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A Theory for Stretchiness

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Physics

Focus: A Theory for Stretchiness

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Superplastic metal alloys can be easily molded into strong, yet complex shapes for airplanes and cars. A new theory attempts to explain at the atomic level why such materials can stretch so easily.

Superplastic alloys are so pliable that some can be stretched to more than 100 times their original length without breaking. The materials are easily shaped into strong parts for jet engines and high-performance cars. But despite decades of study, researchers do not yet understand fundamentally why superplastic materials are so stretchy. In the 11 September *PRL* a Chilean physicist describes a theory that explains superplasticity and is consistent with data on several alloys under a wide range of conditions. He proposes that the movement of atomic vacancies creates a “rolling action” that allows microcrystals to slide past one another as the material stretches.

Most everyday solids can elongate by, at most, one or two percent without breaking. Superplastic solids can elongate under physical stress by more than 200%, and some stretch far more. Engineers use superplastics to build metal parts that are thin yet strong. They warm an alloy until it enters its superplastic state–often above 700 K–create the desired part while the alloy is pliable, and then let it cool and harden.

Currently researchers understand some aspects of superplasticity, but not at the most microscopic level. John Pilling of Michigan Technological University in Houghton suggests thinking of a superplastic as “a rubber bag filled with ball bearings, with some molasses in between.” The ball bearings are grains of crystalline material less than 10 μm across. When the material is stretched, the ball bearings stay intact, but they move about to accommodate a longer, thinner rubber bag. When the bag is one ball-bearing thick, it can stretch no more. Researchers have known for decades that the grains were crucial for superplasticity, but no one understood the process by which grains slide past one another.

According to the new work by Miguel Lagos of the University of Chile in Santiago, the molasses between the ball bearings corresponds to grain boundaries. One way in which the perfectly ordered material in a grain breaks down at a boundary is by exhibiting vacancies–points in the crystal structure where an atom is missing. At all but the lowest temperatures, an agitated atom has enough energy to move from its assigned spot in the crystalline grain into a vacancy, so the vacancy moves. In Lagos’s theory, vacancies in grain boundaries move in closed loops between two grains as the grains push against one another, facilitating the relative motion of the grains without harming the structure of the grains themselves. According to Lagos, the vacancies in the grain boundaries function much like the rollers of a conveyor belt.

Experimenters measure the rate at which superplastics stretch depending on the pulling force applied and the size of the grains. Pilling applauds the theory because no existing models could adequately explain the data, while Lagos’s theory has matched the data well for six different alloys, for several grain sizes, over a range as wide as 200 K in temperature. “It’s about bloody time” for such a creative theory on superplastics, says Pilling. “It’s so original and refreshing, and it seems to work so well.”

–Brandon Brown

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Highlighted article

Elastic Instability of Grain Boundaries and the Physical Origin of Superplasticity

Miguel Lagos

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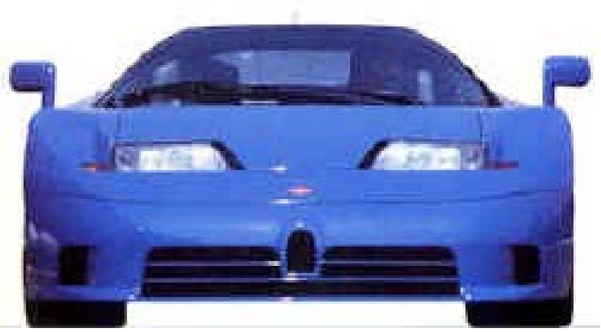
Figures



Superform Aluminium

Souped-up superplastic. Parts of the Bugatti EB110 are made from superplastic aluminum alloys, which can be easily molded into complex shapes. A new theory attempts to explain at the atomic level why such materials can stretch so easily.