The use of rutile cored wires for welding high strength steel in crane fabrication

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High strength steels are increasingly applied in crane fabrication, with the aim to obtain weight savings or a higher lifting capacity. Simultaneously, cored wire welding is becoming more popular. This has to do with the high quality demands cranes are subjected to for security reasons, but also with the higher welding productivity cored wires offer.

On the European welding consumable market, the availability of cored wires for high strength steel has been limited to mainly metal-cored and basic types. Recently, however, ESAB has introduced two rutile types with a minimum yield strength of 620 and 700 MPa under the product names OK Tubrod 15.07 and OK Tubrod 15.09 respectively.

The wires are characterised by high welding productivity, good mechanical properties, a very low weld metal hydrogen content, and above all, excellent weldability.

ESAB developed these wires at the request of several European crane fabricators, among which the Dutch company Huisman-Itrec. They tested the OK Tubrod 15.09 for welding Weldox 700 and have gained production experience in a number of projects.

OK Tubrod 15.07 is still in its testing stage. At this moment, it is being tested for the mechanised welding of pipelines in X80.

This article will introduce the new rutile cored wires for high strength steel, while describing the experiences of Huisman-Itrec with the OK Tubrod 15.09.

Huisman-Itrec

Huisman-Itrec B.V. in Rotterdam, is the result of a merger in 1981 between the crane fabricator Huisman and the engineering bureau Itrec. Their most important activity is the construction of cranes and other lifting equipment for the offshore industry, the dock industry, civil works and shipbuilding. With design facilities for engineering, hydraulic and electric propulsion systems,

and for software, the company delivers client specified installations. Huisman-Itrec specialise in systems that are not available on the market as standard products. Examples are cranes for deep-water applications, and ship motion compensation systems. Other products built by Huisman-Itrec are floating sheerlegs, self propelled heavy transporters, equipment for installing pipelines on the seabed, drilling equipment, and even amusement park attractions. These products are delivered to clients all over the world.

The company constructs according to the requirements of the leading approval societies in this branch of industry (e.g. Lloyds), and execute a high quality standard. When not building on site, products are tested with in-house facilities, before delivery.

AWS A5.29-98	EN 12535-00	Approvals	
OK Tubrod 15.07	E101T1-K7M H4	T 62 4 Mn2Ni P M 2 H5	–
OK Tubrod 15.09	E111T1-GMH4	T 69 4 Z P M 2 H5	ABS*, LR*

*Table 1. AWS and EN classifications and approvals. *= limited approval.*

Figure 1. Vertically-up welding of a crane beam in Weldox 700.

Figure 2. Vertically-up welding of a crane beam in Weldox 700.

OK Tubrod 15.07 and 15.09

Both types are all-positional rutile cored wires with AWS and EN classifications according to table 1. The strength properties are tuned for high strength steel with a minimum yield strength of 620 and 700 MPa, with good CVN toughness at –40ºC. Table 2 gives the all-weld metal chemical composition and mechanical properties.

The wires are developed for all-positional welding under 80%Ar/20%CO_2 shielding gas, falling within EN 439 class M21. Vertical down welding, however, is not recommended because of the high risk of cracking in the first thin layer; especially in fabrications with a high restraint.

It concerns butt-closed cored wires with a filling degree of approximately 18%. The slag is fast freezing to support the weld pool during positional welding. The arc action is spray-arc at all welding currents, and the weldability is excellent. Another advantage is that, with the same wire size, a uniform parameter setting can be used when components have to be welded in several positions.

The high productivity, compared to solid wires and basic cored wires, becomes apparent in positional welding (PC, PF and PE). Vertically-up welding with a deposition rate of 3kg/h, for instance, is attainable.

The weld metal hydrogen content falls within Class H5 of EN785 for the operating envelope of parameters and corresponding stick-out lengths, which is exceptional for rutile consumables. This is of great importance for the welding of high strength steels. Normally, the weld metal has a higher Carbon Equivalent than the high strength parent metal, and therefore it will undergo the austenite-ferrite transition later. For this reason, hydrogen in the weld metal will not be able to diffuse to the heat affected zone and remain in the weld metal. Add this to the limited heat input, needed to give the weld metal sufficient strength properties, and all ingredients are present to cause hydrogen induced cracking. Low-hydrogen weld metal is therefore crucial for successful crack-free welding. This is also reflected by the preheating recommendations for Weldox 700, which are based on H5 class filler materials (Table 3).

The wires are not recommended for constructions that are submitted to a stress relief treatment, which would result in partial loss of toughness properties. In these cases, the use of a basic cored wire is advised.

Experiences with OK Tubrod 15.09 in crane fabrication

The introduction of OK Tubrod 15.09 at Huisman-Itrec is part of a general transition from solid to cored wire welding, carried through over the past years by the welding department with the aim to improve the all-over welding productivity. An additional advantage, especially with rutile cored wires, is that also temporary welders master the required skills relatively quickly, which enhances the flexibility required by production.

At this moment, over 85% of all weld metal is deposited with metal cored or rutile cored wires, which brought along a substantial increase in productivity. It concerns mainly manual welding, but the welding department is investigating the possibilities of light mechanisation. All welders are certified up to H-L045 (6G).

	%C	%Si	%Mn	%Ni	%Mo	%P	%S
OK 15.07	0.04-0.07	0.30-0.50	1.45-1.75	2.30-2.70	–	<0.020	<0.020
OK 15.09	0.04-0.09	0.30-0.50	0.95-1.35	2.50-3.10	0.25-0.35	<0.015	<0.015

	Rp0.2 (MPa)	Rm (MPa)	A5d (%)	ISO-V (J at –40ºC)
OK 15.07	>620	700-830	>18	>47 (>27 at –50ºC)
OK 15.09	>690	770-900	>16	>41

Table 2. All weld metal chemical composition and mechanical properties.

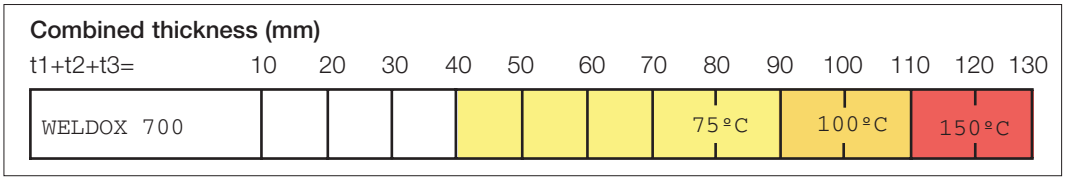


Table 3. Preheating recommendations for Weldox 700 based on a maximum heat input of 1.7kJ/mm and low-hydrogen weld metal (EN 785 class H5).

Correct heat input	**1.2-1.4KJ/mm/Tp 80ºC/Ti 170ºC**						
Tensile test	Rm (MPa)		Re (MPa)		A (%)		
	848		825		15.6		
CVN at –40ºC (Av.3)	WF	FL	FL+2mm	FL+5mm	WR	FR	FR+2mm
	54	54	161	161	33	39	122
Hardness HV10 (Av.3)	Weldox 700		WBZ	Las	WBZ		Weldox 700
Root	273		434	297	417		279
Center weld	276		343	259	331		286
Bend test	Magnaflux			Ultrasonic			
OK	no indications			no indications			

High heat input	**1.7-2.0 KJ/mm/Tp 80ºC/Ti 190ºC**						
Tensile test	Rm (MPa)		Re (MPa)		A (%)		
			841		780	15	
CVN at –40ºC (Av.3)	WF	FL	FL+2mm	FL+5mm	WR	FR	FR+2mm
	54	102	168	123	31	30	135
Hardness HV10 (Av.3)	Weldox 700		WBZ	Las	WBZ		Weldox 700
Root	266		397	290	395		282
Center weld	266		343	289	346		861
Bend test	Magnaflux			Ultrasonic			
OK	no indications			no indications			

Table 4. Mechanical weld metal properties at a correct heat input and a too high heat input. V-joint/ plate thickness 30mm, combined thickness 60mm/ Weldox 700 Heat no. 366631/ position PF. WF = Weld Face, FL = Fusion Line, WR = Weld Root, FR = Fusion Line Root.

Figure 3. Crane pedestal part.

Figure 4. Vertically-up welding of a pedestal part.

Huisman-Itrec increasingly applies Weldox 700 high strength steel for the construction of lifting equipment. The components to be welded, such as crane beams, masts and pedestal parts, are too large to be turned, making positional welding unavoidable. Until recently, the Weldox 700 was welded with a combination of coated electrodes and solid wire, but also here the company wanted to change over to 100% cored wire welding. That is why they requested ESAB to develop such a wire, which received a positive reply, also motivated from an international context.

After the development of the wire, Huisman-Itrec submitted the first test spools to a rough test to verify the suitability for welding Weldox 700. It concerned a V-joint in thick plate, welded in PF position without preheating and without controlling the interpass temperature. The strength properties of the joint were measured by tensile tests with transverse and longitudinal test bars. Cross weld, a tensile strength of 769MPa was obtained, with the rupture in the parent metal. In the longitudinal direction, the yield strength was too low (668MPa) whereas a tensile strength of 754MPa was satisfactory.

	Rm (MPa)	**Re (MPa)**	**A5 (%)**	**CVN –40ºC (J)**
Weldox 700	780-930	>700	>14	>27
Heat nr. 366631	826	759	15	158(Av.3)

The CVN toughness (Av. 3) was 53J at –40ºC for the weld and 42J for the root (welded on ceramic strip). The results of the side bend tests were good. Subsequent ultrasone and magnaflux testing proved that the weld was free of defects and, more importantly, cracks.

WPS'es

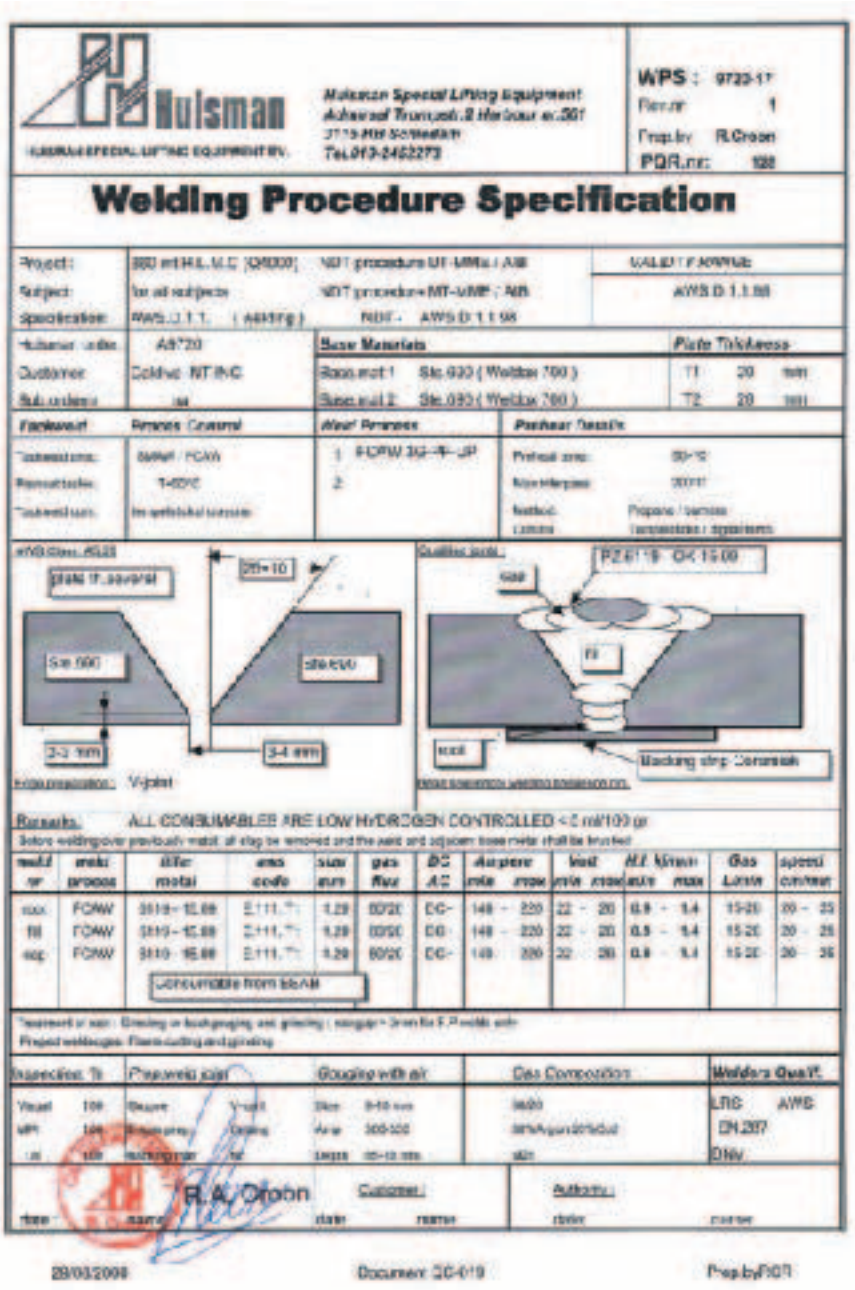
On the basis of these results, the welding department of Huisman-Itrec decided to continue the investigation, aiming at the establishing of suitable welding procedure specifications (WPS) for Weldox 700. In addition, the company wanted to obtain a Lloyds yard approval for a project with a CVN requirement of 27J at –40ºC, awaiting the general Lloyds approval ESAB had requested.

Table 3 gives the preheat recommendations for Weldox 700, based on a weld metal hydrogen content of max. 5ml/100g deposited weld metal and a maximum heat input of 1.7kJ/mm. To understand the effect of the heat input on the mechanical properties, test plates were welded (800×30×30mm) at a correct heat input (1.2-1.4kJ/mm) and at higher heat input (1.7–2.0 kJ/mm). Table 4 summarises the results.

The strength requirements of Weldox 700 (Table 5) were met, as well as the maximum hardness requirement of 425HV10. The same is valid for the CVN toughness of the weld; even for the root.

On the basis of these results, Huisman-Itrec was granted the local approval they needed for OK Tubrod 15.09, valid for one specific product and one batch. Figure 5 shows a WPS for the position PF that Huisman-Itrec developed subsequently.

In a later stage, ESAB obtained the general Lloyds approval; be it with a limitation. For this class of consumables, Lloyds has a CVN demand of 69J at –40ºC. For rutile consumables, this is too high, however. That is why the approval is limited to projects with CVN requirements of 42J at –40ºC or lower, which is sufficient for many applications.


Huisman

Welding Procedure Specification

WPS : 9722-17

PQR.nr: 128

Project:

Subject:

Specification:

Customer:

Base Materials

Plate Thickness

Remarks: ALL CONSUMABLES ARE LOW HYDROGEN CONTROLLED

Consumable from ESAB

Welders Qual.

R.A. Croon

Customer

Authority

Document 20-019

Fabrication experience

Huisman-Itrec applies OK Tubrod 15.09 for welding in PF position. For downhand work, they kept on using a metal-cored type. After successful use on a smaller project, OK Tubrod 15.09 was utilised for a bigger project, the fabrication of a series of cranes for Mammoet B.V. The figures 1 to 4 show the application of the wire.

It is applied successfully for the vertically-up welding of crane beams, pedestal parts and other crane components. The welders are very pleased with the new consumable and also temporary workers learn to use it within an acceptable period of time. Essential for welding Weldox 700 is that the low heat input, needed to obtain sufficient strength and toughness, can be maintained well, also in PF position. This is more difficult with solid wire, basic, or metal-cored wires, because these are welded close to the short arc mode. The success also becomes apparent from the 100% ultrasonic and magnaflux NDT that was performed. The defect rate was below 0.5%.

About the author

Ben Altemühl, BSc, welding engineer, joined ESAB in 1990 as sales promotion manager for FILARC Welding Industries in the Netherlands. Since 1999, he has been responsible for the sales promotion of all cored-wire products within ESAB Europe's Business Area Consumables.