ABOUT THE IMAGES

Hot metal cooling after casting.
(TDHSTER / SHUTTERSTOCK.COM)

Rolling mill processing steel plate. How metals are processed affects their microstructure and hence their properties.
(SAYAM TRIRATTANAPAIBOON / SHUTTERSTOCK.COM)

Ford F-150 trucks now use high-strength aluminum rather than steel for their body, reducing weight and increasing efficiency and pulling power.
(DRIFTING LIGHT / SHUTTERSTOCK.COM)

TOUGH STUFF

Extreme Materials for Extreme Challenges

Bombs that work reliably are important to U.S. national security. That requires knowing how the materials in a bomb behave under extreme conditions. Several decades of fundamental research supported by the DOE Basic Energy Sciences office created new understanding and practical tools to predict how metals deform, how they age, how they fail, and how to make them stronger. The impact of that knowledge has transformed not just the management of the U.S. nuclear weapons stockpile, but also virtually every sector that uses metal—steel and aluminum, energy, automotive, aircraft, and other industries.

The Breakthrough

Understanding how the composition of a metal alloy—and how that metal is processed—both affect the microstructure of metals and in turn control their behavior.

- This knowledge, painstakingly acquired over decades of research, is now embedded in widely-used computer programs that can predict behavior and that can thus be used to design stronger alloys. Both bomb makers and the automotive industry use the same program to test new weapons designs or how a truck bumper will perform in a crash.
- Similar programs are used by steelmakers and aluminum manufacturers to guide metal processing in ways that reduce defects and enable lighter and stronger materials for many applications.

The Impact

New alloys and the ability to predict behaviors under extreme conditions have transformed entire industries.

- Updating nuclear weapons in the U.S. stockpile will require new manufacturing practices, and the Nuclear Posture Review envisions a more agile and flexible deterrent. Both of these will call upon the BES-enabled science base.
- The ability to accurately predict embrittlement and stress cracking caused by the intense radiation in nuclear reactors has allowed regulatory authorities to extend operating licenses from 40 to 60 years, with 80 years now under consideration.
- Widespread use of lighter, stronger alloys has benefited cars, airplanes, and many other applications. Ford F-150 trucks, for example, now use high strength aluminum for their bodies, rather than steel, reducing weight and increasing pulling power.

The Takeaway

Fundamental research into the behavior of metals has paid off in unexpected ways. As the U.S. sets out to upgrade its infrastructure, the ability to design and manufacture materials that are stronger, lighter, and better able to resist corrosion will repay that original investment many times over.

Adapted from chapter 2 of A Remarkable Return on Investment in Fundamental Research, U.S. DOE, June 2018.
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