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Faculty of Mechanical Engineering
Department of Materials Engineering

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dean of the Faculty of Mechanical Engineering of the University of Žilina in Žilina

Terchová, Slovakia
30 January – 1 February, 2013

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APPLICATION OF HIGH STRENGTH STEEL OF THE S690QL CLASS FOR APPLICATION TO WELDED STRUCTURES

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Abstract

High strength steels belong into a group of high quality steels, with exceptional mechanical properties, especially in respect to strength and toughness. Those favorable properties are being achieved by application of special procedures of thermo-mechanical processing and simultaneous alloying. In this paper are considered the most important properties of a special class of high strength steels S690QL, which can be classified into the group of special low alloyed steels. It is also pointed to advantages that those steels have with respect to other steels, as well as to possibilities for application of those steels for responsible welded structures.

Key words: *High strength steel, S690QL, Mechanical properties, Hardness, Microstructure.*

1. Introduction

Considered steels of the S690QL class are being produced in Sweden and are known under the commercial mark WELDOX 700. They are produced according to precisely defined production phases and strictly controlled chemical composition. Such a treatment enables acquiring exceptionally high mechanical properties. Their structure is interphase, what makes them easily weldable, but only for sheets of relatively small thickness. For production of the more massive welded structures exact instructions and recommendations must be followed, related to selection of the optimal welding technology. Those steels are prone to appearance of cold cracks. They are being produced by a thermo-mechanical processing of semi finished pieces at high temperatures. The process consists of heating of a material up to the austenite region, when the recrystalization is complete, then follows rolling at that temperature and quenching (Q). After that they are tempered (T) in order to obtain the interphase structures and maintaining the high mechanical properties. Those steels are used for manufacturing of hoists and cranes, steel platforms, civil engineering machines, transportation tanks, for parts and assemblies exposed to high dynamic loads, responsible welded structures and others.

Steels of the S690QL class belong to a group of special low alloyed steels where the chemical composition is prescribed by the manufacturer (Table 1, [1 – 3]). The carbon content is limited to 0.20 % what improves the weldability. Addition of small quantities of other alloying elements causes improvement of those steels' properties, where should be especially emphasized content of niobium and boron which deoxidize steel and significantly make steel grains smaller.

Table 1

Prescribed chemical composition of S690QL steels

Mark	Require-ment	Content of chemical elements, %														
		C	Mn	Si	P	S	Cr	Mo	Ni	V	Al	B	Cu	Ti	N	Nb
S690QL	Prescri-bed	0.20	1.50	0.60	0.020	0.010	0.70	0.70	2.0	0.09	0.015	0.005	0.30	0.040	0.010	0.040

There exist three versions of the S690 steels, S690Q, S690QL and S690QL1, which differ from each other only by guaranteed impact toughness (S690Q-WELDOX D has guaranteed impact toughness of – 27 J at – 20 °C, S690QL-WELDOX E has – 27 J at – 40 °C and S690QL1-WELDOX F has – 27 J at – 60 °C, [2, 3].

2. Properties of S690QL steels

The main reason for mass application of the high strength steels of this class are the exceptionally high mechanical characteristics (tensile strength and yield stress) as well as the favorable impact toughness. The basic data provided by manufacturer of these steels are given in Table 2 [1].

Table 2

Prescribed mechanical characteristics of S690QL steels

Steel mark	Thickness [mm]	R_m [MPa]	R_P [MPa]	A_5 [%]	Microstructure
Weldox 700 (D, E or F)	4.0 – 53.0	780 – 930	700	14	Interphase structure, tempered
	53.1 – 100	780 – 930	650	14	
	100.1 – 130	710 – 900	630	14	

It should be emphasized that, related to thermo-mechanical procedure of manufacturing these steels, their application is limited to working temperatures which do no exceed 580 °C, because, even when the tempering temperature is exceeded, the significant worsening of mechanical properties may occur [2, 3].

3. EXPERIMENTAL INVESTIGATIONS

Experimental testing of the S690QL steel included mechanical tensile test, impact toughness test and investigation of microstructure as well as hardness measurements.

Tensile test. Four specimens were prepared from the plate of thickness 15 mm (Fig. 1). The prepared samples were tested at the ZWICK/ROEL Z 100 testing machine, with the measurement range of 1 to 100 kN. The strain rate was 10 mm/min. Test results are presented in Table 3. Physical appearance of the tested sample is shown in Fig. 2. Based on sample fracture point appearance it can be concluded that this steel possess favorable toughness [2].

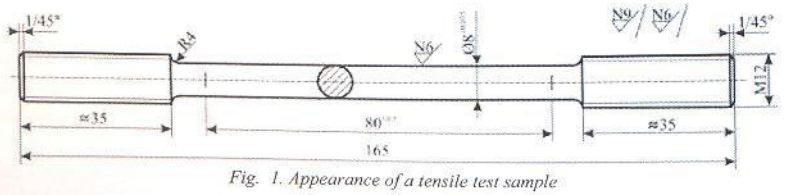

Fig. 1. Appearance of a tensile test sample

Table 3

Experimental results of tensile test

Sample No.	L_0 [mm]	S_0 [mm^2]	$R_{p0.2}$ [MPa]	R_m [MPa]	A_g [%]	$A_{11.3}$ [%]
1	89.28	50.27	781.94	797.81	1.73	14.19
2	89.28	50.27	809.40	839.92	5.79	11.30
3	88.42	50.01	800.41	835.52	4.86	9.98
4	88.29	50.27	811.95	842.45	5.48	10.92

Fig. 2. Sample appearance prior to (left) and after the test (right)

Characteristic force-displacement diagram in tension is shown in Fig. 3.

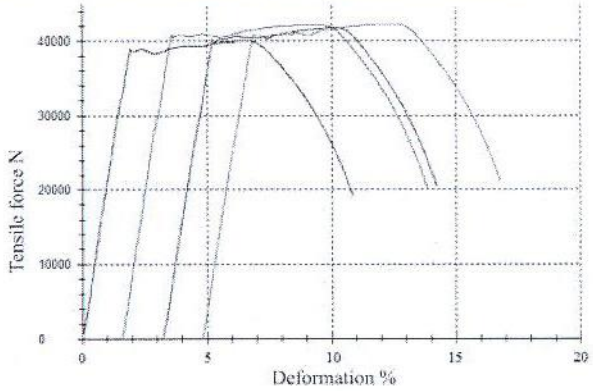

Fig. 3. Tension test diagram for four samples

Impact toughness test. According to procedure, similar to that one for the tensile test, six samples were prepared (Figs. 4 and 5) for the toughness impact test. Tests were performed on the Charpy pendulum in the accredited laboratory of the Fiat Automobiles Serbia in Kragujevac. Results of these tests of the base metal, at room and lowered temperatures, are presented in Table 4 (according to standard EN 10045-1).

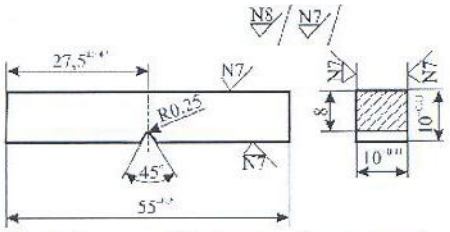

Fig. 4. Appearance of the impact toughness test sample

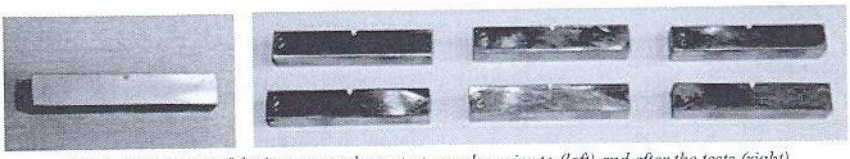

Fig. 5. Appearance of the impact toughness test samples prior to (left) and after the tests (right)

Table 4

Values of impact toughens at room and lowered temperatures

Material type	Temperature [°C]	Impact toughness [KV, J]
S690QL (Weldox 700)	+ 20	172; 166; 171
	- 40	157; 158; 155

Microstructure test. This test referred primarily to determination of sizes and distribution of grains, where the structure of the considered steel was estimated as interphase tempered one (Fig. 6) [4]. Measured values of the base metal hardness were within limits 274 to 281 HV (according to standard EN1321). Experimentally obtained results confirmed the fact that the S690QL class steels have exceptional mechanical properties, even better than those prescribed by standard EN 10025:2004. This conclusion enables and justifies application of those steels for very responsible structures.

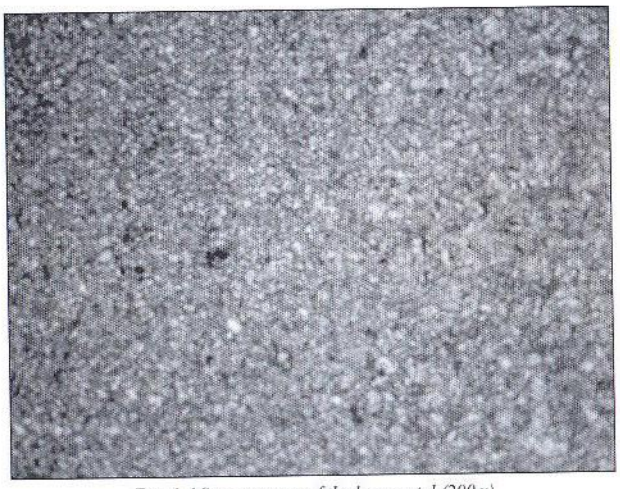

Fig. 6. Microstructure of the base metal (200 x)

4. Importance and application of S690QL steels

Application of the S690QL steels is primarily related to very responsible structures made by welding. Related to that, it should be emphasized that in selecting the welding technology, it is necessary to grasp all the influential factors and to select the adequate welding technology, since the uncontrolled heat input can result in worsening of properties acquired through the complex thermo-mechanical processing. This paper is an attempt only