TECHSUPPORT #64

Static strength in joints of Strenx grades

Joints made with the Strenx™ grades are frequently subjected to static strength requirements. A basis for attaining very high levels of static strength for these joints is that:
-Suitable types of consumables are selected.
-The recommendations regarding the cooling time $t_{8/5}$ in the joint, during welding, is followed.

INTRODUCTION

Tensile test evaluations of joints are mostly carried out for fully penetrated butt joints. In order to interpret these kinds of tensile tests accurately, it is important to know the possibilities and the limitations of the test procedure.

The preceding issues are addressed further in the following context. Since the Hardox® grades are developed for wear resistance, the exact levels of static strength in joints of these steel grades are seldom stated and are therefore not accounted for.

SUITABLE TYPES OF CONSUMABLES

In order to attain joints with very high levels of static strength, it is recommended that the Strenx grades are welded using low-alloyed consumables with strengths that are presented in table 1.

Steel grade to be welded	Approximate yield strength of the consumable, all weld metal [MPa]
Strenx 700	700
Strenx 900–Strenx 1300	900

TABLE 1: APPROPRIATE YIELD STRENGTH FOR LOW-ALLOYED CONSUMABLES

Consumables with yield strengths of approximately 900 MPa in the all weld metal represent the highest available strength on the market. For the Strenx grades, the toughness of the weld metal in the joint typically exceed the stated minimum requirements when welding is performed using the consumables mentioned in table 1.

Low-alloyed consumables with yield strengths higher than 700 MPa typically have higher preheating requirements than the Strenx grades. The cause for this measure is to minimize the risk of hydrogen cracks in the weld metal. More information in this respect can be found in TechSupport # 60, available at www.ssab.com, or in the Welding handbook for the Hardox and Strenx grades.

THE INFLUENCE FROM THE WELDING PARAMETERS

The welding performance will create non-uniform thermal cycles throughout the joint. The peak temperature in the HAZ rises the closer it is to the center of the arc, which is illustrated in figure 1.

The parameter $t_{8/5}$ expresses the cooling time in the joint between 800 °C and 500°C, according to figure 2. Evaluations show that the $t_{8/5}$ value can be regarded as constant throughout the joint for a given welding performance as long as the peak temperature reaches above 900 °C.

For a given joint, the cooling time $t_{8/5}$ increases with a rise in the heat input, holding other welding parameters constant including the preheating performance, when applied.

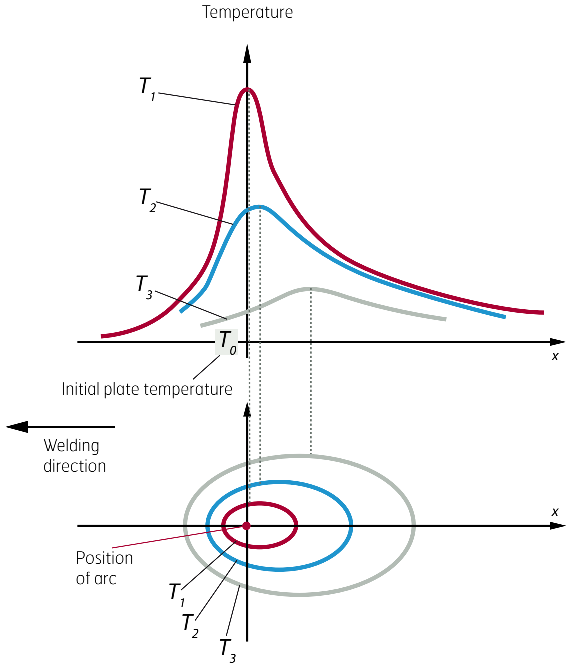

FIGURE 1: THE HEATING / COOLING RATE AND THE PEAK TEMPERATURE DECREASE WITH INCREASED DISTANCE TO THE ARC.

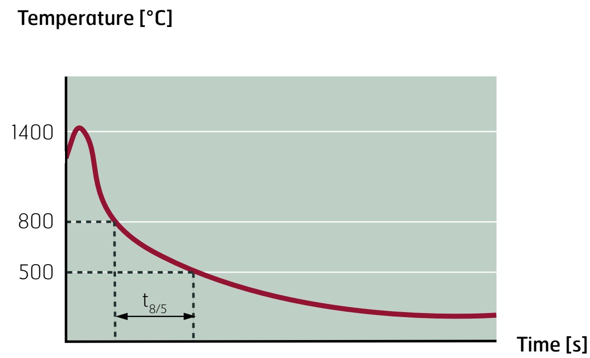

FIGURE 2: THE HEATING / COOLING RATE AND THE PEAK TEMPERATURE DECREASE WITH INCREASED DISTANCE TO THE ARC.

The welding parameters in terms of the $t_{8/5}$ value affect the mechanical properties, including the static strength, in the joint. Achieving a very high static strength in the joint is associated with keeping the cooling time $t_{8/5}$ within specific intervals according to table 2. If welding is performed with higher $t_{8/5}$ values than those recommended, the static strength in the joint can be reduced. The minimum level for the $t_{8/5}$ value is primarily set by the restrictions that ensure an optimal welding process. This issue covers the welding methods MAG, MMA, TIG and SAW. However, a $t_{8/5}$ level below the normal recommended interval can cause a reduction of the toughness in the joint, even though the static strength in the joint may not be reduced.

Steel grade	Recommended $t_{8/5}$ intervals [s]*
Strenx 700	5–25
Strenx 900	5–20
Strenx 960–Strenx 1300	5–15

* Valid for a typical min. impact toughness of 27 J at -40 °C in the HAZ.

TABLE 2: RECOMMENDED $t_{8/5}$ INTERVALS.

However, there is actually no need to calculate the $t_{8/5}$ value. An appropriate $t_{8/5}$ value is automatically attained if our general welding recommendations for the welding processes MAG, TIG, MMA and SAW are applied. These recommendations can be found in the Welding brochure or the Welding handbook for the Strenx and Hardox grades.

The purpose for calculating the $t_{8/5}$ value is to give a further understanding of the welding performance in relation to the heat input. The determination of the $t_{8/5}$ value for a welding performance is explained in chapter 3 of the Welding handbook for the Hardox and Strenx grades.

CONSIDERATIONS TO BE MADE DUE TO THE CHARACTERISTICS OF THE TENSILE TEST PERFORMANCE

The measurements and evaluations of tensile tests differ to a certain extent when joints are evaluated in comparison to unaffected parent metals. There are issues that are emphasized in this respect. First, most types of joints are deformed to an extent due to the welding performance. During the execution of the tensile test, the specimen can be straightened according to figure 3. As a consequence, the yield strength in the joint may measure lower than it actually is, but at the same time, the measure of the tensile strength transverse to the joint will be highly accurate. Despite this fact, the levels of yield strength in joints are accounted for as these values can serve as indications of typical outcomes.

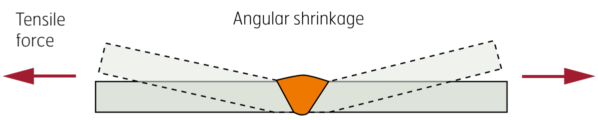

FIGURE 3: STRAIGHTENING OF THE SPECIMEN DURING A TENSILE TEST

Second, elongation values transverse to the direction of the joint in quenched/quenched and tempered steels, including the Strenx grades, is typically of less importance. The reason is that the joint has nonuniform mechanical properties, where the lowest strength is frequently located in the HAZ or in the weld metal. Plastic deformations can, therefore, be primarily located in the HAZ, see figure 4, and/or in the weld metal, which typically results in low levels of elongation in comparison to the elongation values for the unaffected parent metal.

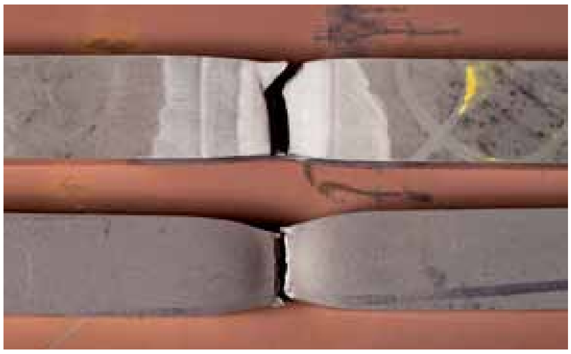

FIGURE 4: THE UPPER TENSILE TEST SPECIMEN INCLUDES A JOINT, WHILE THE LOWER SPECIMEN CONSISTS OF UNAFFECTED PARENT METAL.

A third issue is to ensure that there is a good grip between the specimen to be tested and the tensile test machine in order to avoid sliding effects. If sliding occurs, it promotes misinterpretations of the measured yield strength in the joint. The tensile strength can, however, typically attain representative values even if a small sliding effect is present.

Other types of joints than butt joints, such as fillet joints, may be more difficult to assess regarding their static strength. For fillet joints, the static strength is often based on calculations regarding throat thickness and leg length. The penetration profile will, however, also contribute to additional strength, see figure 5.
As a result, the actual strength in the joint may be higher than the results of many types of calculations.

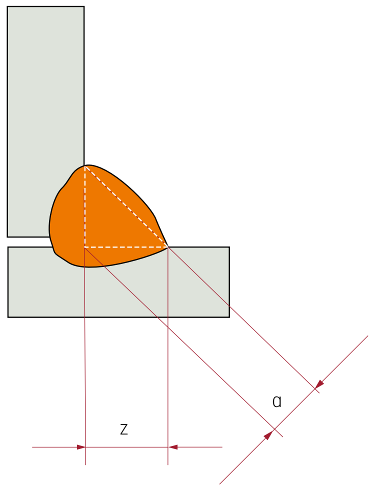

FIGURE 5: APPEARANCE OF A FILLET JOINT.

KEY

Z = THE LEG LENGTH, WHICH IS THE SIDE OF THE LARGEST ISOSCELES TRIANGLE THAT CAN BE INSCRIBED IN THE SECTION.

A = THE TROAT THICKNESS, WHICH IS THE HEIGHT OF THE LARGEST ISOSCELES TRIANGLE THAT CAN BE INSCRIBED IN THE SECTION.

TYPICAL VALUES OF STATIC STRENGTHS

Achieving very high levels of static strength in the joints is feasible when our normal welding recommendations are followed. This will also ensure a typical impact toughness in the HAZ of min. 27 J measured at -40 °C. The values have a natural tendency to scatter to some extent even during situations where tensile specimens are taken from the same joint. The values presented in table 3 indicate what to expect in terms of static strength for fully penetrated butt joints of equal plate thickness. These results are based on the excessive weld metal at the cap and root section in the test specimen being removed prior to evaluation. This means that the thickness of the weld metal is the same as for the plate thickness in the joint.

The values shown in table 3 represent the most commonly used plate thicknesses. Contact SSAB for further assistance if information is desired regarding other plate thicknesses for these steel grades. Strenx 700 has been further developed and updated information regarding the static strength in joints will be published in later versions of this TechSupport.

When there are high static strength requirements for a joint, SSAB recommends that the static strength is evaluated for the particular joint, applying representative welding parameters for the welding production to come.

Steel	Pt [mm]	$t_{8/5}$ [s]	Yield strength, $R_{p0.2}$ [MPa]	Tensile strength R_m [MPa]	Typical location of fracture
Strenx 900	Pt≤30	5–20	780–850	940–1000	The HAZ or/and the weld metal
Strenx 960	Pt≤30	5–15	900–980	1000–1050	The HAZ or/and the weld metal
Strenx 1100	Pt≤25*	5–15	950–1030	1010–1090	The weld metal
Strenx 1300	Pt≤10*	5–15	1000–1100	1100–1200	The HAZ or/and the weld metal

*The complete thickness interval for this steel grade

TABLE 3: FREQUENT OUTCOMES OF STATIC STRENGTHS IN FULLY PENETRATED BUTT JOINTS. THESE VALUES REPRESENT STRENGTHS TRANSVERSE TO THE JOINT DIRECTION.

SSAB is a Nordic and US-based steel company. SSAB offers value added products and services developed in close cooperation with its customers to create a stronger, lighter and more sustainable world. SSAB has employees in over 50 countries. SSAB has production facilities in Sweden, Finland and the US. SSAB is listed on the NASDAQ OMX Nordic Exchange in Stockholm and has a secondary listing on the NASDAQ OMX in Helsinki. www.ssab.com.

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