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WELDABILITY OF MICROALLOYED HIGH STRENGTH STEELS TStE 420 and S960QL

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The paper presents research of weldability of microalloyed high strength steels TStE 420 and S960QL after weld thermal cycle simulation. Beside mechanical properties hardness and impact strength, the microstructures of characteristic weld thermal cycled structures for both steels are given. The results will contribure to determination of weakest points in Heat Affected Zone of both steels.

Key words: weldability, high strength steels, mechanical properties, TStE 420, S960QL

INTRODUCTION

More intensive utilization of improved and high-strength steels occurred more decades ago, firstly in industrialized countries around the world, and somewhat later also in our country. High-strength steels greatly reduce required mass and increase capacity and toughness.

These steels are used mostly for:

- construction of road and rail vehicles
- construction of civil engineering machinery so called heavy loads (high speed rotors)
- construction of airplanes
- rocket and space technology
- construction of ships
- construction of cranes (harbor and mobile), etc.

Depending on the flow stress, three groups of these steels are distinguished (there are different classifications of authors, however, the most commonly cited is:

- *fine grained steels* with *yield strength* of up to 500 MPa, called steels of increased strength, which is reached after rolling and normalizing
- fine grained steels with yield *strength* from 500 to 1 000 MPa, called high strength steels, which is achieved after improving
- *fine grained steels* with *yield strength* above 1 000 MPa, called ultra high strength steels, achieved by thermomechanical rolling.

In this work authors will present results of weldability investigations after weld thermal cycle simulation on representant of fine grained steel with yield strength up to 500 MPa (TStE 420 steel) and of fine grained steel with yield strength from 500 to 1 000 MPa (S960QL steel).

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EXPERIMENT PLAN

The experiment plan was to assess the hardness and impact toughness after welding of microalloyed steel of increased strength TStE 420, and high strength steel S960QL. Chemical composition and mechanical properties of both tested steels were obtained in laboratory measurements by the author, as presented in the Tables 1-4.

Table 1 **Composition of the TStE420 steel [1,2]**

C	0,18
Si	0,3
Mn	1,47
P	0,017
S	0,005
Ni	0,22
N	0,016
Al	0,023
V	0,13
Cu	0,02

Table 2 **Mechanical properties of steel TStE420 [1,2]**

Yield Strength $R_{p0,2}$ / MPa		422
Tensile Strength R_m / MPa		577
Elongationa A_5 / %		30
Contraction Z / %		61,9
Bending α =180 °	Longitudinal	+
	Transfersal	+
Toughness, K_V / J longitudinally	at 20 °C	261
	at -20 °C	245
	at -40 °C	182

Specimens were cut out in the direction of the base material rolling. Each panel was checked for direction of fibers during rolling. Thickness of base material was 15 mm. Calculated values of preheating temperatures for the steel TStE 420 are shown in the Figure 1, and in the Figure 2 the same values refer to the steel S960QL.

Determination of hydrogen content in the weld was performed by the glycerin method according to HRN C.H3.018/83.

Table 3 **Composition of S960QL steel [2,3]**

C	0,17
Si	0,47
Mn	1,42
P	0,008
S	0,003
Cr	0,59
Mo	0,56
Ni	0,79
Nb	0,02
V	0,05
Cu	0,03
Ti	0,01

Table 4 **Mechanical properties of S960QL steel [2,3]**

Yield Strength $R_{p0,2}$ / MPa		1 020
Tensile Strength R_m / MPa		1 080
Elongationa A_5 / %		16
Contraction Z / %		61,9
Toughness, K_V / J longitudinally	at 0 °C	158
	at -20 °C	76
	at -40 °C	58

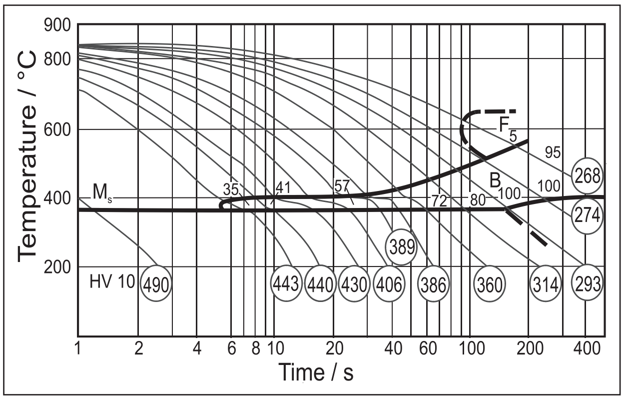

Figure 1 Calculated values of preheating temperatures for the steel TStE 420 [4]

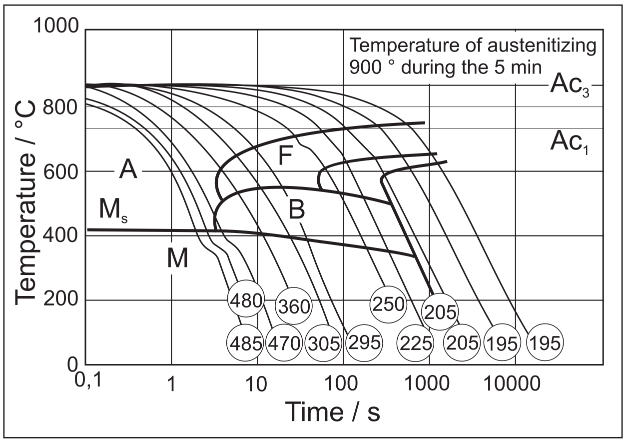

Figure 2 Calculated values of preheating temperatures for the steel S960QL [2]

EXPERIMENT RESULTS

Weld thermal cycle simulation was performed on Smitweld TCS 1405 simulator. After single pass weld thermal cycle simulation on different weld cycle peak temperatures, hardness of specimens are shown at Figures 3, 4.

Measurement of impact toughness was performed on simulated specimens at a temperature of 20 °C. Diagram of dependence of impact toughness within double simulation on T_{max} of the second simulation cycle is presented on the Figures 5 and 6.

As seen in the diagram, it is to conclude that maximum values for impact toughness were obtained when T_{max} of the second simulation cycle was 780 °C.

The above diagram shows that maximum values for impact toughness were obtained when T_{max} of the second simulation cycle was 600 °C. After measuring of hardness, metallographic examination was performed

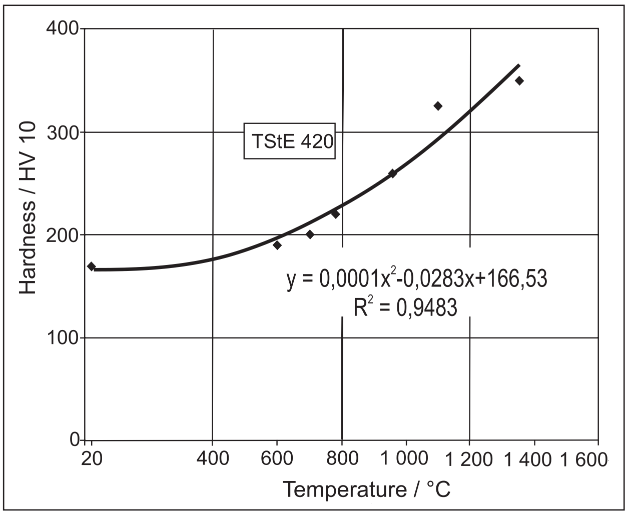

Figure 3 Dependence of the mean value of hardness of TStE 420 steel on the temperature of single pass simulation (peak temperatures are 20, 600,700, 780, 960, 1 100 and 1 350 °C)

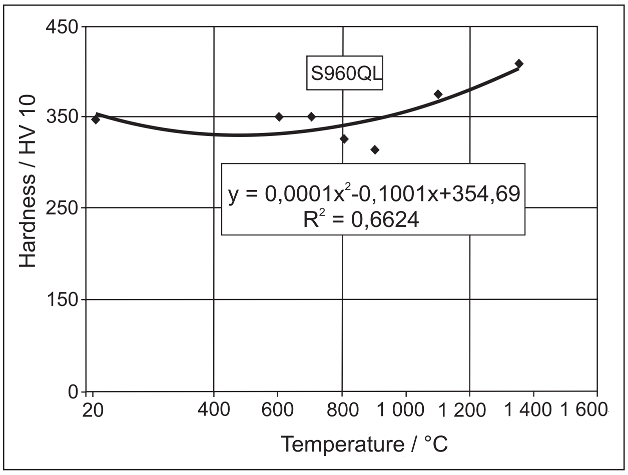

Figure 4 Dependence of the mean value of hardness of S960QL steel on the temperature of single pass simulation (peak temperatures are 20, 600,700, 800, 900, 1 100 and 1 350 °C)

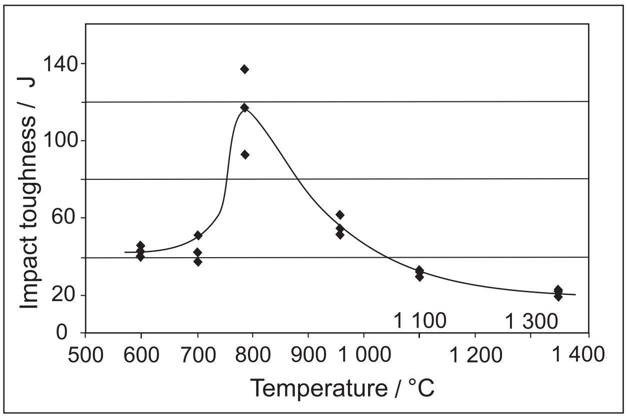

Figure 5 Diagram of dependence of impact toughness on T_{max} of the single simulation cycle for the steel TStE 420 for different peak thermal cycle temperatures

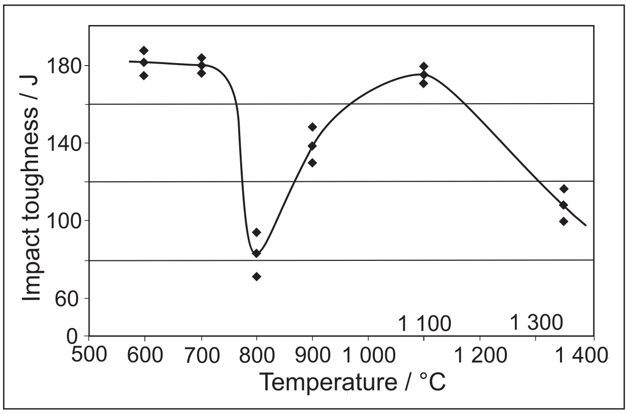

Figure 6 Diagram of dependence of impact toughness on T_{max} of the single simulation cycle for the steel S960QL for different peak thermal cycle temperatures

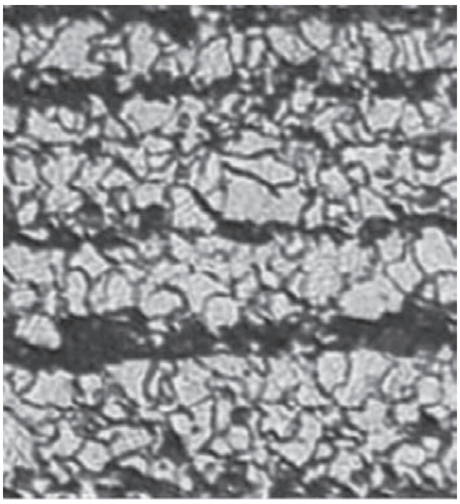

Figure 7 Microstructure of base metal steel TStE 420; magnification 200 x

on samples of base materials, as well as on simulated specimens, as shown in Figures 7 -10. Examination of microstructure of TStE 420 was performed on normal optical microscope and microstructure of S960QL on scanning microscope (for base metal and for weld cycled specimen).

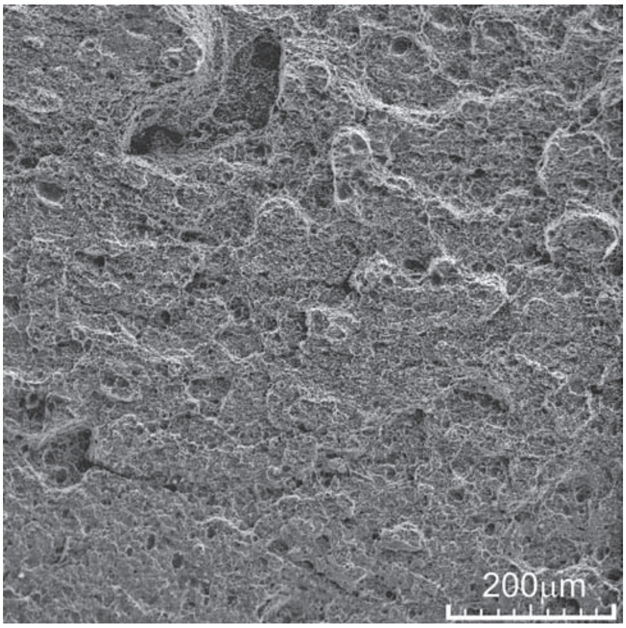

Figure 8 Microstructure of base metal steel steel S960QL; magnification 200 x

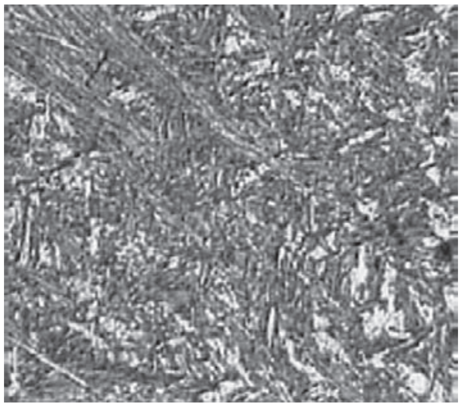

Figure 9 Microstructure of of the steel TStE 420, peak temperature of thermal cycle 1 300 °C, magnification 200 x

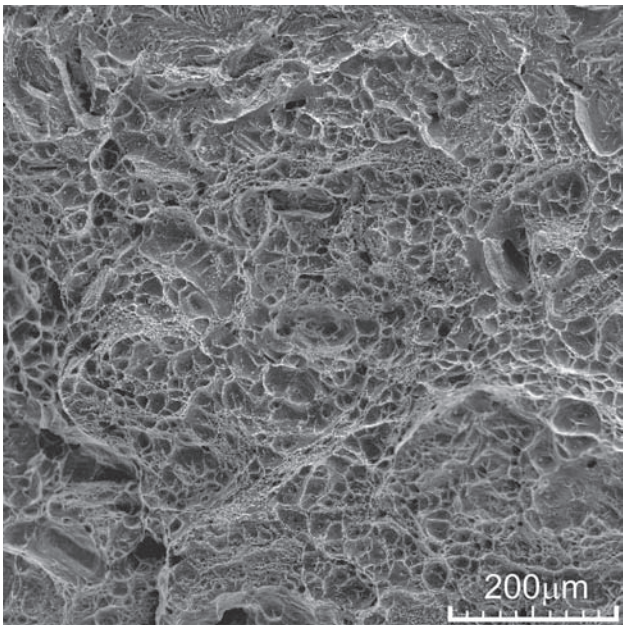

Figure 10 Microstructure of the steel S960QL, peak temperature of thermal cycle 1 300 °C, magnification 200 x

CONCLUSION

Microalloyed steel of increased strength TStE 420 shall be welded at such parameters to reach time of cooling from 800 - 500 °C for 8 - 10 s. Within such parameters, hardness in the HAZ at the fusion line in heat affected zone is reduced (as wel as the risk of cold cracks), while the values of impact toughness are higher than marginal values of transition into fragile condition. [5-8] The author's values for impact toughness are related to fine ferrite grain as a result of the maximum at a temperature little higher than A_{c3}, being 780 °C in the performed experiment. Reduce of impact toughness occurs above that temperature. Moreover, maximum of impact toughness at 780 °C reduces hardness. Further increase of temperature causes decrease of impact toughness (Figure 5), which is correlated to the increase of hardness (diagram of the Figure 3). Welding technology of the steel S960QL is based on the controlled input of energy during welding process (preheating, temperature between passes, heat input achieved by electric arc, additional heating) and strict compliance with the defined procedure, all with the aim to avoid occurrence of cold cracks and other failures, and to achieve the required properties of welded joints. Insufficient input of heat usually affects the increase in strength and hardness of the welded joint, which, along with residual stresses and the presence of hydrogen in the weld, may cause cold cracks, while reducing deformability and increasing susceptibility to brittle fractures [8]. The highest values for impact toughness are obtained for tempered martensite with smaller portion of bainite, which occurs due to hardness of 320 - 350 HV (Figures 4 and 6). Simulation of weld thermal cycle provides results that can be used in optimization of parameters for welding of microalloyed high strength steels. These results can be used in real welding process to achieve optimal mechanical properties of welded joints of microalloyed high strength steels.

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Note: Responsible translator: Martina Šuto, prof., University of J. J. Strossmayer of Osijek, Croatia