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Refurbishing of Continuous Casting Roller Jackets by Using Flux Cored Wires and Strip Cladding

Pierre Gérard, Charles Louppe

SOUDOKAY S.A. (Böhler Welding Group), Rue de l'Yser, 2, B-7180 Seneffe, Belgium
e-mail: pierre.gerard@soudokay.be; charles.louppe@soudokay.be

Abstract

Member of the Böhler Welding group, Soudokay is specialized in the production of flux cored wires for overlaying as well as welding fluxes for the strip cladding process. The steel industry is one of its focus segments for years, giving it a great experience in repair and maintenance of continuous casting lines.

Expert in overlaying techniques, Soudokay has developed very specifics alloys, especially dedicated to withstand these different stresses. Different martensitic stainless steels have been studied, having different content in Cr, Ni, Mo and N. The welding consumables will also strongly depend on the welding process and welding procedure. Indeed, some of them are over alloyed, being designed for a two layers cladding procedure, when the classic one will request a three layers cladding deposit. The latest development has led to the production of super martensitic stainless steels, being welded with both strip cladding process and SAW techniques.

Not only the alloy but also the welding process and welding procedure will influence strongly the life time of the rollers but also the productivity of the welding workshop doing the maintenance of the line as well as the productivity of the continuous line itself. Based on its experience, Soudokay has defined guidelines in order to select the most appropriate solution in terms of welding consumable, welding procedure and process control.

Wear Solicitations in the CC line

Depending on its position in the continuous casting line, the rollers are subjected to different type of wear. At the upper part of the line, thermal shocks and resulting fire cracking are predominant.

At the lower part of the line, depending however on the effectiveness of water cooling, the mechanical stresses and the metal to metal wear progressively tend to play a more significant role.

In order to analyze more deeply the wear process, we need to take into account, the following factors:

- The effect of the oxidation.
- The quality of the cooling water
- The effect of the erosion caused by steam formation,
- The wear caused by oxides formation, between rollers and the long product.
- Presence of alternating bending stresses and thermal fatigue.

Overlaying Alloys

Some history

The best suitable alloy for a resistance against a mix of wear and corrosion will be the martensitic stainless steel. Indeed, by a balance between addition of carbides formers and heat treatment, we will get weld overlays having hardness between 40HRc and 45HRc, values which have showed the best results in service. It is also true that the addition of alloying elements will have to be carefully controlled in order to obtain a minimum of 5% of delta ferrite in order to minimise the stress corrosion. Moreover, a maximum of 10% of delta ferrite will be accepted for fatigue strength resistance consideration.

When the continuous casting line process has been developed, the first welding procedure for the repair of the rollers was simply to rebuild the shape of these ones by using a Cr-Mo steel matching the base metal. In the early nineties, the welding companies started to study and develop better solutions and the next step has been the welding of the martensitic SS AISI 420. This has showed good resistance in terms of abrasion wear but we quite poor resistance in terms of stress corrosion as well as fatigue strength.

After some years, the alloy AISI 410NiMo has been used in order to obtain between 5% and 10% of delta ferrite for the reasons explained here above. This alloy has been used during years, showing quite good service life but still with too much cracking resulting from the stress corrosion.

This is the reason why Soudokay has started to developed 410NiMo alloy with addition of Nitrogen in order to decrease the C content and in consequence to increase the resistance against corrosion but also by keeping the hardness level.

Only the rollers located at the very top of the line couldn't show good results. Indeed, at this place, the working temperature is the highest. However, working closely with the steel factories, Soudokay has been able to introduce a new solution: the supermatensitic steel.
In any case, the heat treatment has to be carefully studied in order to optimize the mechanical properties of the weld overlay.

Overlaying alloys: chemical composition and properties

Basically, the continuous casting rollers are made from steel 42CrMo4, 25CrMo4, 16CrMo44, 21CrMoV5.11

The level of carbon in these steels varies from 0,2% to about 0,4%. In consequence, it has been necessary to develop different welding consumables in order to reach the same requested microstructure independently of the base material.

You will find here below the most famous Soudokay wires used for the refurbishing of cc rollers.

We have to distinguish mainly three kinds of alloys:

1) for rebuilding application :

SK 20CrMo-SA

2) for the overlaying of new rollers by welding one layer :

SK 743-O

3) for the overlaying of new rollers by welding two layers :

SK 740L-SA and SK 740H-SA

4) for the overlaying of new or worned out rollers by welding multiple layers (minimum three layers) :

SK 742N-SK

5) for the overlaying of the two first segments of the line by the using the SAW strip cladding process : the supermartensitic

Soudotape 430L + RECORD RT168

Table 1. Chemical composition of the all weld metal [%]

	C	Mn	Si	Cr	Ni	Mo	V	Nb	N
SK 20CrMo-SA	0,13	1,00	0,50	0,60		0,30			
SK 410NiMo-SA	0,04	1,00	0,30	12,00	5,00	0,90			
SK 743-O	0,02	0,57	0,92	19,60	6,40	1,40		1,00	0,12
SK 740L-SA	0,08	1,00	0,90	15,50	4,00	1,70	0,20	0,20	
SK 740H-SA	0,08	0,70	0,70	16,80	4,60	2,00	0,25	0,27	
SK 742N-SK	0,05	1,20	0,40	13,50	3,30	1,30	0,15	0,10	0,10
Soudotape 430L + RT168	0,02	0,22	0,79	13,00	5,20	2,60			

This article will be focused mainly on the SK 742N-SK and the supermartensitic Soudotape 430L + RT168. Indeed, the first on is the most popular one and the second one is one of the latest development of Soudokay for that application.

SK 742N-SK

The microstructure of the SK 742N-SK can be found here below. We are in the area of martensit, ferrit and a few austenite. This last one will be immediately transformed in martensit after heat treatment.

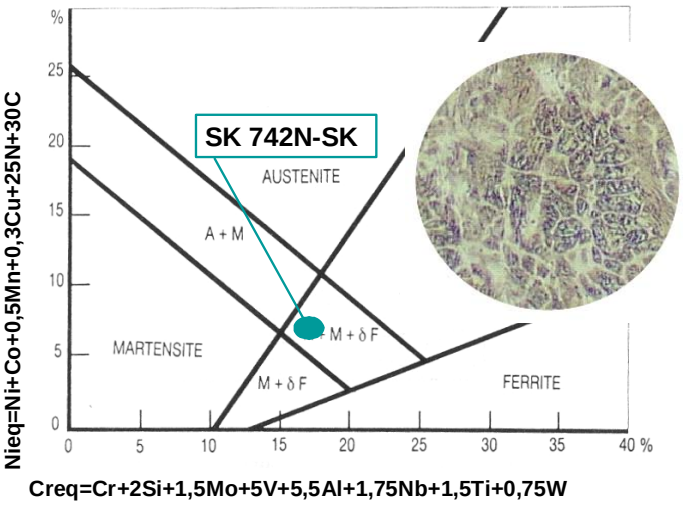

Fig. 1. Schaeffler Diagramm SK 742N-SK

The requested hardness can be obtained by applying a heat treatment. In most of the cases, the rollers are treated at about 525°C in order to get 42HRc.

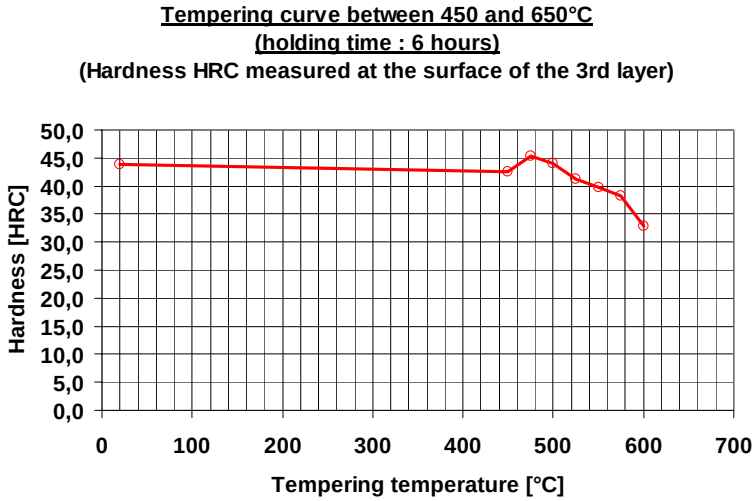

Fig. 2. Tempering curve

The main goal of the heat treatment will not be the modification of the hardness but certainly the improving of the tensile properties of the weld. In an as welded condition, the weld will not have more than 1% of elongation before cracking. After heat treatment, we will obtain up to 10% of elongation.

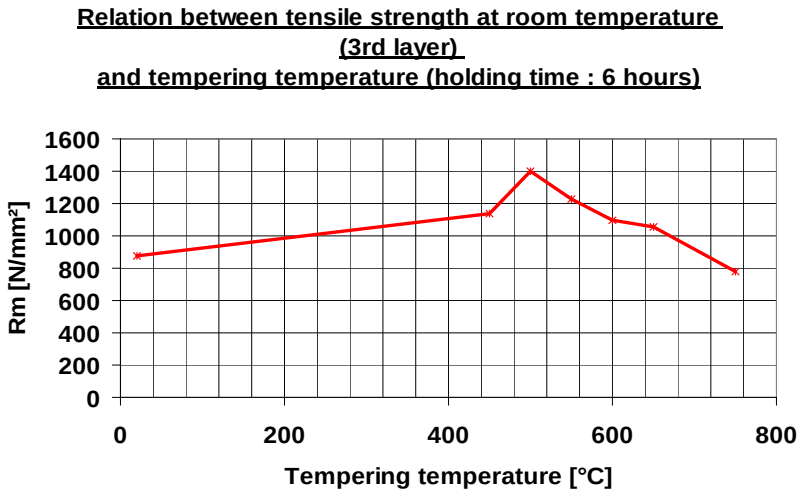

Fig. 3. Relation between tensile strength and tempering temperature

The fire cracks are the results of crystallographic transformations appearing on the external surface of the roller, caused by the contact with the hot steel. The cracks will always tend to propagate from the surface towards the centre of the roller, by mechanical fatigue process.
It is absolutely necessary to decrease this tendency to cracking by increasing the elongation properties.

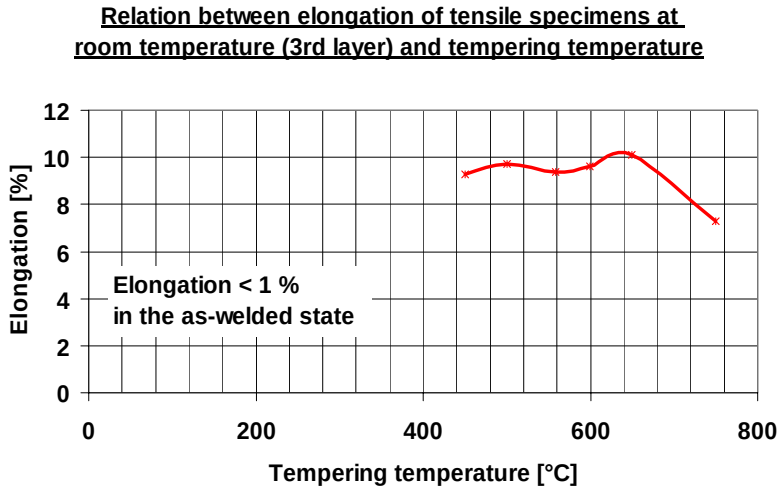

Fig. 4. Relation between elongation and tempering temperature

Soudotape 430L + RECORD RT168

At the very top of the continuous casting line, the more severe stresses are corrosion and hot oxidation. The wear caused by abrasion is much lower than in the rest of the line as the metal is still in a soft condition as not completely solidified.

That the reason why it is accepted to apply overlaying materials having lower hardness but better corrosion resistance. We have in consequence chosen the supermartensitic structure. Indeed it has a much better corrosion resistance than a classic martensitic type (very low C) but still having good wear resistance properties .

Several trials in the two first segments have been done in service and have shown excellent results compared to martensitic-ferritic structures.

Fig. 5. Service life of supermartensitic vs martensitic

A post weld heat treatment is advised: 500-550°C during 6 hours.

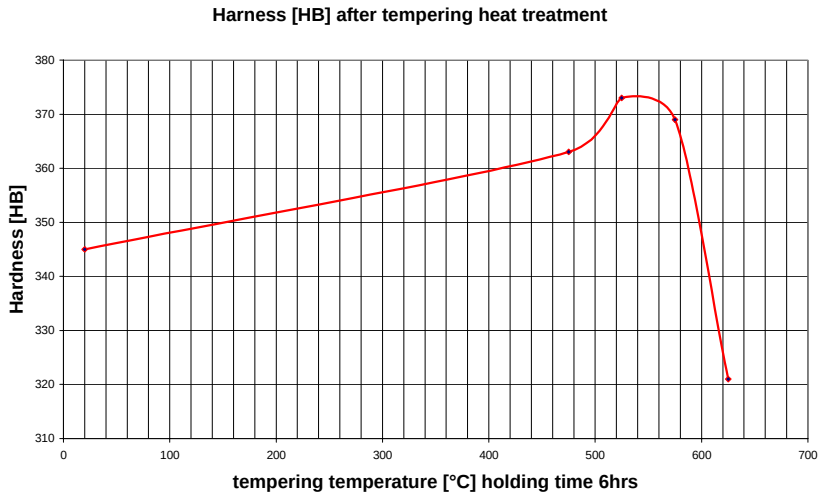

Fig. 6. Hardness after tempering heat treatment

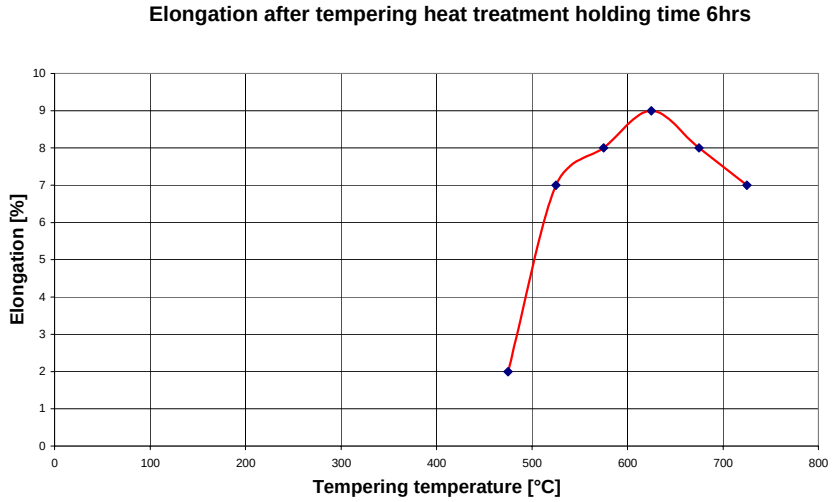

Fig. 7. Elongation after tempering heat treatment

The Process of Refurbishing

The preparation of the rollers before welding

The surface has to be clean of any dust, rust, grease or oil.

Remove all the existing cracksby machining and control it by a dye penetrant liquid test.

Please check the hardness before welding in order to check the existence of a previous hardfacing. If this one exists, it is preferable to machine it in order to reach the base metal.

We also advice the protection of the journals of the roll during the welding process, in order to avoid any spattering on them.

A preheat at 250°C before starting welding will be needed. It is necessary to be sure that the temperature is uniform inside the roller, reason why you have to apply the correct soaking time, depending on the diameter of the roller.

Typically:

DIAMETER [mm]	SOAKING TIME [Hrs]
150	2
300	3
600	5

The welding processes

Different welding process can be used. Typically, by using flux cored wires, the choice will be done between the open arc process, the submerged arc process using agglomerated fluxes and the gas shielding process in some particular cases. We strongly consider that the welding procedure must be based on a weaving technique. Indeed, by welding with stringer beads, the number of heat affected zones will be multiplied by a factor of at least 10. As these zones are more sensible to the corrosion, their number has to be reduced as much as possible.
The strip cladding process is also very often used for the overlaying of rollers. In most of the cases, the submerged arc process is used but the electroslag process can also be a possibility. This technique is very convenient for the overlaying of rollers as it provides wide beads, without any need for a weaving system.

Open arc welding process

The heat for welding is produced by an electric arc between the filler metal electrode and the workpiece. The flux contained within the electrode can make the electrode self-shielding. The core ingredients protect the weld metal from the atmosphere without external shielding.

This process has several advantages:

- The welding machine is simpler, with no need for flux or gas feeding equipment.
- It is well suited for the overlaying of small diameter rollers, where the use of SAW makes the welding critical.
- No extra costs for flux or gas.

But obviously, has also some disadvantages:

- More fumes and spattering, in consequence a strong extraction system is required (inducing also more noise).
- The removal of the slag (from elements coming from the core of the wire) is less easy than in SAW. Indeed, this slag is much thinner.
- The equipment must be adapted. Indeed, it is necessary to protect the welder from the high intensity of the light.
- The efficiency of the welding is about 87%.

Submerged arc welding process

The heat for SAW is generated by an arc between the flux cored wire and the workpiece. This one is maintained in a cavity of molten flux which refines the weld metal and protects it from atmospheric contamination.

Advantages of the process:

- The arc is covered by the welding flux, meaning elimination of all arc flashed, spatters and fume.

- The shielding provided by the flux is not sensitive to wind as in gas shielded methods.
- The slag removal is very easy and automatic when using a proper welding flux
- The control of the bead by welding is very easy and the process is very convenient for the welder.
- The efficiency of the process is 97%.

Disadvantages of the process:

- Extra costs for the flux
- Needs for the recycling of the slag, it makes extra waste disposals.

Table 2. Typical welding parameters for Open Arc Welding on CC rollers

Typical welding parameters for Open Arc Welding on CC rollers				
DIA (mm)	1.6	2,4	2 x 2,4	2.8
Voltage (V)	26 - 28	26 - 28	26 - 28	26 - 28
Current (A)	180 - 300	300 - 450	450 - 800	350 - 550
welding speed (cm/min)	25	13	15	15
Oscillation (mm)	40	40	40	50
Depos rate (Kg/h)	Up to 6	Up to 8	Up to 15	Up to 10

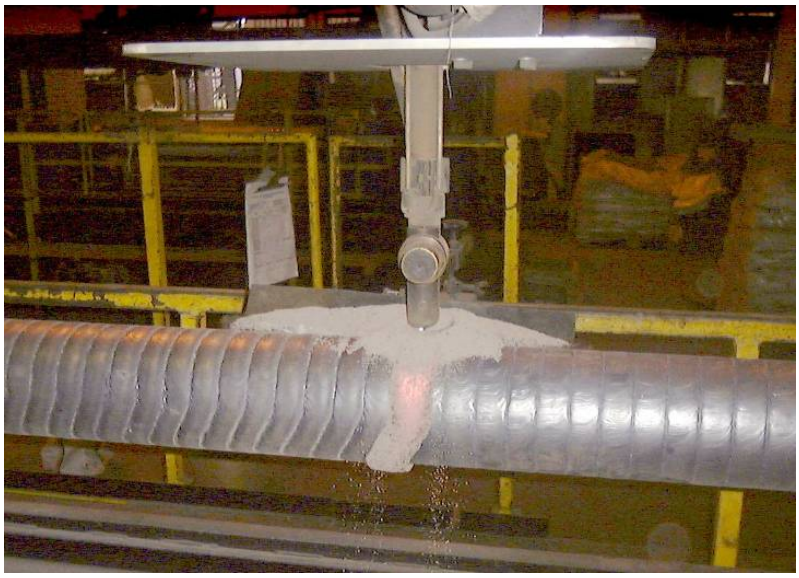

Fig. 8. SAW single wire overlaying

Table 3. Typical welding parameters for SAW on CC rollers

Typical welding parameters for SAW on CC rollers				
DIA (mm)	2,4	2 x 2,4	3,2	4
Voltage (V)	28 - 30	28 - 30	28 - 30	28 - 30
Current (A)	300 - 450	450 - 750	350 - 600	450 - 650
welding speed (cm/min)	16	16	13	15
Oscillation (mm)	40	60	40	50
Depos rate (Kg/h)	Up to 8	Up to 16	Up to 12	Up to 12

Strip Cladding

The strip cladding method can be used both in submerged arc welding or electroslag welding. As the slag is liquid and not covered by flux during the welding, the ESW process is not often used for the overlaying of rollers. Indeed, the risk of flowing of the weld metal is much higher as the capability of the slag to maintain the liquid metal is much lower compared with SAW.

The size of the strip used varies from a width of 30mm to 60mm. The thickness will always be 0.5mm which is the optimal one.

Table 4. Typical welding parameters for SAW strip cladding on CC rollers

Typical welding parameters for SAW strip cladding on CC rollers		
	30mmx0,5mm	**60mmx0,5mm**
Current (A)	350 - 450	550 - 1000
Tension (V)	23-26	24-28
Speed (cm/min)	17 - 23	10 – 20
Depos rate (Kg/h)	Up to 6	Up to 12

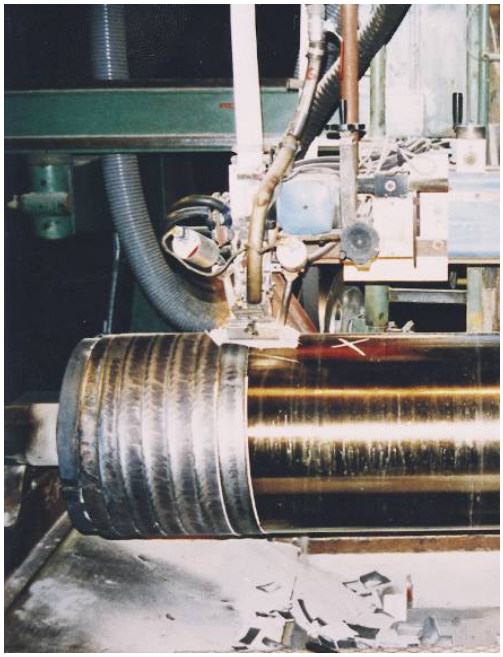

Fig. 9. SAW Strip Cladding

Advantages of the process:

- The welding machine used does not differ from the one used in SAW using flux cored wires. Only the welding head must be removed and a cladding nozzle must be improved.
- The efficiency of the process is very high, higher than 100% as some alloying elements are provided by the welding flux.
- No weaving system is required
- Very high deposition rates can be obtained.
- The risk of having defects is lower than by using a flux cored wire (no weaving…).
- Dilution with base metal will be about 20% compared to 40% by using a flux cored wire. In consequence, fewer layers will have to be welded to get the requested chemical analysis.

Disadvantages of the process:

- Even by using strips 30x0.5mm, the process is limited to the diameter of the rollers. Indeed, very small rollers (smaller than 150mm in diameter) can not be properly overlaid by strip cladding.
- The preparation of the rollers must be slightly modified. Indeed, the machining has to be done considering that the width of the bead can not be modified like it can be by modified by using a flux cored wire.

The refurbishing techniques using flux cored wires: single wire vs. twin wire techniques

The productivity is one of the main concerns of the welding workshops today. Indeed, with the constant increase of the labour costs, the need to find other sources of economies becomes more and more important.

By overlaying with flux cored wires, two main SAW techniques can be used. The first one is the welding by using a single wire, very often in diameter 3.2mm. The second one is the welding with a twin wire technique, two times 2.4mm.
The two tables here below give the differences in welding parameters as well as differences in technical results for the overlaying of a one meter long roller having a diameter of 300mm.

Table 5. Welding parameters

	Procedure 1 : twin arc	Procedure 2 : single arc
Flux cored wire	SK 742N-SK	SK 742N-SK
Welding flux	RECORD SK	RECORD SK
Diameter of the wire	2 x 2,4mm	3.2mm
Amperage	700-750Amps	500Amps
Voltage	28-29V	28-29V
Welding speed	14cm/min	13cm/min
Oscillation width	60mm	40mm
Oscillation frequency	40/min	30/min
Overlap	7-8mm	7-8mm

Table 6. Technical comparison between the two procedures

	Procedure 1 : twin arc	Procedure 2 : single arc
Preheat	250°C	250°C
Interpass	300°C	300°C
Thickness of the deposit	4 Layers : 12 mm	4 Layers : 12 mm
Deposition rate	16kg/hr	10kg/hr
Arc time per layer welded	1h30min	2h30min
Arc time to surface the roll in its entire	6h00min	10h00min

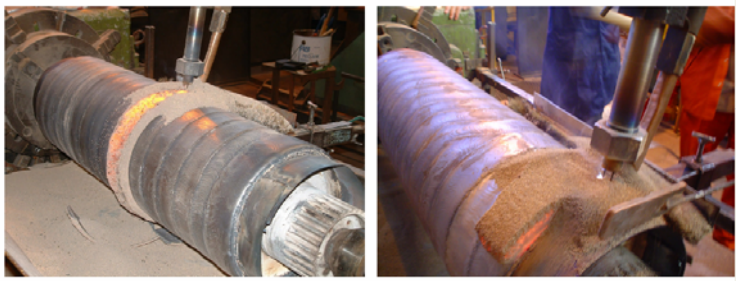

Fig. 10. Procedure 2 – Twin wire welding head 2 x 2.4 mm

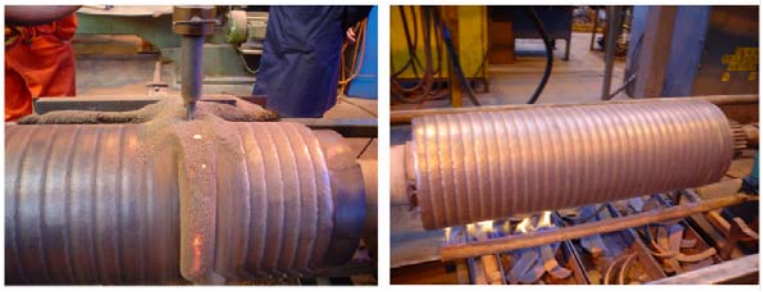

Fig. 11. Procedure 1 – Single welding head 3.2 mm

Recondiționarea cilindrilor pentru turnarea continuă utilizând sârme cu inimă de flux şi bandă de încărcare

Rezumat

Membru al grupului Böhler Welding, Soudokay este specializată în producția de sârme cu inimă de flux pentru încărcare, precum şi de fluxuri pentru sudare pentru procesul de încărcare cu bandă. Industria metalurgică reprezintă unul dintre segmentele sale țintă de mulți ani, conferindu-i o mare experiență în repararea şi mentenanța liniilor de turnare continuă.

Expertă în tehnicile de încărcare, Soudokay a dezvoltat aliaje foarte specifice, destinate în mod special pentru a rezista diferitelor solicitări. Au fost studiate diferite oțeluri inoxidabile martensitice, prezentând conținuturi diferite de Cr, Ni, Mo şi N. Consumabilele pentru sudare vor depinde, de asemenea, foarte mult de procesul de sudare şi de procedeul de sudare. Într-adevăr, unele dintre ele sunt supra-aliate, fiind proiectate pentru un procedeu de încărcare cu două straturi, în timp ce procedeul clasic va necesita depunerea a trei straturi. Cele mai recente dezvoltări au condus la producerea de oțeluri inoxidabile super martensitice, care pot fi sudate atât prin procesul de încărcare cu bandă cât şi cu tehnicile SAF.

Nu numai aliajul, dar şi procesul de sudare şi procedeul de sudare vor influența puternic durata de viață a rolelor, alături de productivitatea atelierului de sudare ce realizează mentenanța liniei, precum şi de productivitatea a însăşi liniei de turnare continuă. Pe baza experienței sale, Soudokay a definit linii directoare pentru selectarea celei mai adecvate soluții în ceea ce priveşte consumabilele pentru sudare, procedeul de sudare şi controlul procesului.