A new way to make lighter, stronger steel -- in a flash

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A Detroit entrepreneur surprised university engineers here recently, when he invented a heat-treatment that makes steel 7 percent stronger than any steel on record – in less than 10 seconds.

In fact, the steel, now trademarked as Flash Bainite, has tested stronger and more shock-absorbing than the most common titanium alloys used by industry.

Now the entrepreneur is working with researchers at Ohio State University to better understand the science behind the new treatment, called flash processing.

What they've discovered may hold the key to making cars and military vehicles lighter, stronger, and more fuel-efficient.

In the current issue of the journal *Materials Science and Technology*, the inventor and his Ohio State partners describe how rapidly heating and cooling steel sheets changes the microstructure inside the alloy to make it stronger and less brittle.

The basic process of heat-treating steel has changed little in the modern age, and engineer Suresh Babu is one of few researchers worldwide who still study how to tune the properties of steel in detail. He's an associate professor of materials science and engineering at Ohio State, and Director of the National Science Foundation (NSF) Center for Integrative Materials Joining for Energy Applications, headquartered at the university.

"Steel is what we would call a 'mature technology.' We'd like to think we know most everything about it," he said. "If someone invented a way to strengthen the strongest steels even a few percent, that would be a big deal. But 7 percent? That's huge."

Yet, when inventor Gary Cola initially approached him, Babu didn't know what to think.

"The process that Gary described – it shouldn't have worked," he said. "I didn't believe him. So he took my students and me to Detroit."

Cola showed them his proprietary lab setup at SFP Works, LLC., where rollers carried steel sheets through flames as hot as 1100 degrees Celsius and then into a cooling liquid bath.

Though the typical temperature and length of time for hardening varies by industry, most steels are heat-treated at around 900 degrees Celsius for a few hours. Others are heated at similar temperatures for days.

Cola's entire process took less than 10 seconds.

He claimed that the resulting steel was 7 percent stronger than martensitic advanced high-strength steel. [Martensitic steel is so named because the internal microstructure is entirely composed of a crystal form called martensite.] Cola further claimed that his steel could be drawn – that is, thinned and lengthened – 30 percent more than martensitic steels without losing its enhanced strength.

If that were true, then Cola's steel could enable carmakers to build frames that are up to 30 percent thinner and lighter without compromising safety. Or, it could reinforce an armored vehicle without weighing it down.

"We asked for a few samples to test, and it turned out that everything he said was true," said Ohio State graduate student Tapasvi Lolla. "Then it was up to us to understand what was happening."

Cola is a self-taught metallurgist, and he wanted help from Babu and his team to reveal the physics behind the process – to understand it in detail so that he could find ways to adapt it and even improve it.

He partnered with Ohio State to provide research support for Brian Hanhold, who was an undergraduate student at the time, and Lolla, who subsequently earned his master's degree working out the answer.

Using an electron microscope, they discovered that Cola's process did indeed form martensite microstructure inside the steel. But they also saw another form called bainite microstructure, scattered with carbon-rich compounds called carbides.

In traditional, slow heat treatments, steel's initial microstructure always dissolves into a homogeneous phase called austenite at peak temperature, Babu explained. But as the steel cools rapidly from this high temperature, all of the austenite normally transforms into martensite.

"We think that, because this new process is so fast with rapid heating and cooling, the carbides don't get a chance to dissolve completely within austenite at high temperature, so they remain in the steel and make this unique microstructure containing bainite, martensite and carbides," Babu said.

Lolla pointed out that this unique microstructure boosts ductility -- meaning that the steel can crumple a great deal before breaking – making it a potential impact-absorber for automotive applications.

Babu, Lolla, Ohio State research scientist Boian Alexandrov, and Cola co-authored the paper with Badri Narayanan, a doctoral student in materials science and engineering.

Now Hanhold is working to carry over his lessons into welding engineering, where he hopes to solve the problem of heat-induced weakening during welding. High-strength steel often weakens just outside the weld joint, where the alloy has been heated and cooled. Hanhold suspects that bringing the speed of Cola's method to welding might minimize the damage to adjacent areas and reduce the weakening.

If he succeeds, his discovery will benefit industrial partners of the NSF Center for Integrative Materials Joining Science for Energy Applications, which formed earlier this year. Ohio State's academic partners on the center include Lehigh University, the University of Wisconsin-Madison, and the Colorado School of Mines.

Provided by The Ohio State University

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