# LASER WELDING OF SELECTED AHSS STEELS

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**Abstract**

The paper deal with laser welding of selected AHSS steels with controlled microstructure. DP600 and DP700 steel is selected for experiment and both these AHSS steels are principally described in theoretical part. Samples of DP600 and TRIP700 were welded and then examined by microhardness test and optical micsrostructure study. Finally, the results are comprised to commonly known characteristics of conventional arc welding.

**Keywords:** laser welding, DP steel, TRIP steel, microhardness, microstructure of HAZ.

## 1 Introduction

The Conventional mild steel has a relatively simple ferritic microstructure; it typically has low carbon content and minimal alloying elements, is readily formed, and is especially sought for its ductility. Widely produced and used, mild steel often serves as a baseline for comparison of other materials. Conventional low- to high-strength steels include IF (interstitial free), BH (bake hardened), and HSLA (high-strength low-alloy). These steels generally have yield strength of less than 550 MPa and ductility that decreases with increased strength. AHSS (Advanced High Strength steels) are more complex, particularly through their microstructures, which are usually multiphase for an improved combination of strength and ductility. The term "multiphase" means the combination of phases such are ferrite, austenite, martensite etc. This balance is carefully constructed to meet performance requirements while maintaining excellent formability (fig. 1). AHSS often has other advantageous mechanical properties, such as high strain-hardening capacity [1].

Equally important to increasing yield strength (YS) and ultimate strength (UTS) is achieving the appropriate combination of formability, weldability, and other characteristics necessary for the automotive application of steel in a competitive market. This necessity generates the large variety of grades in different stages of development. Typical nowadays used AHSS steels are DP and TRIP steels considered in this work.

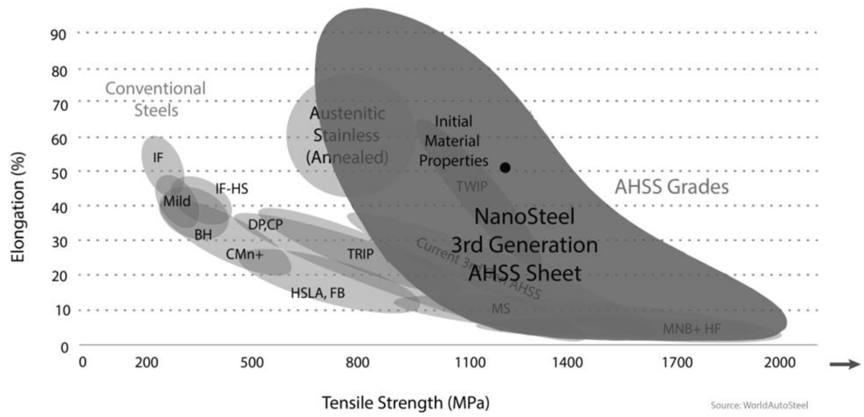


***Fig. 1*** *YS and UTS of AHSS steels [1]*

## 2 Used Materials and methods

### 2.1 Dual phase (DP) steels

The microstructure of DP steel consists of a soft ferrite matrix and discreet hard martensitic islands, as shown in Figure 2. The ferrite is continuous for many grades up to DP780, but as volume fractions of martensite exceed 50 percent (as might be found in DP 980 or higher strengths), the ferrite may become discontinuous.

The combination of hard and soft phases results in an excellent strength-ductility balance, with strength increasing with increasing amount of martensite.

DP steels can be hot- or cold-formed and also have high bake hardening behavior. If hot-rolled, cooling is carefully controlled to produce the ferritic-martensitic structure from austenite. If continuously annealed or hot-dipped, the final structure is produced from a dual phase ferritic-austenitic structure that is rapidly cooled to transform some of the austenite to martensite [2].

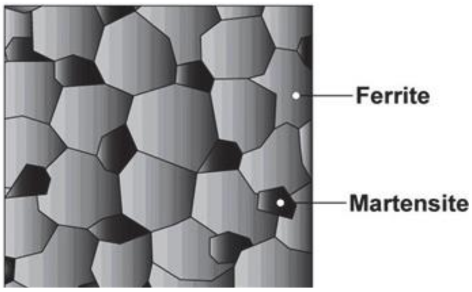


***Fig. 2*** *Schematic microstructure of DP steel [3]*

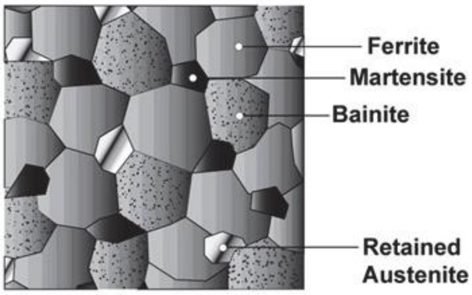


***Fig. 3*** *Schematic microstructure of TRIP steel [3]*

The soft ferrite in the final DP material is exceptionally ductile and absorbs strain around the martensitic islands, enabling uniform elongation with high work hardening rate and fatigue strength. Additionally, DP steels can absorb a lot of strain energy. Unlike conventional steels (even the traditional BH steels), bake hardening does not decrease with increasing pre-strain for DP steels.

### 2.2 TRIP steels

TRIP benefits from a multi-phase microstructure with a soft ferrite matrix embedded with hard phases. The matrix contains a high amount of retained austenite (at least 5 percent), plus some martensite and bainite, as shown in the schematic of figure 3. TRIP has a high carbon content to stabilize the meta-stable austenite below ambient temperatures. Silicon and/or aluminum are often included to accelerate the ferrite/bainite formation while suppressing carbide formation in this region [4, 5].

TRIP steel received its name for its unique behavior during plastic strain: in addition to the dispersal of hard phases, the austenite transforms to martensite. This transformation allows the high hardening rate to endure at very high strain levels, hence “Transformation-Induced Plasticity.” The amount of strain required to initiate this transformation may be managed by regulating the stability of the austenite by controlling its carbon content, size, morphology or alloy content. Amount of retained austenite increases fatigue resistance.

### 2.3 Experimental methods

DP and TRIP steels are considered as good weldable according to carbon equivalent value. Basic difficulties of their welding is in the risk of structure or morphology changes of phases like austenite or martensite what are key factors for mechanical and other properties of the steel. Appropriate welding methods are laser welding due to small heat affected area or welding in protective atmospheres of inert gases (TIG, MIG). Active atmospheres are not advisable due to chemical reactions between gases in protective atmosphere and weld metal.

The laser YLS 5000 - S1 (maximal power 5 kW and wave length 1, 06 μm) of YbYAG type were used for welding of experimental samples. Welding parameters used for both experimental steels are shown in table 1. After welding, cross sections of welds were cut and these samples prepared using standard sample preparation procedure for optical metallography, consist of grinding, polishing and finally etching (nital, 2%). The finished samples were then examined by microhardness test and microstructure study.

***Table 1*** *Welding parameters*

| Laser power [W] | Welding speed [$mm.s^{-1}$] | Focal distance [mm] |
|---|---|---|
| 2000 | 50 | 10 |

### 2.4 Used materials

Two advanced high strength steels were used for the experiment – dual phase steel DP 600 and trip steel TRIP 700. Their chemical composition and basic mechanical properties are shown in table 2. Several experimental weld joints were made by these steel to realize experiments.

***Table 2*** *Chemical composition and mechanical properties of DP600 and TRIP700 steels*

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DP600** | **Chem. comp. [wt. %]** | **C** | **Si** | **Mn** | **P** | **S** | **Cu** | **Al** | **Cr** | **Ni** | **V** | **Ti** | **Nb** |
| | | 0.111 | 0.279 | 1.963 | 0.026 | 0.002 | 0.019 | 0.031 | 0.206 | 0.002 | 0.012 | 0.002 | 0.02 |
| | **Mech. properties** | **$R_m$** [MPa] | | | | **$R_m$** [MPa] | | | | **$A_5$** [%] | | | |
| | | 624 | | | | 379 | | | | 16 | | | |
| **TRIP700** | **Chem. comp. [wt. %]** | **C** | **Si** | **Mn** | **P** | **S** | **Cu** | **Al** | **Cr** | **Ni** | **V** | **Ti** | **Nb** |
| | | 0.18 | 0.089 | 1.591 | 0.028 | 0.002 | 0.023 | 2,26 | 0.042 | 0.032 | 0.007 | 0.022 | 0.022 |
| | **Mech. properties** | **$R_m$** [MPa] | | | | **$R_m$** [MPa] | | | | **$A_5$** [%] | | | |
| | | 730 | | | | 460 | | | | 23 | | | |

## 3 Experimental results

### 3.1 Course of microhardness across welding joint

Course of microhardness across welding joint were examined by Vickers Hardness test with load force F=0,98 N (0,1 kp) and indentation time t=10 s. Curves presented for both examined steel on fig. 2 are obtained as the arithmetic mean from measurement on three equal samples.

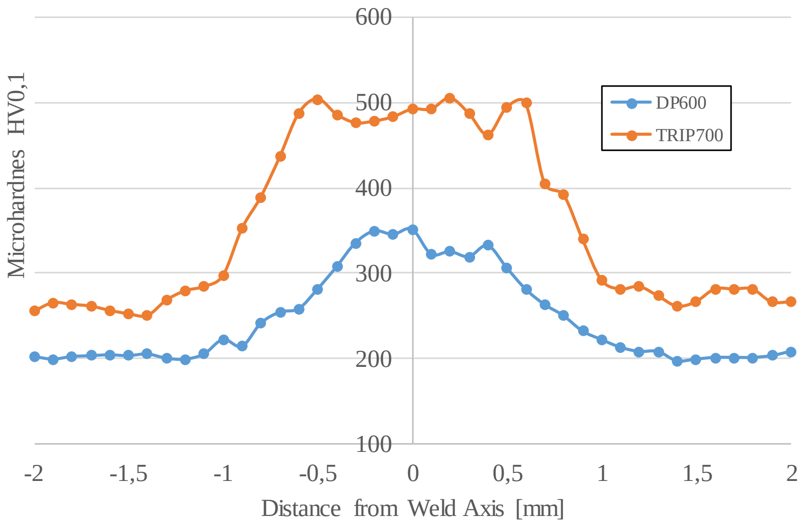


***Fig. 2*** *Course of microhardness across welding joint*

Heat affected area (HAZ) is relative narrow (2 mm) in comparison to arc welded joint (10-20 mm) [4]. HAZ in both cases is characterized by increasing of hardness but is too brittle. There is not using filler material in laser welding, so hardness changes are caused by phase transformations induced by heat from welding.

### 3.2 Microstructure of experimental samples

Microstructure and macrostructure of cross section for both DP600 and TRIP700 steels are shown on fig. 3. Macrostructure of both joints (fig. 3a, 3b) are clear without abrupt junction to area of weld metal what is characteristic for arc welding with filler.

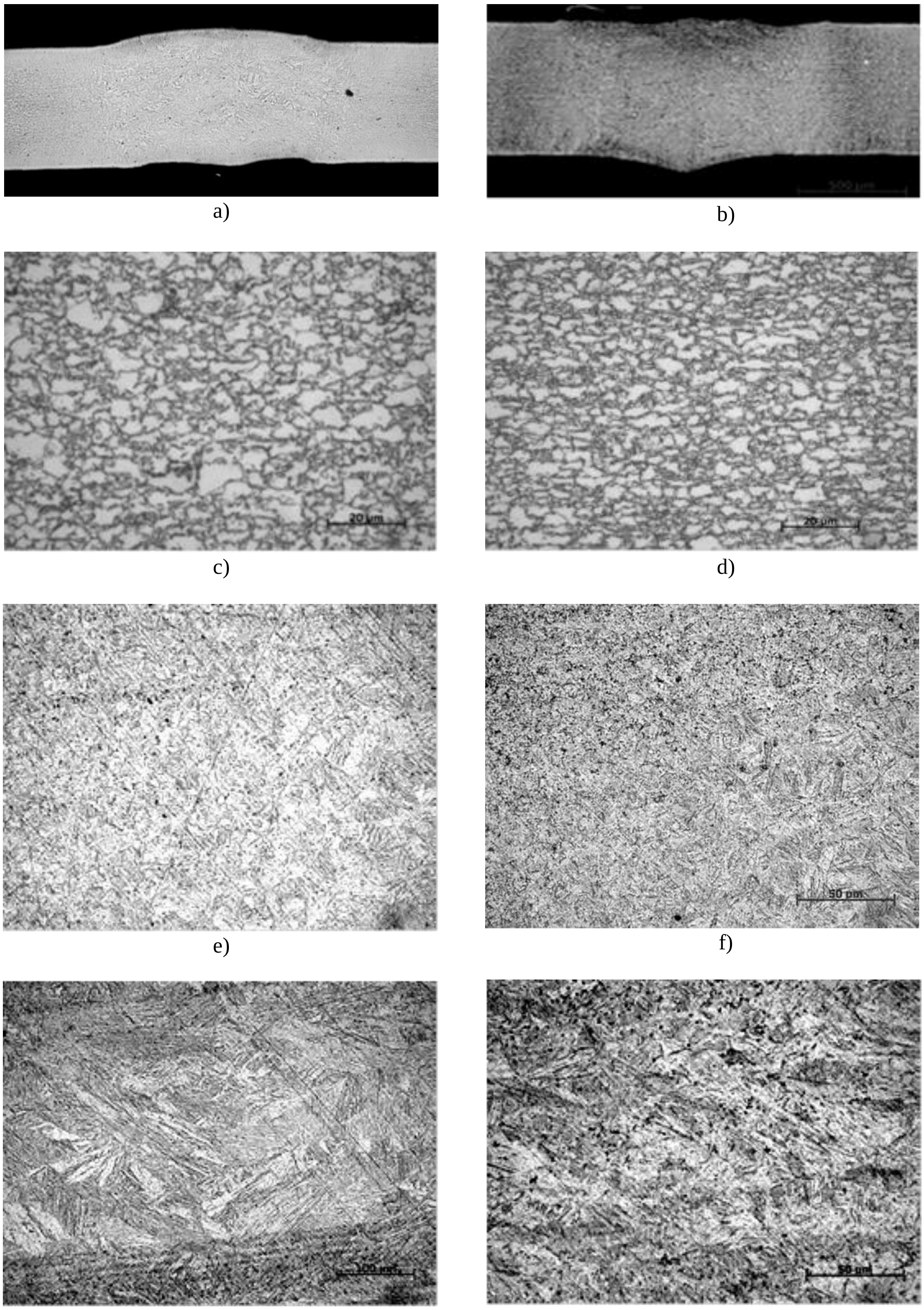


***Fig. 3*** *Microstructure of experimental samples*

*DP600 : a – macro, c - BM, e – HAZ, g – WM*
*TRIP700 : b – macro, d - BM, f – HAZ, h – WM*

Microstructure of both base metals (fig. 3c, 3d) corresponds to used steel types. DP 600 has martensitic particles dispersed in ferritic matrix. Numerically is the ratio of ferrite approximately 80% and martensite 20 %. Finer magnificence or another type of microscopy is needed to recognize all structural phases in TRIP700 steels.

Microstrcure of HAZ is completely different in comparison to base metal for both steels (fig. 3e, 3f). Origin ferritic-martnesitic (DP600) or ferritic-martensitic-banitic-austenitic (TRIP700) with characteristic key morphology has changed to heterogeneous one. In a case of DP600, HAZ is consist of fine martensitic needles and also white ferritic blocks were observed. In a case of TRIP700 is HAZ consisted of bainite and ferrite.

Weld metal (WM) of DP600 (fig. 3g) is characterized with large martensitic laths, where in a case of TRIP700 upper bainite and martensite were observed in WM. In both cases, grain coarsen in the direction to the middle of weld.

## 4 Conclusion

DP600 and TRIP700 are advanced high strength steels with using in automotive industry mainly for car bodies. Both steels are beside high tensile strength characterized by increased plastic properties – elongation and thougness. Conventional arc welding methods have disadvantages as are small assortment of suitable filler material (with appropriate mechanical properties), wide heat affected zone and therefore deformations of at thin sheets welding, limited welding positions, increased requirements on weld surface cleanliness etc.

Progresssive welding methods as is laser welding solve many of these disadvantages. The experiment presented in the paper prove that laser welding has small heat affected zone what is important for AHSS steels with controlled microstructure. Study of microstructure of HAZ and WM described negative changes of mictrostructure, different from origin design microstructure.

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