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Joining of Advanced High Strength Steels

Abstract: This paper describes joining of Advanced High Strength Steels (AHSS). Over the past 2 to 3 decades the usage of AHSS has increased constantly, and will continue. In order to succeed with the overall design it is of importance to know how to design AHSS from e.g. fatigue, bending and welding point of view. As presented in this paper, AHSS has to be treated differently than mild steel regarding welding.

Keywords: AHSS, Advanced High Strength Steels, welding properties

Introduction

The definition of AHSS is normally that the steel has a yield strength that is higher than approxi-mately 450 MPa. In order to achieve an advanced high strength steel (AHSS) one have to have a specific material chemistry as well as a process route in the steel mill that gives the specific mechanical properties.

SSAB is, among other steel mills, a producer of AHSS up to yield strengths of 1300 MPa. Of course, it is of interest to be able use this material in different ways, from a design point of view. For instance, it is of interest to bend and weld such a material.

Welding of AHSS produced by SSAB gives benefits such as the following:

– the weldability is good,
– any welding method can be used,
– there is low risk for defects,
– resulting in good strength and impact toughness.

This is true if the heat input is controlled. When welding AHSS it is very important to use the right heat input for the specific joint set-up (i.e. joint configuration and material thickness). The weldability is good thanks to the low carbon equivalent, as can be seen in figure 1.

Filler materials

What type of filler material should be used while welding AHSS? This is a relevant question and the answer to this can be found in figure 2 for different welding processes.

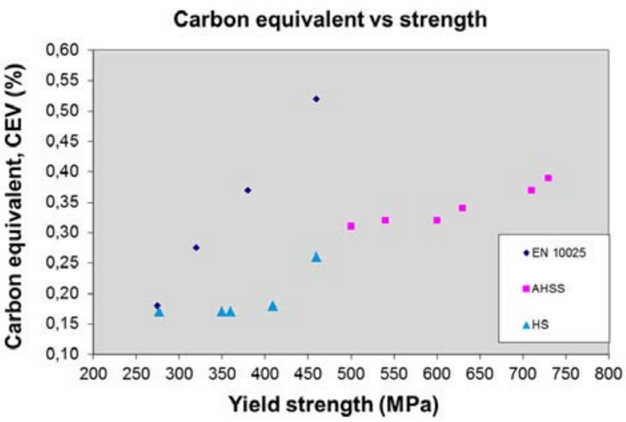

Fig. 1. Carbon equivalent.

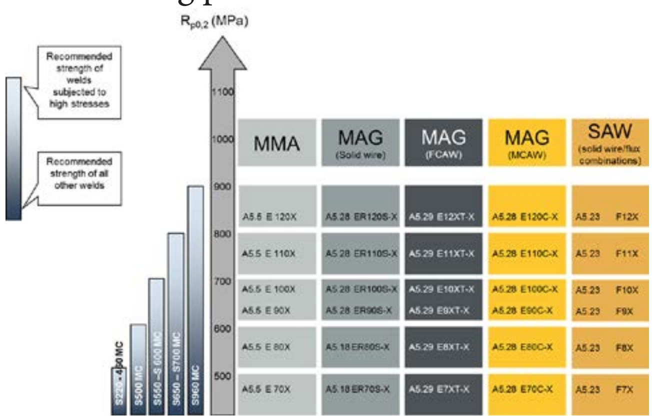

Fig. 2. Examples of filler materials to be used while welding AHSS.

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Normally SSAB recommends using an under matching filler material when it is possible from a design point of view. For instance, under matching filler materials the following can be used:
- when the weld is in a low stress area, see figure 3,
- for fillet welds,
- welding to an ordinary mild steel,
- when the reinforcement is not removed,
- if the joint is subjected to fatigue loads.

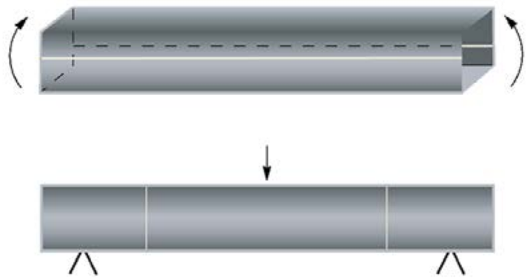

Fig. 3. Weld in a low stress area

Heat input

As mentioned earlier, it is very important to control the heat input to the material in order to achieve good mechanical properties of the weld. Figure 4 shows a hardness profile of a Domex 700 MC material with a thickness of 6 mm. As can be seen, there is a softening in HAZ. Due to this reason it is of importance to minimize the hardness drop as well as the width of HAZ.

Welding of all AHSS, independent of steel producer, results in a hardness profile similar to the one in figure 4. So, it is obvious that one have to control the heat input in order to keep the mechanical properties of the weld similar to the ones of the parent material. Figure 5 shows mechanical properties of Domex 700 (thickness 6 mm) welded with 1, 2 or 3 passes. Welding with 1 pass is equal to high heat input. By increasing the number of passes, the heat input will decrease.

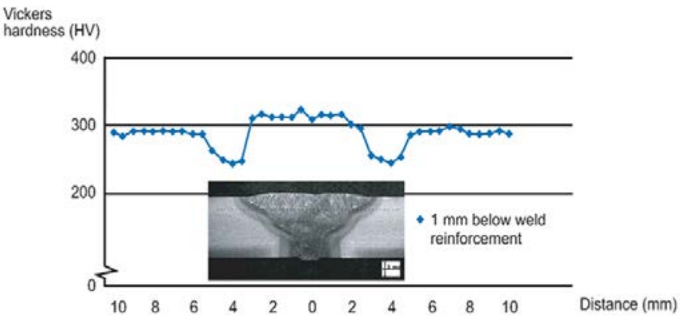

Fig. 4. Hardness profile of Domex 700MC, 6 mm (GMAW)

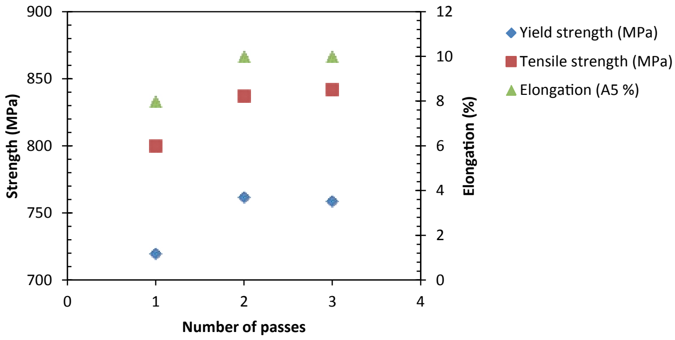

Fig. 5. Mechanical properties vs. number of passes. 1 pass equal to high heat input, 3 passes low heat input

As can be seen in figure 5 the mechanical properties increases with increasing number of passes. Due to this reason, SSAB recommends to weld with a certain maximum heat input. Depending on material thickness this results in different numbers of passes, see figure 6.

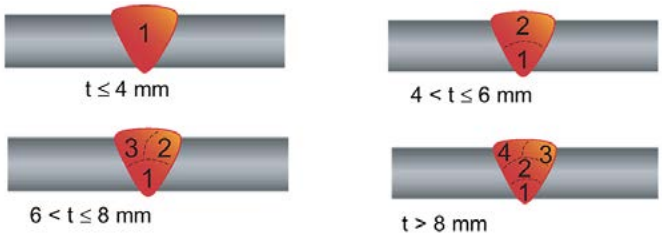

Fig. 6. Number of passes depending on material thickness

As in the case of mechanical properties, it is also of importance to use the right number of passes in order to achieve good impact toughness. The impact toughness depends on where the notch loca-tion is and due to that reason, five different locations are investigated in such a test. These locations are shown in figure 7.

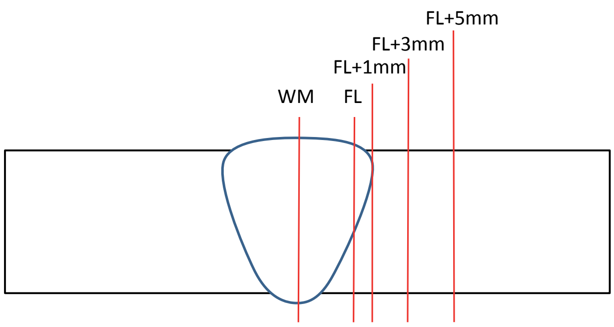

Fig. 7. Notch locations.

SSAB has made numerous of such investigations for all different grades and thicknesses. Figure 8 shows an impact toughness test of Domex 700 MC (6 mm) welded with one pass, two passes or three passes. As in the case of mechanical properties, one pass represents high heat input and three passes low heat input. The result can be seen in figure 8.

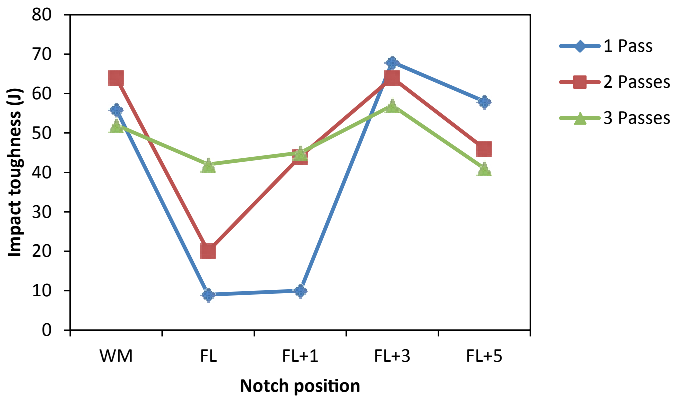

Fig. 8. Impact toughness vs. number of passes for different notch locations.

As shown in figure 8, it is of importance to weld with low heat input (3 passes) in order to achieve good impact properties at all locations, from weld metal to fusion line + 5 mm. All these tests make it possible to give recommendations, such as the importance of using the right heat input in the case of impact toughness, i.e. use the right number of passes for a given thickness, see figure 9.

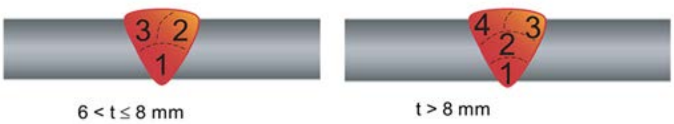

Fig. 9. Impact toughness of the welded joint

It is also of interest to use the right inter-pass temperature for different steels:

- Domex 355MC – Domex 550MC; inter-pass temperature max 150°C,
- Domex 600MC – Domex 700MC; inter-pass temperature max 100°C.

Welding of Weldox and Hardox

Since the microstructure of Weldox and Hardox differs from Domex it is of importance to take some further precautions. Both Weldox and Hardox are susceptible to hydrogen cracking. Due to that reason different grades and thicknesses has to be preheated. Figure 10 shows recommended preheat temperatures for both Weldox and Hardox.

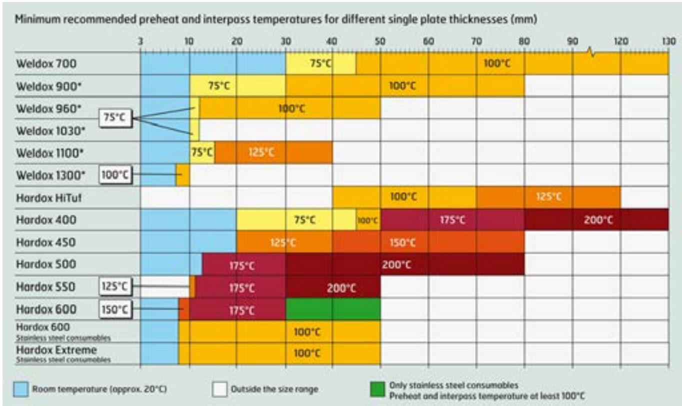

Fig. 10. Preheat temperatures for Weldox and Hardox

When preheating, it is of importance to do this in the right way. Figure 11 shows a schematic how this should be done. If possible the preheating should be done from the back side of the plate and temperature measurement on the opposite side (i.e. same side as the weld). Further, the temperature should be measured 75 mm away from the weld, and measured after 2 minutes for every 25 mm of thickness (i.e. measure the temperature 4 minutes after finished preheating for a 50 mm plate). By doing this, the temperature of the area around the weld will have the appropriate preheating temperature.

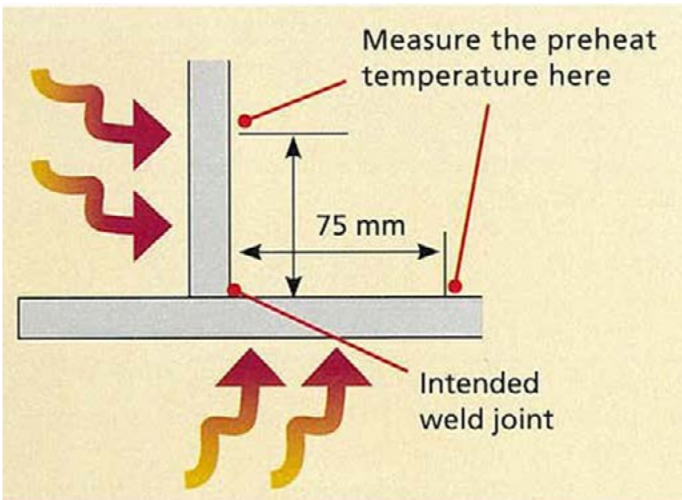

Fig. 11. Schematic of the preheating operation

Distortion

Distortion of welded joints is costly for the industry. It is therefore of interest to minimize distortion and subsequent straightening operations. Since AHSS have higher residual stresses in the plate compared to mild steel it is of importance, also in this case, to reduce the heat input to the material. It is also of importance to spread the heat during welding. Minimizing distortion can be done in different ways:

- Weld from high levels of restraint to sections with lower level of restraint,
- Back step welding,
- Skip welding,
- Reduce the joint angle,
- Symmetrical joints.

WeldCalc

In order to succeed with welding of AHSS, SSAB provides the software WeldCalc. It is easy to use the software and it gives the user important information about welding parameters, preheat tempera¬tures, inter pass temperatures etc. Figure 12 shows a graph produced by WeldCalc.

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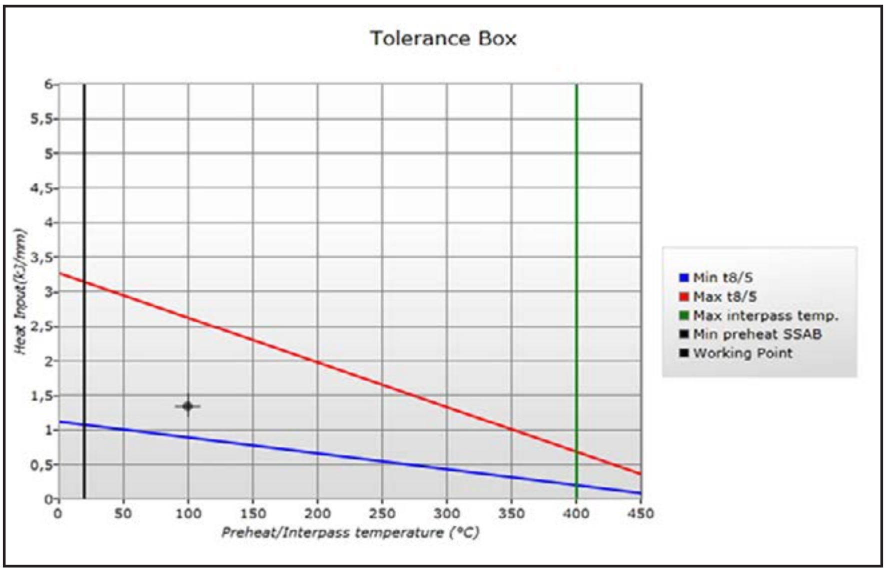

Fig. 12. WeldCalc