PRESS RELEASE

Innovative Steel Casting: TRIP/TWIP Effect Paves the Way for Safer and More Sustainable Components

Fraunhofer IWU and the TU Bergakademie Freiberg have achieved a breakthrough in steel casting technology. Their development of a cold-formable, copper-alloyed austenitic steel cast with TRIP/TWIP properties marks a milestone in material science. It also opens up entirely new perspectives for safety-critical applications. The new alloy offers an unprecedented combination of strength and ductility: it is highly load-bearing and can still undergo plastic deformation.

The Secret of the TRIP/TWIP Effect

The core of this innovation lies in the so-called TRIP/TWIP effect, which gives the new steel casting its exceptional properties. TRIP stands for "Transformation Induced Plasticity" and TWIP stands for "Twinning Induced Plasticity." These mechanisms cause the microstructure within the material to change under stress, leading to a significant increase in strength and ductility.

- TRIP Effect: Under mechanical stress, part of the austenite, a soft and tough phase, transforms into martensite, a stiff and strong phase. This transformation leads to local hardening and increases resistance to cracking.
- TWIP Effect: In this case, deformation twins form in the austenite. These twins also contribute to the hardening and increased toughness of the material.

Both effects enhance the ability of the material to absorb mechanical energy or improve its tensile strength:

“By combining these two effects, the strength of the material increases significantly, and component failure under dynamic loading sets in later. Furthermore, the formability and energy absorption capacity in the event of an impact are greatly improved,” explains Nadine Lehnert, who leads the project at Fraunhofer IWU within the DFG-funded research project "Cold Forming of Steel Castings."

How It Works: The initial form of the steel casting alloy is transformed through cold bulk forming in a product with a fine-grained, re-transformed austenitic microstructure. The manufacturing route begins with a coarse-grained austenitic structure. First, a die reduces the diameter of the workpiece. This mechanical stress leads to a partially martensitic structure due to the TRIP/TWIP effect. The subsequent heat treatment in the furnace results in a reduced grain size (fine-graining) of the component, thanks to the reversion

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of martensite back to austenite. Under high stress, a crack may develop in the item, specifically in the austenitic structure, but it will not lead to failure. Instead, the martensitic transformation of the microstructure stops further cracking. The subsequent hardening (martensite) of the material even increases load-bearing capacity.

Applications with High Safety Potential

The unique properties of the new steel casting make it ideal for safety-critical applications, where demands for strength, toughness, and reliability are particularly high.

- **Automotive**: Screws, chassis components, crash absorbers, and body structures could benefit from high energy absorption and crash safety.
- **Aerospace**: Structural components and fasteners can become lighter and more resilient with the new steel casting.
- **Medical Technology**: The strength and biocompatibility of implants and surgical instruments could increase.
- **Construction and Infrastructure**: Mountain anchors and fasteners for bridges and tunnels would gain in safety thanks to enhanced crack resistance. The alloy excels where durability under extreme loads is crucial.

Energy-Efficient Cold Forming as a Key Technology

Another key advantage of the new steel casting is its suitability for cold bulk forming. This process allows components to be manufactured at room temperature, making energy-intensive processes such as hot rolling unnecessary. "The cold-forming process chain is significantly shorter and more efficient. We start with a pre-cast workpiece, which is then directly formed. This eliminates numerous energy-intensive steps such as heating, rolling, and pickling, which are required in hot forming," explains Lehnert.

Sustainability and Economic Efficiency in Focus

In addition to the technical benefits, the development of the new steel casting also contributes to sustainability and economic efficiency.

- **Resource Conservation, Health Considerations**: The partial substitution of nickel with copper reduces the use of expensive and scarce resources and risks to health during processing.
- **Energy Savings**: Cold forming consumes significantly less energy than hot forming, which leads to less CO2 emissions.

- **Cost Efficiency**: The streamlined process chain, reduced material usage, and less gas consumption (due to cold bulk forming) help lower production costs.

A Look into the Future

These findings form the basis for the targeted use of the TRIP/TWIP effect in safety-critical applications. Future research at Fraunhofer IWU will focus on optimizing the forming process and precisely tailoring material properties. “Our goal is to fully exploit the potential of the TRIP/TWIP effect and enable the cost-effective production of high-performance components for various applications,” says Lehnert.

Fig. 1 In mountain anchors, which secure rock walls along transport routes, tunnel walls, or mining chambers in underground construction, falling rock material can cause damage to the anchor. In the examined cold-formed alloy, this stress leads to a re-hardening of the material. Connection elements also benefit from this effect. © Fraunhofer IWU

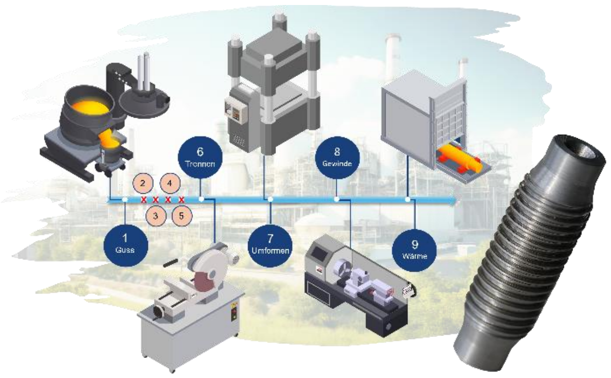

Fig. 2 Manufacturing of connection elements from wire semi-finished products: Compared to the traditional process chain, cold bulk forming eliminates the steps of hot rolling (2), heat treatment (3), pickling (4), and cold drawing/rolling to final dimensions (5) Annually, 1.5 GJ/t of energy and 40 tons of CO2 could be saved in Germany. © Fraunhofer IWU/Freepik

Gefördert durch DFG Deutsche Forschungsgemeinschaft

The project "Alloy and Microstructure Design of Austenitic Cr-Ni-Cu-N Cast Steel with TRIP/TWIP Properties for Cold Bulk Forming" by Fraunhofer IWU and the TU Bergakademie Freiberg was funded by the German Research Foundation (DFG).

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