouts (driven by laser-induced shocks) in aluminum thin films with accelerations in the range of 10 trillion g's. The research appears in the Sept. 23 edition of the journal Physical Review Letters.

"The details of how solid materials rapidly deform on sub-micron-length scales have been the subject of speculation for decades," Armstrong said. "For the first time, our experiments can test fundamental scaling laws on time and length scales where they may start to break down at strain rates that are orders of magnitude larger than previously examined."

"In solids, a sufficiently large amplitude shock produces irreversible plastic deformation and relaxes the initial stress," Crowhurst said. "As the amplitude continues to increase, and if the shock drive is maintained, a steady-wave shock profile evolves, which propagates indefinitely without change in form."

But the team said that a fundamental understanding of shock-induced deformation is still lacking. In particular, little is understood about the behavior of materials, including metals, during the initial phase of shock compression and at high strain rates.

"Our original goal was not too ambitious," Crowhurst said. "We only wanted to show that measurements on ultrafast time scales could achieve consistency with longer time scale experiments. We did this, but then got a surprise – unexpected insight into shock wave phenomena."

The researchers measured shock rises in aluminum and obtained shock stresses, shock widths and strain rates. They used the information to test the validity, at ultrahigh strain rates, of the invariance of the dissipative action, as well as the dependence of the strain rate on the shock stress.

Though completely destroyed at the end of the experiment, the research team was able to see the aluminum being compressed to 400,000 atmospheres in about 20 trillionths of a second.

Provided by Lawrence Livermore National Laboratory

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