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Application of high-strength AHSS steels with TRIP effect in motorcar bodywork

Throughout the years, the dynamically developing motor industry has caused an increase in the demand for high-strength materials with a good yield point, which at the same time assure a reduced vehicle weight, thus leading to the reduction of fuel consumption and combustion gas emission as well as an improvement of the vehicle's passive safety.

Designing new types of steel is justified by the necessity of adaptation of the high strengths (above 500 MPa, without a loss of plastic properties) of construction steels of low production costs. They are, among others, low-alloy TRIP steels applied in the construction of motorcar bodyworks [1, 2, 3], which have a multiphase structure consisting of ferrite, bainite/martensite and austenite. Their excellent combination of strength and plastic properties is a result of the presence of austenite, which transforms into martensite during plastic deformation. In traditional TRIP steels, the chemical composition is: 0.1÷0.4% C, 1.5% Mn, 1.5% Si. The demand for TRIP steels with a higher strength than that of the traditional ones (800÷1200 MPa) has caused an increase of the carbon content to about 0.4%; however, higher carbon levels lead to serious problems in the steel's weldability and cause difficulties in the hot rolling treatment. That is why micro-additions of Ti, Nb and V were introduced into the steel, in order to maintain low contents of carbon, usually <0.25% [2, 3], which are an interesting alternative for these steels. The microstructure of the multiphase TRIP (Transformation Induced Plasticity) steel is shown in Figure 1. It consists of ferrite, small amounts of retained austenite, bainite and martensite, where the volume fraction of the austenite at room temperature depends on the temperature of austenatization and the cooling rate [4].

Beside the control of the retained austenite's stability, the control of the volume fraction of different component phases (ferrite, bainite and martensite) is also important. This, in turn, can be achieved by a precise design of thermal samples [5].

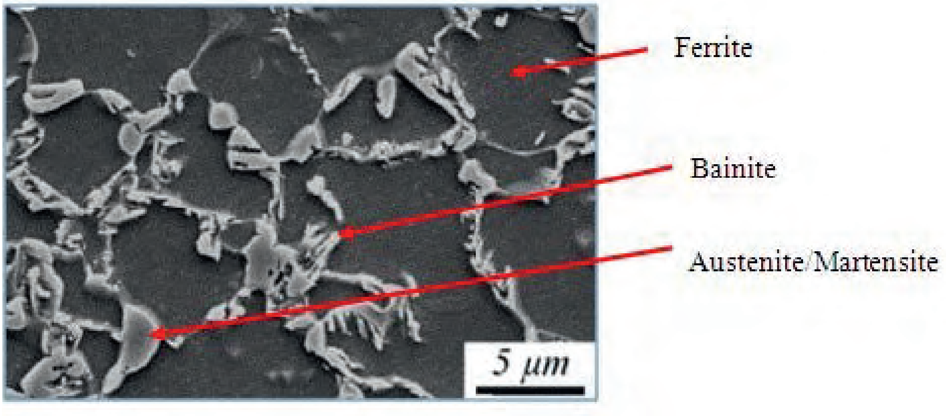

Fig. 1. Microstructure of multiphase TRIP steels [4]

The most frequent solution is a two-stage thermal treatment, consisting of heating the steel up to the intercritical annealing temperature (IA) in the area of the co-existence of phase ferrite + austenite, followed by rapid cooling (with a halt), where a mixed structure is formed, consisting of ferrite (α), retained austenite (γ), bainite (B) and martensite (M), Figure 2 [6].

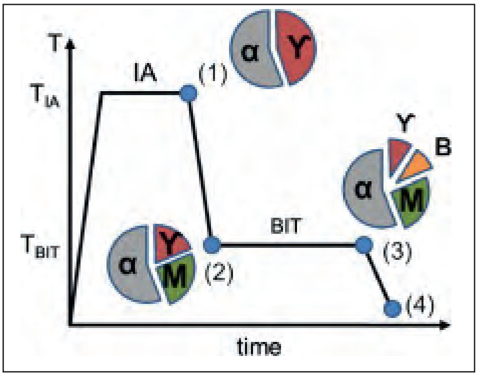

Fig. 2. Schematics of two-stage thermal treatment of TRIP steel [6]

The initial structure, under the effect of temperature, is transformed into a two-phase structure, consisting of austenite and ferrite. This structure contributes to the improvement of ductibility. The ductile ferrite and austenite facilitate plastic treatment. This is followed by cooling to T_{BIT} temperature, at which a partial transformation of austenite into bainite takes place, the latter being the strongest phase. Next, cooling to room temperature is performed. This is a necessary condition to obtain the TRIP effect and a higher plasticity [6].

Multiphase TRIP steels are mostly obtained by thermal treatment of cold-rolled metal sheets, which also includes annealing at temperature $A_{c1} \div A_{c3}$, controlled cooling to $350 \div 480^0$C (bainitic transformation range), annealing at this temperature in order to enrich the final fraction of austenite in C, with a limited cementite precipitation, and slow cooling to room temperature [7].

During the rapid plastic deformation, the metastable austenite transforms into martensite, absorbing the energy and, at the same time, additionally strengthening the material. Thus, this transformation involves the occurrence of the so-called transformational plasticity.

The chemical composition of TRIP steels with micro-additions varies. The carbon content is within the range of 0.10%÷0.25%; alloy additions are also used, i.e.: Mn, Si, Al, P, Nb, Ti, V. Manganese (0.4%÷2.5%) is the stabilizer of the retained austenite and it also prevents the martensitic transformation during the cooling to room temperature as well as lowers the temperature of cementite precipitation and activity coefficient of C in ferrite and austenite. Silicon (0.4%÷1.8%) is responsible for the refinement of the microstrcuture as well as the stabilization of the ferrite. It also hinders the cementite precipitation process during the bainitic transformation. Aluminium (ok. 1%) retards cementite precipitation, accelerates bainite formation and increases carbon solubility in ferrite [8].

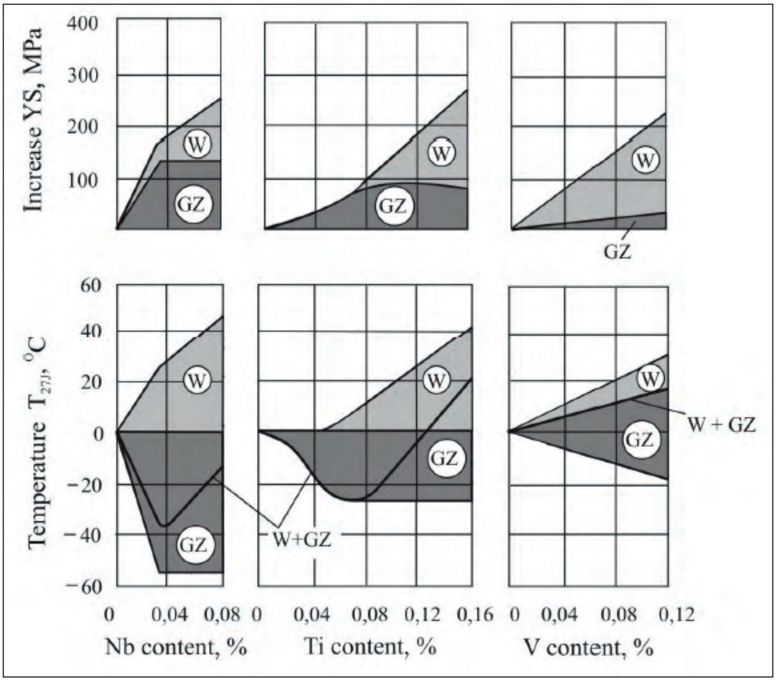

Fig. 3. Effect of micro-additions of Nb, Ti and V on yield point increase Re, MPa (Increase YS, MPa) and temperature of ductile to brittle transition of low-carbon steels T_{27J}, ^{0}C [9]

Micro-additions dissolved in a solid solution reduce the mobility of the grain boundaries and increase the temperature of austenite recrystallization, whereas micro-additions precipitating in the form of dispersive particles of interstitial phases limit the grain growth and retard the courses of static recrystallization. The most effective among the additions is niobium (as compared to titanium or vanadium – Fig. 3), which affects steel strengthening by way of grain refinement (GZ) and precipitation hardening (W) as well as lowers the temperature of the ductile to brittle transition [7, 9, 10].

The following step in the development of modern steel sheets of high strength and plasticity are the third generation AHSS steels (Fig. 4).

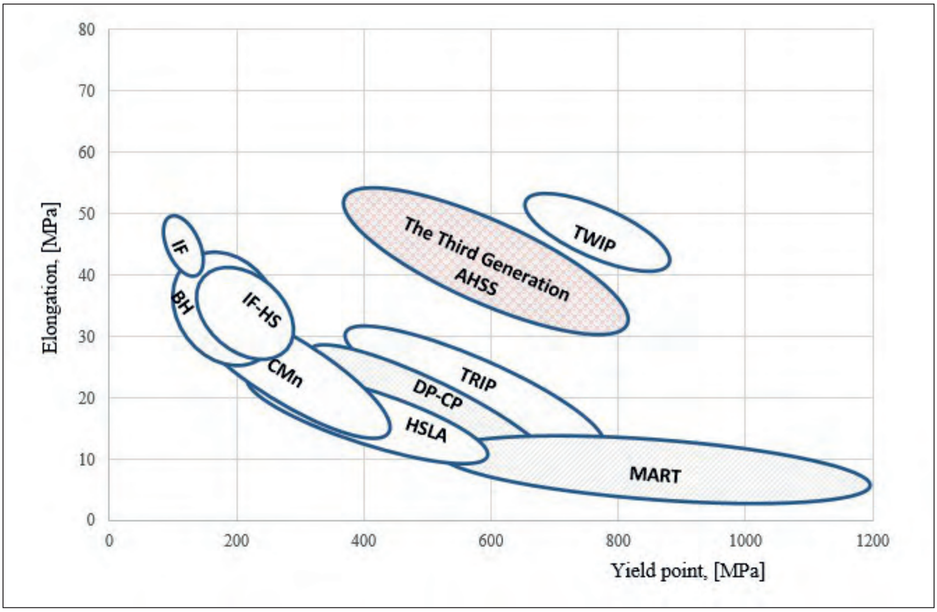

Fig. 4. Steel classification in motor industry [11]

The main idea of this group of steels is obtaining mechanical and plastic properties from the range between generation I steels (DP, CP, TRIP) and generation II steels (TWIP). The new concepts of microstructure involve an increase in the volume fraction of hard elements and retained austenite, refinement of the microstructure by the introduction of micro-additions Nb, Ti and V as well as an increase of the Mn content with respect to the classic TRIP steels.

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Abstract

The paper discusses the AHSS steels with the TRIP (Transformation Induced Plasticity) effect used in the construction of motorcar bodywork components, which characterize in excellent properties. It also points to possible prospects of development in motor industry.

Key words: Transformation Induced Plasticity, AHSS steels, Automotive Industry

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