TWIP/TRIP STEELS. FUTURE TRENDS IN AUTOMOTIVE INDUSTRIES

R. Pla-Ferrando S. Sánchez-Caballero, M.A. Selles, A.V. Martínez-Sanz
Universitat Politècnica de Valencia, Pl. Ferrándiz Carbonell, s/n, 03801 Alcoy, Spain
rpla@mcm.upv.es

Keywords: AHSS , Twip Steel , Metal Forming, Stamping,

Abstract: This paper aims to introduce a new type of steels which promise to have high relevance in future automotive structures. They will probably change the way the structural elements are now designed. First the most significant properties are described. Then environmental profits of its implantation are described. Finally the conclusions shows its suitability for a wide range of applications where an increase of safety with weight reduction are required.

1. INTRODUCTION.

In 2005, Arcelor and ThyssenKrupp Stahl Auto, the two main suppliers of European automotive steel, decided to join their efforts to develop a new family of manganese steel (TWIP steels). This news opened the door to the possibility of further reductions in vehicle weight. Considered by many people as a innovation, TWIP steels can present significant changes in the design and production of cars.

Five years earlier, Georg Frommeyer, the Max-Planck-Institut IRON FOR RESEARCH published an article called *Supra-Ductile and High-Strength Steels Manganese-TRIP/TWIP for High Energy Absorption Purposes[1]* . Frommeyer research has developed around steels with high manganese content (15 to 30%), and additional quantities of silicon and aluminum.

2. THE AUTOMOTIVE INDUSTRY

Cars are involved in a strong change during de last years. A car is built from many different materials, but the main structure – known as the Body In White (BIW) – is usually made of steel pressings welded together to form a strong ,stiff and secure frame.

BIW refers to the stage in automobile manufacturing in which a car body's sheet metal components have been welded together. Is the stage of the manufacturing process before moving parts (doors, hoods, and deck lids as well as fenders) ,the motor, chassis sub-assemblies, or trim (glass, seats,airbagas, upholstery, electronics, etc.) have been added and before painting.

This method of construction, with steel, accounts for 99.9 per cent of all the cars produced in the world. The remaining 0.1 per cent are mostly constructed with an aluminium BIW, while a very small number (less than 0.01 per cent) are constructed from carbon-fibre composite[2].

The BIW of a vehicle accounts for 20 per cent of the vehicle mass. The weight of the closures (doors, bonnet and boot/rear hatch), chassis (suspension parts) and driveline bring the total amount of steel and other ferrous metals to more than 60 per cent.

A Golf, Astra , Ford Scort or Toyota Corolla (C segment Car) weighed about 7500 N in de 70`s. Since then, the weight has increased a five percent for every model change. Nowadays any of these models has duplicated its weight. The reason is clear, people needs air conditioning systems, ABS, ASR, airbag, hybrid vehicles, an average of 20 engines, and other control systems[2, 3].

Technically there are two conflicting requirements, on the one hand increasing comfort and safety, and the other, emission reduction and sustainability. In order to be fulfilled must ensure that the constituent parts of the vehicles are lighter weight and higher performance as well as lower consumption than the old elements. And this required not only by competition between brands, but European legislation such as the NCAP safety, the Euro 5 diesel emissions target the New Vehicle 130 g/km CO_2 for 2012-2015 and by 2015 ELVD "95% per vehicle mass reused / Recovered, 85% per vehicle mass reused / recycled "

Scientists and designers have worked to produce new materials, decreasing the weight of steel in automobiles, and increasing passengers' safety. Simultaneously, new methods of production an design have been developed, like New Steel Body(NSB®) by Thyssen Krupp with enormous weight savings.

3. THE NEW STEELS.

We can classify the steels used in the body of a car into three groups depending on its tensile strength: Mild Steels (<300MPa), Ultra High Strength Steels (>700MPa) (AHSS), and High Strength Steels (HSS) between of the two previous ones.

During the last years, significant advances have been done in the second group, named advanced high strength steels (AHSS), steels designed for lighter BIW and cheaper cars. The evolution has been constant, and nowadays we can speak of a third generation of AHSS, positioned in the gap located between the first and third generation.

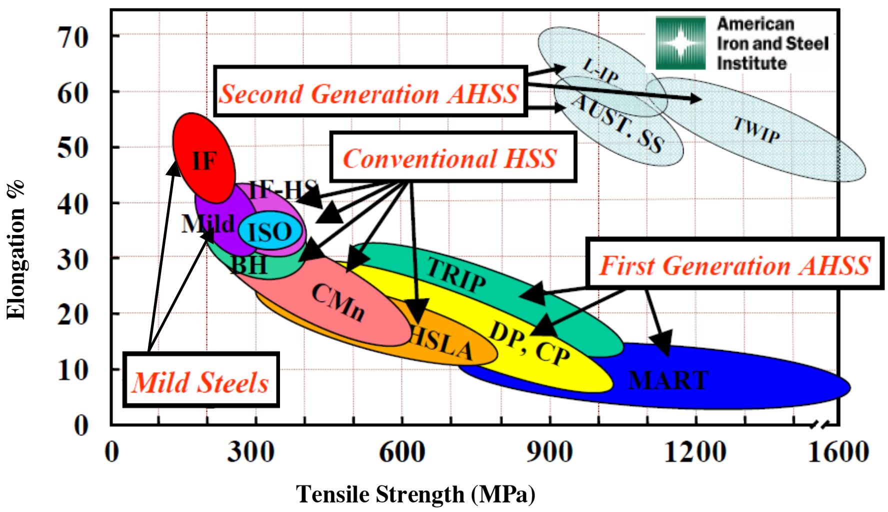

Figure 1. The Three generations of AHSS. The third in the gap between the other two.

The main difference between conventional steels HSS and more advanced AHSS is its microstructure. In the HSS is a ferrite single phase, while AHSS are multiple phases, which may contain ferrite, martensite, bainite, and / or retained austenite in quantities sufficient to produce different mechanical properties. Some types of AHSS have increased hardenability and strength-ductility properties longer than conventional steels.

The manufacture of the AHSS is more complex than conventional steels. Control in manufacturing should be greater since it is based on the percentages of different phases present. Within this classification, we find the so-called Dual Phase (DP), Transformation-Induced Plasticity (TRIP), Complex Phase (CP), High-strength low-alloy (HSLA) steel Ferritic-bainitic (FB), Twinning-Induced Plasticity (TWIP), Hot-Formed (HF) Post-Forming Heat-Treatable (PFHT).

TWIP steels (Twinning-Induced Plasticity) have a high content of manganese (17-30%), which determined that the steel is fully austenitic at room temperature. This makes the main mode of deformation is the twinning within the grains. The twinning causes a high value of instantaneous hardening rate (**n** value) with a very fine microstructure. The boundaries of the resulting twins act as grain boundaries and reinforcing steel. TWIP steels combine an extremely high resistance to a very high formability. The **n** value increases to a value of 0.4 with an engineering strain of approx. 30% and remains constant up to a total elongation of about 50%. The tensile strength is greater than 1100 MPa, and its ability to deformation can reach 95%. According to information provided by Arcelor Auto + Thyssen Krupp can reach a deformation of 35% for a resistance of 1400 MPa. TWIP steels have exceptional capacity absorb crash energy.

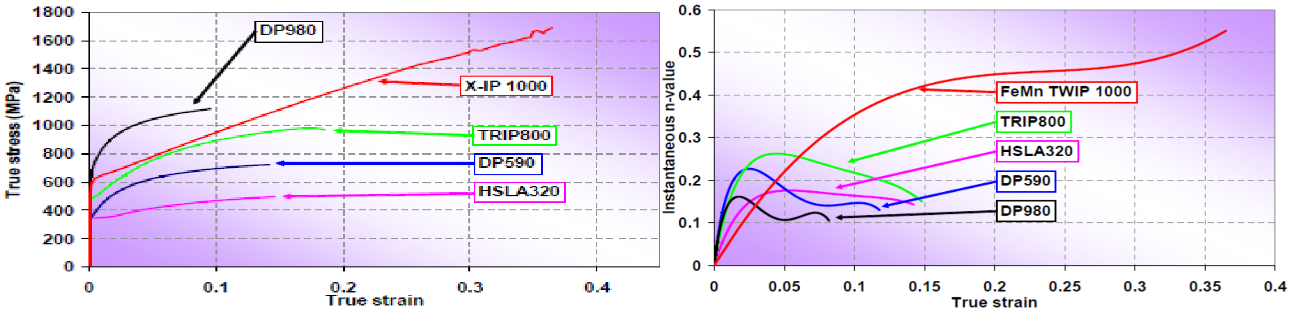

Figure 2. TWIP (X-IP 100) and other AHSS Stress-Strain curves. Strain hardening exponent (n) evolution. (Source Arcelor)

Advances in design methodologies and manufacturing are unstoppable. A BIW today is composed of a structure of parts of different steels. Each element has a defined role, composition and structure of the steel is best fit. It is possible to find 10 different types of steel in a vehicle[4]. AISI forecasting is to reduce the average consumption of steel per car by 8% between 2007 and 2015, reducing the use of Mild Steel in 6.5%, and increasing the use of AHSS steels.

4. STEEL MANUFACTURING AND THE ENVIRONMENT. DSC TECHNOLOGY.

Direct Strip Casting (DSC) can to make steel coils in a continuous process, with hot reduction of 60 to 70%[5]. Process description: The melt is fed on a revolving steel conveyor belt via a dispenser system. The belt, acting like the mould in conventional continuous casting, is intensively water-cooled from below. Solidification (primary cooling) and secondary cooling takes place in a protective atmosphere (shrouding: Ar, Ar / CO2). Hence, material losses are reduced and adverse effects on product quality due to oxidation are avoided. In the secondary cooling zone, a homogeneous temperature distribution at a level suitable for rolling is adjusted. Afterwards, the yielded strip (cast thickness range: 10 - 15 mm) is conveyed into an in-line rolling mill (3- or 4-step rolling) , and enabling the coverage of 90 % of the thickness range of a typical hot-rolling mill. The final downstream (tertiary) cooling and the coiler correspond to those used in conventional casting technology.

High Mn-containing TRIP/TWIP HSD® steels: The characteristics of the DSC process, is th.e.rapid solidification under a protective gas atmosphere, no friction, the absence of bending, spraywater cooling and casting powder, and a sufficient degree of hot reduction, offer, as mentioned, prospects for the production of new steel grades with higher amounts of alloying elements, e.g. **Mn**(≈ 10-27 %), **Si** (< 3 %), **Al** (< 6 %) and **C** (< 2 %).

The enhancement of strength and ductility values, compared to conventional steels, is achieved by using the TRIP- and TWIP-effect, and corrosion resistance [6] depend on chemical composition and process control.

4. INTERST IN TWIP STEEL. THE FUTURE.

When Frommeyer´s research became public, a race began. An important number of researches have been made; the biggest steel producers and important automotive producers have reached TWIP steel patents in a short time. Now it is being investigated to reduce the cost of TWIP.

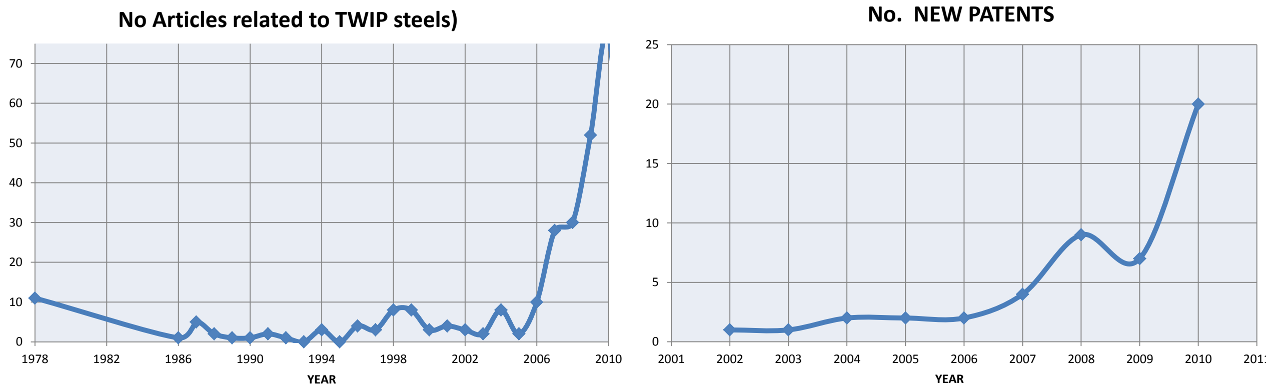

Figure 3. No Articles related to TWIP steels (Source Scopus) and new patents (Source Free Patent)

5. REFERENCES

[1] **O. Grässel**, *et al.*, "High strength Fe-Mn-(Al, Si) TRIP/TWIP steels development -- properties -- application," *International Journal of Plasticity,* vol. 16, pp. 1391-1409, 2000.
[2] **C. AUTOMOTIVE**, "POCKET BOOK OF STEEL," *CORUS AUTOMOTIVE,* 2009.
[3] **B. C. De Cooman**, *et al.*, "High Mn TWIP Steels for Automotive Applications, New Trends and Developments in Automotive System Engineering," *InTech Marcello Chiaberge (Ed.),* pp. 101-102, (2011).
[4] **D. K. Matlock and J. G. Speer**, "Third Generation of AHSS: Microstructure Design Concepts," ed, 2009, pp. 185-205.
[5] **K. H. Spitzer**, *et al.*, "Direct Strip Casting (DSC) - An Option for the Production of New Steel Grades," *Steel Research International,* vol. 74, pp. 724-731, 2003.
[6] **L. Mujica**, *et al.*, "Development and characterization of novel corrosion-resistant TWIP steels," *Steel Research International,* vol. 82, pp. 26-31, 2011.