Fraunhofer
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# Modeling High-Strength and Highly-Ductile Sheet Metals from TWIP-Steels

**In recent years, a significant increase in research activities dedicated to high strength steel sheet metals in the automobile industry has been seen. In order to meet high demands while simultaneously realizing appropriate shapes, the steel industry has developed a new class of high-strength, highly-ductile steel: a Fe-Mn, alloy system based TWIP steel (twinning induced plasticity). The Fraunhofer Institute for Mechanics of Materials IWM has undertaken a project, along with five project partners, which uses material modeling to take into account the special properties of this material class. This should yield a more accurate interpretation of the sheet metal forming processes and component evaluation than has previously been possible.**

This class of steel combines the required strength with high ductility. For example, with a tensile strength of approx. 1000 MPa, an elongation of 40 – 50% is ultimately reached: this is a combination of properties that cannot be achieved with conventional steels. This is one of the indicators as to why TWIP steels are so interesting to the automobile industry: by using TWIP steels, both the energy absorption of components and the structural safety of the vehicle can be significantly improved. The strength of this material allows for a reduction of the sheet thickness used in components and contributes to a more efficient use of resources.

## Deformation Behavior of TWIP Steels

In contrast to conventional steels, where plastic deformation occurs through the movement of dislocations, in the case of TWIP-steels and so-called “twinning” an additional deformation mechanism is activated. The orientation of the crystal lattice in a grain changes within lamellar-shaped areas which have a width of 10 - 30 nm. These segments, referred to as twins, inhibit the movement of dislocations. This lead to a dynamic microstructure refinement, which accounts for the higher strength and strain hardening rate of TWIP steels. This effect is schematically depicted in Figure 1.

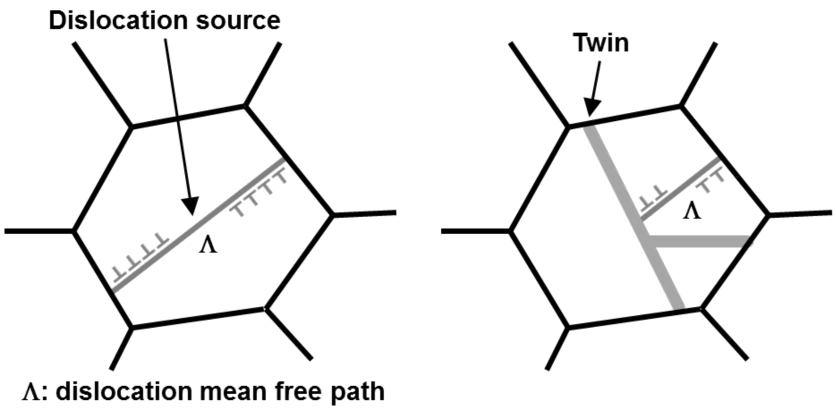


**Fig. 1:** *Illustration of the dynamical Hall-Petch effect. The creation of twins inhibits dislocations.*

Material models are required for the simulative process design and component characterization of TWIP steel and make it possible to precisely predict forming behavior and to provide successful approaches for industrial application. This type of model is currently being developed as a goal of the EU-funded project TWIP4EU. Alongside the Fraunhofer IWM, which acts as project coordinator are five project partners: DYNAmore GmbH, ESI GmbH, Faurecia Autositze GmbH, Swerea KIMAB AB and Salzgitter Mannesmann Forschung GmbH. The focus of the project is divided between material characterization, material modeling and implementation as well as the validation of findings.

## Material Modeling

The differences in macroscopic behavior compared to conventional steels are identifiable because of the TWIP effects. For example, the strain hardening of TWIP steels is dependent on the loading condition. As an illustration of this, experiments have shown that there is less hardening under shear stress than under uniaxial tensile load. The cause for this effect has been presumed to be dependent on the twinning rate under different loading conditions.

Scientists at the Fraunhofer IWM have developed an appropriate material model so that the mechanical properties of TWIP steel can be accurately described. An essential characteristic of this model is the physically based description of microstructural properties and especially the evolution of the twin volume fraction depending on deformation and state of stress. The development of these microstructural properties is directly considered when calculating macroscopic material behavior.

Figure 2 shows the mechanical stress and evolution of the twin volume fraction as a function of the logarithmical strain in a uniaxial tensile test. A comparison with the experimental data shows that both the macroscopic behavior and the microstructural properties can be accurately described by the model in a uniaxial tensile test.

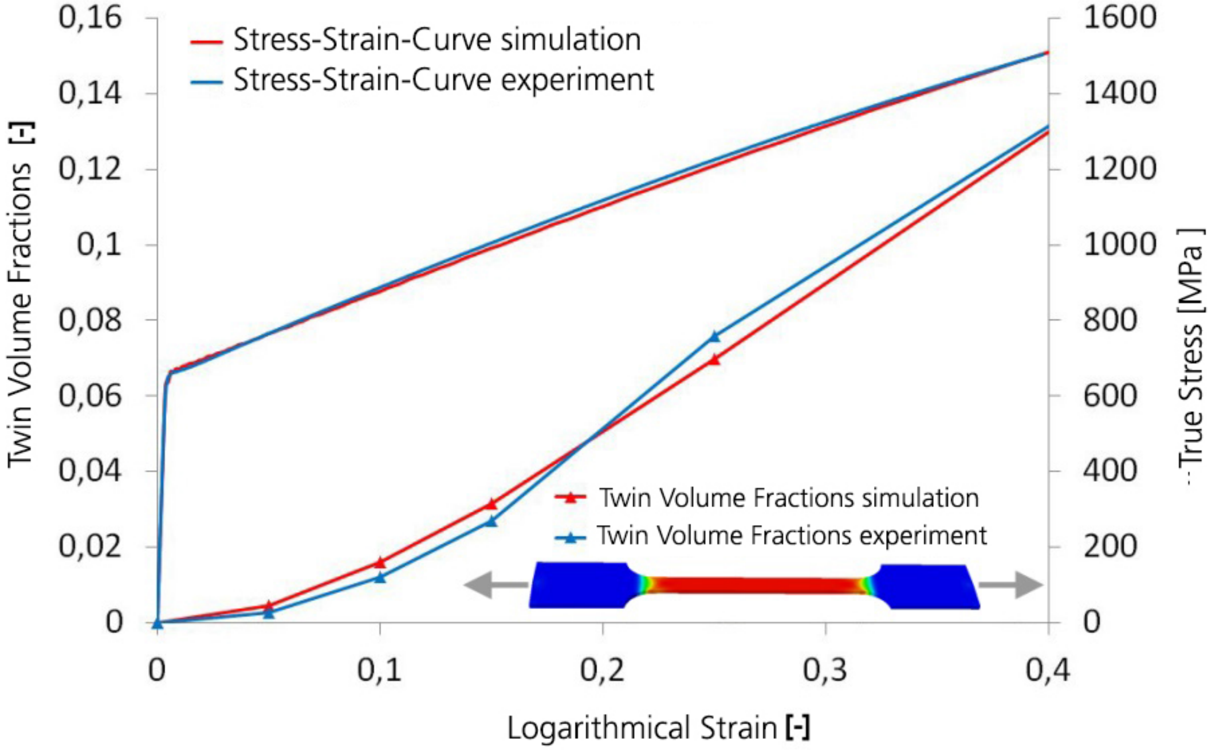


Figure 2: Comparison between the experimental data and simulation model of the stress-strain curve and the evolution of the twin volume fraction.

In the course of the project, the component illustrated in figure 3 will be analyzed. This, on the one hand, has a complex geometry which requires a high degree of formability. On the other, the component is crash relevant so must be sufficiently strong. The first forming experiments with the component using TWIP steel were successful, as depicted in figure 3. In the next step, the current design can be optimized in consideration of the special properties of TWIP steel using the TWIP4EU developed material model.

The conclusion of the research project should provide a material model which can be made available in a commercial software package such as LS-Dyna or PAM-Stamp. This model will be able to characterize the special material properties of TWIP steel and will be used to carry out forming simulations of sheet metals made from TWIP steel with industrially required precision.


Figure 3 shows a backrest sidemember, chosen as a suitable TWIP steel manufactured demonstrator part for the validation of the developed material model.


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