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Comparison Study between TBF and Q&P Steels in Sheet Metal Forming: An Overview

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Abstract - *The modern automobile industry reached a high level of development of steel grades with extraordinary strength and formability, through different new production processes and new processing strategies. The third generation of advanced high strength steel is a new concept that have been developed lately and have already been incorporated in the modern car body structures. The main objective of this work is to review some recent third-generation advanced high strength steel grades applied in sheet metal forming processes mainly from the viewpoint of automotive industry.*

Key Words: AHSS, mechanical properties, automotive industry, microstructure…

1. INTRODUCTION

Sheet metal forming is one of the most important processes to produce wide range of consumer and industrial products. In this process, sheet metal material is a very important parameter to be considered, especially in the automotive industry, where the goal is to reach a very good size and shape of vehicle parts at the fastest and economical possible way. However, steel is favoured for automotive applications since many years, because it has preferable properties and many beneficial features like the changeability in strength levels and flexibility concerning formability [1].

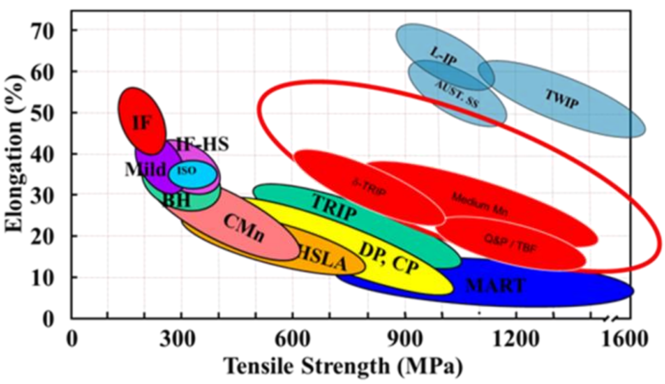

Fig -1: Various automotive steels and their corresponding elongations and tensile strengths [2]

Therefore, the competition in car manufacturing besides the market requirements for weight reduction, enhanced fuel efficiency, elevated safety precautions, and increasing comfort requirements; leads to a huge development of new steel grades with a high strength-ductility combination.

In this work, the present state of development will be overviewed concerning the application of recent third generation of advanced high strength steels grades (3-GEN AHSS) in sheet metal forming processes mainly from the viewpoint of automotive industry.

2. THIRD GENERATION AHSS

All the three generations of AHSS has been developed in order to satisfy as much as possible all the functional performance needs for the modern vehicle's parts (see Figure 1). Each generation of AHSS has a unique chemical composition, mechanical properties, and microstructures, processing routes, advantages and disadvantages in their applications.

The 1-GEN AHSS including dual-phase (DP), complex-phase (CP), and transformation-induced plasticity (TRIP) steels have high strength but lower formability.

The 2-GEN AHSS consisting of the Twinning Induced Plasticity (TWIP) steels, some austenitic Stainless Steels (AUST SS), with high manganese (Mn) content makes their application for the automotive industry so expensive [1]. Furthermore, we have to mention in this group the Lightweight Induced Plasticity – L-IP steels, too.

The 3-GEN AHSS including quenching and partitioning (Q&P), TRIP bainitic ferrite (TBF) steels, and the others are still under development (medium manganese, density reduced TRIP (δ-TRIP) and nano steels). All 3-GEN AHSS grades are characterized by multiphase constituents (ferrite, martensite, bainite and metastable/retained austenite).

3. TBF AND Q&P STEELS

The conventional TRIP steels that belong to the 2-GEN AHSS have many features like the high ability to be formed into complex components during forming operations with global deformation such as deep drawing, but when it comes to the cutting or hole expansion operations, where localized deformation is required it will lead to cracks formation. The retained austenite in this steel transform into martensite in the plastic zone, which called the trip effect. Resulting to the development of internal stresses, and consequently the propagation of micro-cracks [3, 4]. Figure 2 shows a schematic comparison of the development of dislocation density in Mild, DP, and conventional TRIP steels [5]. Where in TRIP-assisted steels, the formation of additional mobile dislocations by the TRIP effect exhibited further improvement in the work hardening of TRIP steels. Thus, enhancement for both strength and ductility. However, to reduce the hardness differences between the phases, enhancing the primary matrix (ferrite) is one of the solutions to avoid this matter, by replacing it with TBF steels (bainite) or Q&P steels (tempered martensite) lath structure [6].

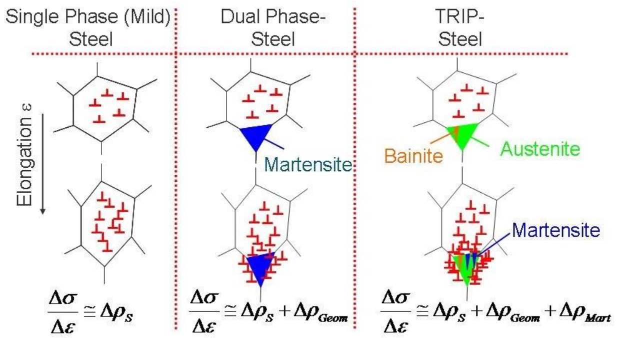

Fig -2: Schematic comparison of the development of dislocation density in Mild, DP, and conventional TRIP steels [5]

The image below (Figure 3) [7], shows the microstructure of the TBF and Q&P steels as observed in the scanning electron microscope (SEM). TBF steels are essentially bainitic ferrite matrix, and for the Q&P steels are consisting of martensite. In addition to metastable retained austenite inclusions in the both microstructures. Clearly, the retained austenite will transform partially to martensite under the TRIP effect, leading to better enhancement of low edge crack susceptibility and high ductility combination, and that gives an excellent performance during the deep drawability operations for both steels [8].

However, the Q&P steel matrix is harder than the TBF steel matrix, and consequently the internal stresses are slightly inferior in the first steel. For this reason, the hole expansion and bendability of TBF steels is a little bit lower compared to Q&P steels. Krizan et al. [9] investigated the influence of the Nb–V microalloying added to conventional TRIP steel on its phase transformations, precipitation state, microstructural evolution during processing and final mechanical properties. They showed that the formation of harder microstructural compounds in the matrix at lower annealing temperatures, resulting in an improvement of hole expansion λ. This confirms the better performance of Q&P steels during the hole expansion and bendability compared to the TBF steels, as shown in Figure 5.

Tensile strength levels for Q & P and TBF steels are usually between 1,000 and 1,500 MPa, with total elongation between 10% and 20%. Bachmaier et al. [10] have investigated the influence of typical continuous annealing line processing parameters on the microstructure and mechanical properties of the industrially produced TBF and Q&P steels with a minimum tensile strength of 980 MPa. Figure 4. shows the spider diagrams of the mechanical properties obtained from the experimental results using a tensile test for specimens with a gauge length of 80 mm measured in longitudinal and transversal direction. It can be claimed that Q&P steel

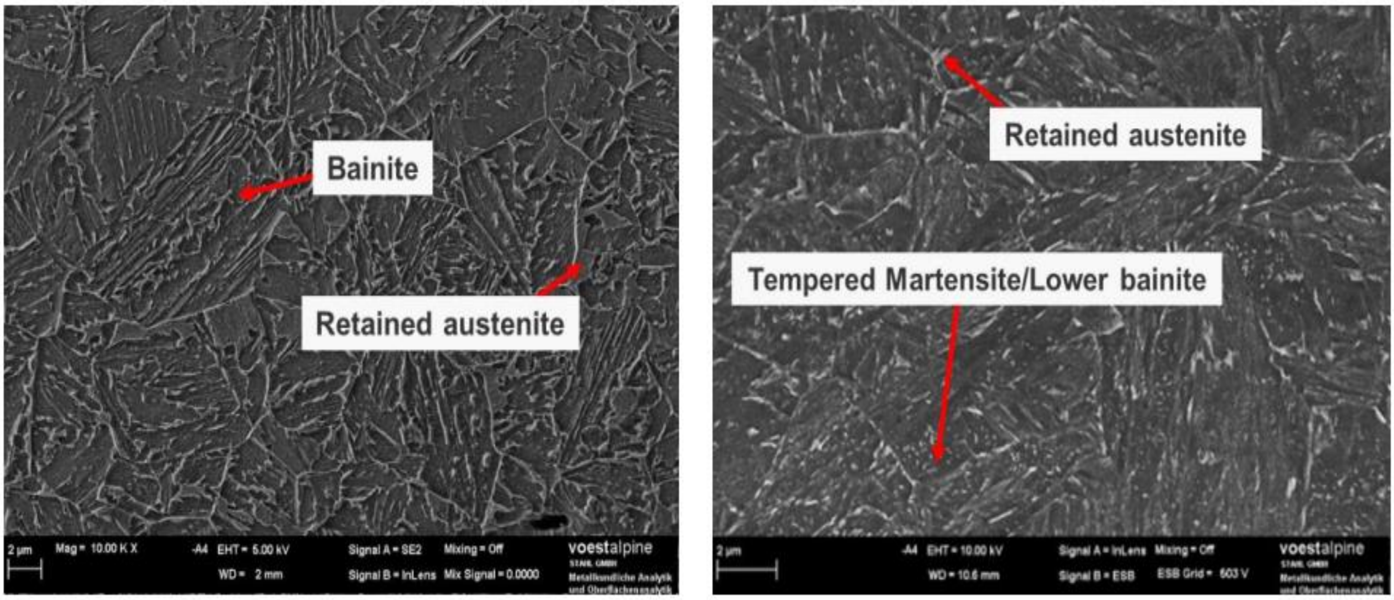

Fig -3: SEM micrographs of TBF steel (left) and Q&P steel (right) [7]

characterized by a lower total elongation and higher yield strength compared to the TBF steel, which means both steels could be used in various structural and safety automobile co-

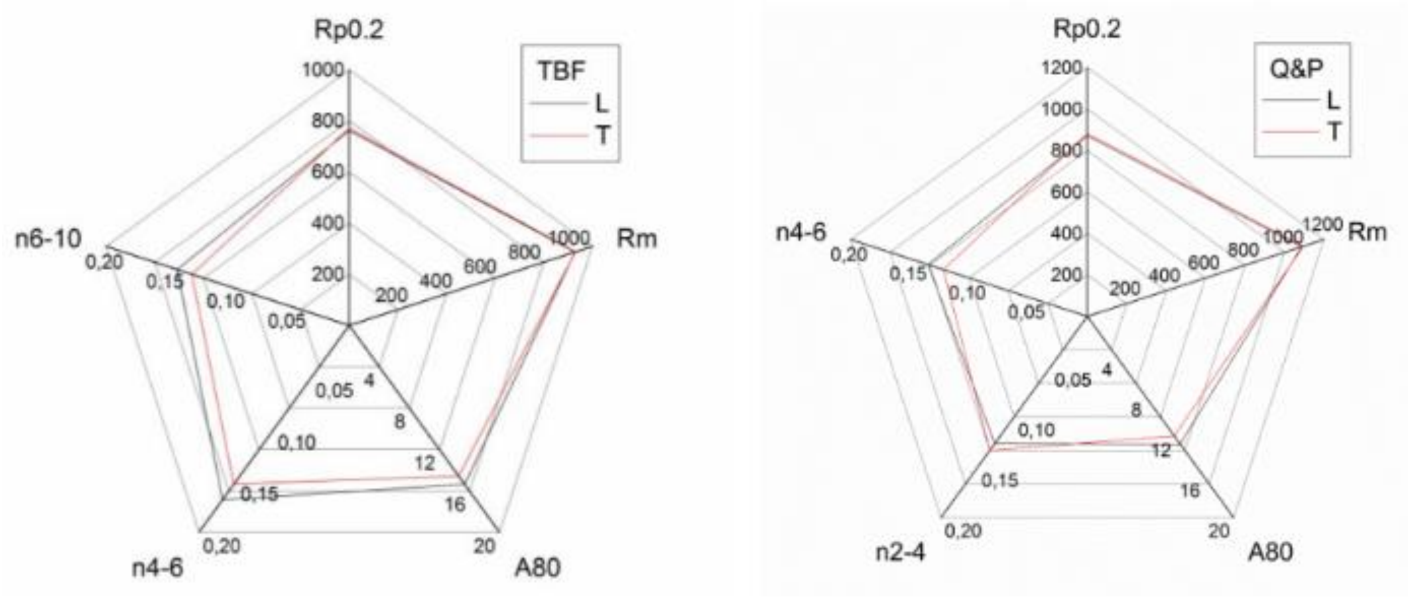

Fig -4: Mechanical properties of industrially annealed TBF and Q&P steels in longitudinal (L) and transversal (T) direction [10]

mponents. especially the applications that require high localized strain realization for the Q&P steel, and the applications that require global deformation for the TBF steel.

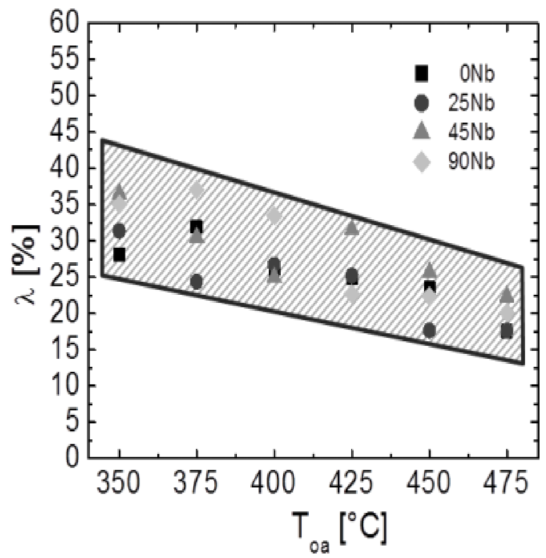

Fig -5: Hole expansion ratio λ as a function of TOA (overaging temperature) for micro-alloyed TBF steels [9]

4. CONCLUSIONS

The insertion of new materials in the automotive industry, it needs developed manufacturing machines, processes, and technologies. As sheet metal forming has a significant role in the automotive industry, both of the designers and forming technologist engineers, they are required to pay more attention. Based on that, the current work reviews some of the new advanced high strength sheet steels for sheet metal forming processes. The 3-GEN AHSS are characterized by a multiphase microstructure, and recently some types have been developed, two of them are in production and have already been incorporated in the modern car body structures: TRIP-aided Bainitic Ferrite (TBF) steels and Quenching-and-Partitioning (Q&P) steels. Both steels have an extraordinary of strength-ductility combination, and that gave them the ability for forming into complex structural parts with different forming operations for example, they can be applied to various structural automobile components such as seat frames, centre-pillar reinforcements, or anti-intrusion structural parts.

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