Svetsaren

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Narrow gap GTA welding of stainless steels

by Korhonen, M., Luukas, M. and Hänninen, H., Helsinki University of Technology, Laboratory of Engineering Materials, Finland

The conventional GTA welding produces good quality welds, but it has its weak points in small deposition rate and very low efficiency. The narrow gap GTA welding improves the quality and assures a much better economic efficiency. Minimising the volume of the weld the narrow gap GTA welding offers a low number of beads, low total heat input, less axial and radial shrinkage which reduces the strain at the root area, the low dwell time in the critical sensitising temperature range and a favourable residual stress profile in the heat affected zone. The improved duty cycle with the low weld volume provides the industrial user with a good economic efficiency.

The narrow gap GTA welding method was investigated for optimizing the mechanical and corrosion properties of thick wall duplex and austenitic stainless steel pipes. The effect of welding parameters, welding consumables, shielding gases and groove geometries were evaluated and the welding equipment was further developed (i.e., new welding torch and video monitoring system). Microstructures of the weldments were examined using optical microscopy. Mechanical properties were examined using tensile, Charpy-V impact toughness and bending tests.

Introduction

The increased demands for improving quality and cost efficiency when welding pulp and paper industry and power plant components have set more requirements for used welding technology. Increased wall thicknesses and quality requirements are achieved using only few welding processes. The conventional GTA welding can produce good quality welds, but it has its weak point at small deposition rate and very low efficiency. Ways for improving the efficiency directly and indirectly can be based on

1. Reduced weld volume
2. Increased deposition rate
3. Lower incidence of weld metal defects
4. Reduction of number of operators (welders)
5. Higher arc efficiency.

The narrow gap GTA welding improves the quality and assures a much better economic efficiency. Minimising the volume of the weld the narrow gap GTA welding offers a low number of beads, low total heat input and less axial and radial shrinkage which reduces the strain at the root area. Also the low dwell time in the critical sensitising temperature range and a favourable residual stress profile in the heat affected zone are achieved by using the narrow gap GTA welding process. The improved duty cycle with the low weld volume provides the industrial user with a good economic efficiency. The narrow gap GTA welding is suitable for welding in all positions, which is required when welding, for example power plant pipelines.

Narrow gap GTA welding

The GTA welding method is applicable for the welding of the stainless steels by offering excellent and uniform quality required for the demanding applications. The GTA welding method is suitable for position welding and therefore it is used for orbital welding of the power plant pipelines. The utilization of the GTA welding for thick wall materials has been limited by its low efficiency compared to GMAW and SAW methods.

Use of the narrow gap GTA welding improves the quality and assures a much better economic efficiency. The advantages attained with the narrow gap GTA welding compared to traditional methods are:

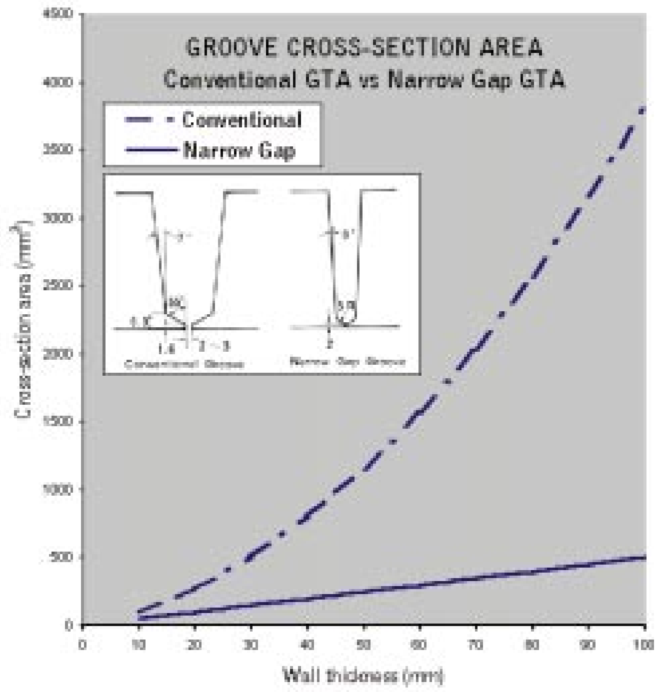


Fig. 1. Groove cross-section area when using the conventional and narrow gap GTA welding.

Power source and optional components
- ESAB ProTIG 315,
- ESAB A25 component system — with AVC, weaving slides and wire feeder,
- ESAB A21 PRD orbital welding head.

Narrow gap welding torch
- ESAB NG, for wall thicknesses up to 50 mm and 80 mm,
- HUT NG1, for wall thicknesses up to 100 mm,
- HUT NG2, for wall thicknesses up to 110 mm.

Workpiece handling equipment
- PEMA-5TNE conventional roller bed,
- ESAB A25 small turn table,

Video monitoring system
- 2 Panasonic colour video cameras (+required optics),
- Micro video camera for orbital welding
- 2 colour video monitors.

Computer
- roller bed control and documentation.

Table 2. Welding equipment used.

1. Reduced weld volume — shorter welding time
2. Lower heat input
3. Lower incidence of weld metal defects
4. Low consumption of filler material
5. Low consumption of shielding gas
6. Lower residual stresses
7. Easy mechanization.

The advantages attained with the narrow gap GTA welding set some extra requirements, which are:

1. Requires more advanced welding equipment
2. Accurate joint preparation
3. More expensive shielding gas.

As shown in Fig. 1, the volume of the groove decreases as a function of wall thickness more effectively when narrow gap method is used. It is profitable to use narrow groove starting from 10 mm wall thickness.

As the number of beads decreases, the arc time and the total welding time are decreased. Consequently, productivity is improved. Also, filler metal consumption is diminished, which increases economic efficiency, especially in the case of welding high-alloyed steels.

Experimental

The narrow gap GTA welding method was investigated for optimising the quality of thick wall duplex, super-duplex and austenitic stainless steel pipes. Duplex and super-duplex stainless steels were welded in flat position and the most of the austenitic stainless steels were

Austenitic Stainless Steels

Material code	Chemical composition (wt -%)									
	C	Mn	Si	P	S	Ni	Cr	Mo	Co	N	Nb
TP 304	0,026	1,66	0,35	0,035	0,014	10,48	18,90	-	-	-	-
SA 376 TP 304	0,050	0,88	0,59	0,028	0,010	10,50	19,00	-	-	-	-
347 Mod	0,023	1,74	0,42	0,027	0,011	11,00	18,30	-	0,09	0,023	0,35
TP 316 LNG	0,015	1,67	0,33	0,025	0,002	11,99	16,85	2,08	0,08	0,075	-

Duplex- and Super-Duplex Stainless Steels

Material code	Chemical composition (wt -%)														
	C	Mn	Si	P	S	Ni	Cr	Mo	Co	N	Nb	Cu	V	Al	W	Ti
PM Duplok 27	0,029	0,73	0,15	0,015	0,003	6,95	26,80	3,14	0,07	0,32	0,015	2,28	0,065	0,009	0,054	0,003

Material code	Chemical composition (wt-%) Max. amounts, if other not mentioned.														
	C	Mn	Si	P	S	Ni	Cr	Mo	Co	N	Nb	Cu	V	Al	W	Ti
Avesta 2205 SRG	0,030	2,00	1,00	0,030	0,020	4,5-6,5	21-23	2,5-3,5	-	0,1-0,2	-	-	-	-	-	0,01

Table 1. Chemical compositions of the tested materials.

Figure 2. Welding test arrangement in the laboratory conditions. Base material welded was PM Duplok 27, with wall thickness 70 mm and outer diameter 600 mm.

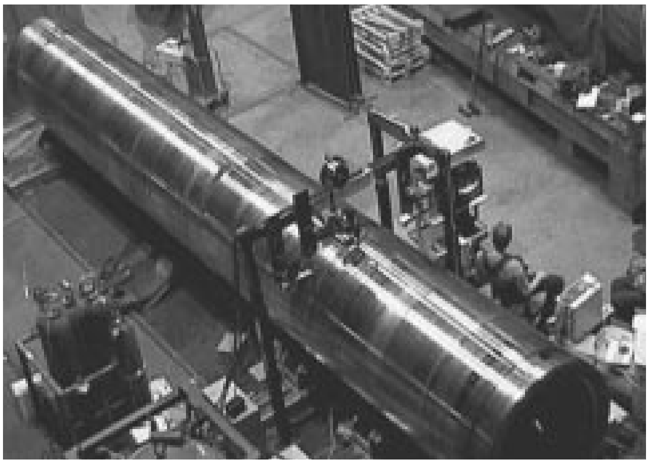


Figure 3. Welding tests running in the industrial environment. Base material welded was PM Duplok 27, with wall thickness 85 mm and outer diameter 1320 mm.

welded using the orbital welding. The effect of welding parameters, welding consumables, shielding gases and groove geometries were evaluated. New welding torch was developed and video monitoring system for controlling the process was installed. Microstructures of the weldments were examined using optical and scanning electron microscopy. Mechanical properties were examined using tensile, Charpy-V impact toughness and bending tests. Most of the welds were examined by non-destructive testing.

Materials

The materials used in welding tests are widely used in pulp and paper industry and nuclear power plants. The

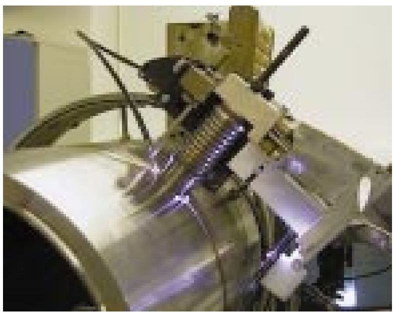


Figure 4. The orbital welding of the austenitic stainless steel.

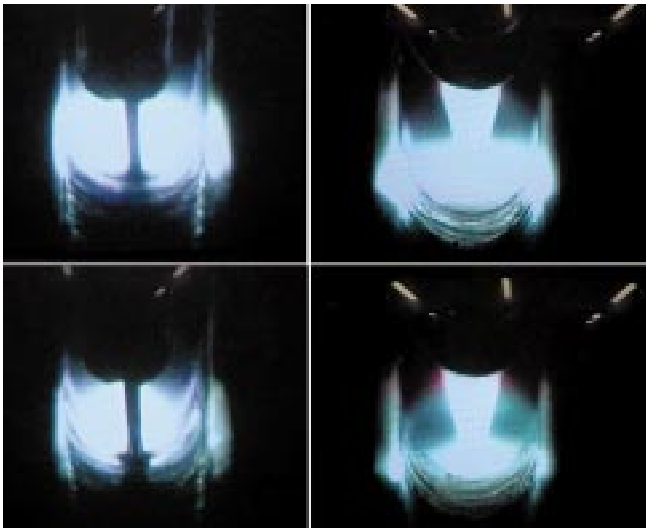


Figure 5. Video monitoring images for controlling the welding process. The filler wire fed into the melt is seen on the left and the solidified weld is seen on the right. The upper pictures show the situation during the pulse current and the lower pictures during the base current.

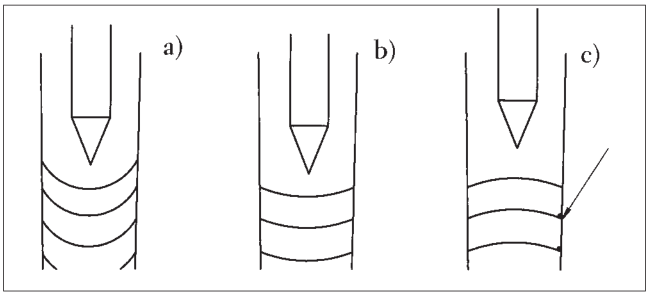


Figure 6. The weld bead profile: a) optimal profile, b) not enough wetting on the side walls, small risk of the lack of fusion at the groove side walls, c) profile not allowed, risk of the lack of fusion at the groove side walls.

chemical compositions of these materials are shown in Table 1.

Welding equipment

The welding equipment used for the tests was mostly from Oy Esab, Finland. The total set of equipment used is shown in Table 2. The new welding torches (HUT NG1 and HUT NG2) were developed to meet the requirements for the quality and the maximum wall thicknesses. The shielding gas usage was reduced more than 30 percent when using the new welding torches.

In Figure 2 is seen the flat position welding of the super-duplex stainless steel in the laboratory conditions and in Figure 3 is seen the flat position welding in the industrial conditions. In Figure 4 is seen the orbital welding of the austenitic stainless steel.The video monitoring system was installed to enable the direct control of the welding process. When using two video cameras and two monitors, the accurate positioning of the filler wire and ensuring the adequate wetting of the groove side walls is easy. In Fig. 5 is seen the views available from the video monitoring system.

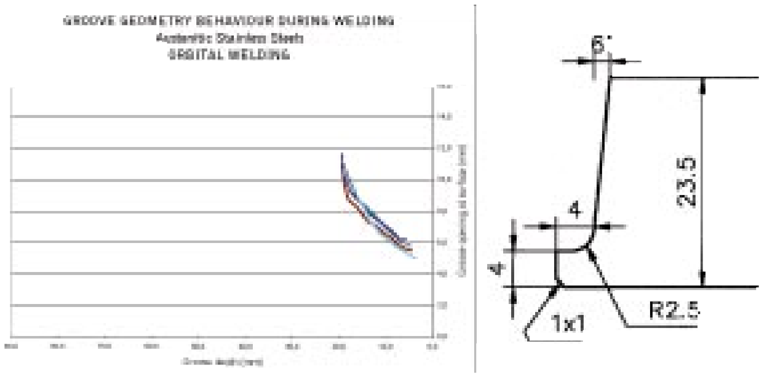


Figure 7. Groove behaviour of the austenitic stainless steels during the orbital welding tests and the selected groove geometry.

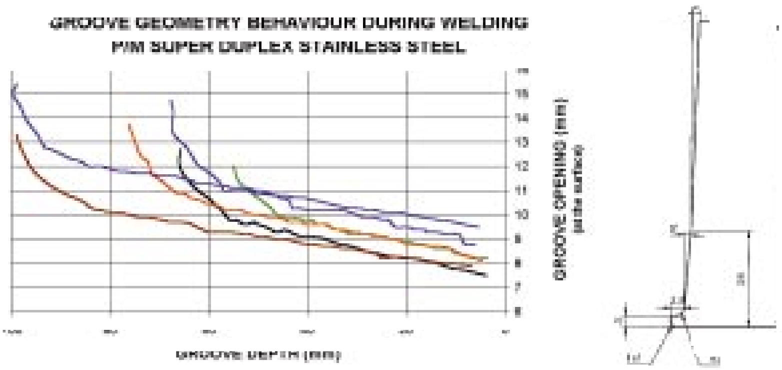


Figure 8. Groove behaviour of the duplex and super duplex stainless steels during the welding tests and the selected groove geometry.

Welding parameters

The most important parameters affecting the welding process are pulse and base currents, arc voltage, filler wire feeding rate and travelling speed. Pulsed currents, arc voltage and travelling speed should be selected so that the heat input remains low and the risk of the lack of fusion is avoided.

Selected welding parameters have a strong effect on the weld bead profile. The preferred weld bead profile should have a concave upper surface with adequate wetting on the side walls with an uniform layer thickness. The optimised weld bead profile minimises the risk of the lack of fusion at the side walls (Fig. 6).

Also the effect of the shielding gas was evaluated by comparing argon (Ar), argon-helium 70%/ 30% (Ar-He 70/30) and argon-helium 50%/ 50% (Ar-He 50/50). As a result was seen that pure argon does not provide enough wetting on the side walls without increasing welding current and arc voltage significantly. However, pure argon (Ar) is ideal as a start gas. Using Ar-He 50/50 or Ar-He 70/30 as a shielding gas increases the arc temperature and weld pool movement and thereby provides an adequate wetting on the side walls without any need to increase welding current and arc voltage.

Groove geometry

The narrow gap GTA welding requires a square groove only. A groove angle (0° to 6°) is used only for the distortion compensation, and the selection of the used angle depends on the properties of the base material and wall thickness welded.

In Figure 7 is seen the groove behaviour of the austenitic stainless steel and the selected groove geometry. In Figure 8 is seen the groove behaviour of the duplex

Fig. 9. Fusion line, weld metal on left. No grain growth seen at heat affected zone. Delta ferrite in weld metal is etched dark. Base metal TP 316 LNG and filler wire OK Autrod 16.32. Magnification 75 x.

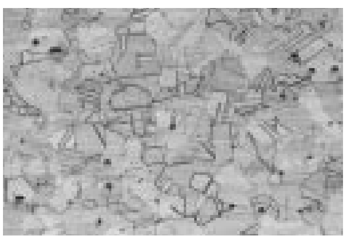


Fig. 10. Base metal 10 mm from fusion line. Magnification 75 x.

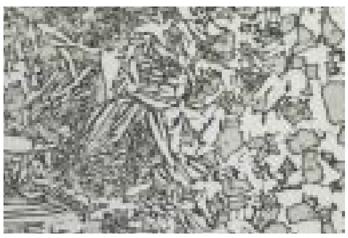


Fig. 11. Fusion line, weld metal on left. No grain growth or changes in phase balance can be seen at heat affected zone. Delta ferrite is etched dark. Base metal PM Duplok 27 and filler wire D27. Magnification 300 x.

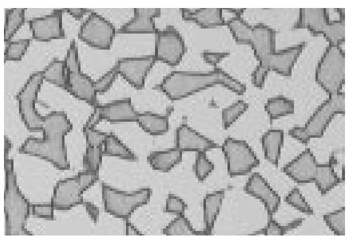


Fig. 12. Base metal 10 mm from fusion line. Delta ferrite is etched dark. Magnification 300 x.

Material data and welding parameters	Macro-section
Base material : SA376 TP304 ø219 X 18 Filler wire : OK AUTROD 16.32 ø1.2 MM Welding position : FLAT POSITION Pulse current : 100-200 A, 0.3 s Base current : 50-100 A, 0.3 s Arc voltage : 11.5 – 12.7 V Filler wire feeding : 0 – 70 cm/min Beads : 12	
Base material : 347 MOD ø270 X 23 Filler wire : OK AUTROD 16.32 ø0.8 MM Welding position : ORBITAL Pulse current : 100-200 A, 0.4 s Base current : 35-60 A, 0.4 s Arc voltage : 11.5 – 12.7 V Filler wire feeding : 0 – 70 cm/min Beads : 12	

Table 3. Material data, welding parameters and macro-sections of some test welds of austenitic stainless steels.

Material data and welding parameters	Macro-section
Base material : AVESTA 2205 SRG ø790 X 47 Filler wire : OK AUTROD 16.86 ø1.2 MM Welding position : FLAT POSITION Pulse current : 180-235 A, 0.3 s Base current : 100-115 A, 0.3 s Arc voltage : 12.5 – 13.3 V Filler wire feeding : 0 – 140 cm/min Beads : 27	
Base material : PM DUPLOK 27 ø1500 X 85 Filler wire : D27 ø1.2 MM Welding position : FLAT POSITION Pulse current : 100-230 A, 0.3 s Base current : 50-125 A, 0.3 s Arc voltage : 11.5 – 13.5 V Filler wire feeding : 0 – 200 cm/min Beads : 45	

Table 4. Material data, welding parameters and macro-sections of some test welds of duplex and super-duplex stainless steels.

Table 5. Mechanical properties of tested austenitic stainless steels.

Base Material	Condition	R_m MPa	$R_{p0.2}$ MPa	Z %	A 50 mm %	CVN J (–10°C)
PM Duplok 27	pwht	884	684	64	25	184
PM Duplok 27	aw	886	674	66	25	140
Avesta 2205 SRG	aw	804	664	77		225(W),95 (FL), 77(FL+5)**
Avesta 2205 SRG	aw	794	651	72		209
Avesta 2205 SRG	pwht	764	507	74		209
Avesta 2205 SRG	pwht	764	509	69		176

** W = weld metal, FL = fusion line, FL + 5 = 5 mm from fusion line to base metal

Table 6. Mechanical properties of tested duplex and super-duplex stainless steels.

Base Material	Condition	R_m MPa	$R_{p0.2}$ MPa	Z %	A 50 mm %	CVN J (–10°C)
TP 304	aw	579	361	51	66	181
TP 304	aw	553	314	46	75	–
TP 304	aw	606	265	75	54	203
SA 376 TP 304	aw	537	337	42	79	165
TP316 LNG	aw	573	363	43	90	196
347MOD - 0° *	aw	551	331	81	56	–
347MOD - 0° *	aw	555	337	81	57	–
347MOD - 180° *	aw	555	359	80	55	–
347MOD - 180° *	aw	560	358	82	56	–
AISI316L - 0° *	aw	578	368	85	52	184(W), 243(FL), 298(FL+3)**
AISI316L - 90° *	aw	593	370	85	50	–
AISI316L - 180° *	aw	579	352	85	54	179(W), 239(FL), 300(FL+3)**
AISI316L - 270° *	aw	578	361	84	48	–

* position
** W = weld metal, FL = fusion line, FL + 3 = 3 mm from fusion line to base metal

Table 7. Results of the 3-point bending tests of some austenitic stainless steel welds. Test specimens were bent in two stages, first to 120 ° and then to 180°.

Material	Specimen No.	Bending angle 120°	Bending angle 180°
SA 376 TP 304 surface	1	No defects	No defects
	2	No defects	No defects
	3	No defects	No defects
SA 376 TP 304 root	1	No defects	No defects
	2	No defects	No defects
TP 316 LNG surface	1	No defects	No defects
	2	No defects	No defects
	3	No defects	No defects

and super duplex stainless steels and the selected groove geometry.

Results

Microstructures of the weldments were examined using optical and scanning electron microscopy. Mechanical properties were examined using tensile, Charpy-V impact toughness and bending tests. Most of the welds were examined by non-destructive testing. In Tables 3 and 4 is seen some examples of material data, welding parameters and macro-sections of the welds.

Metallography

All test welds were examined using optical microscopy to ensure that not secondary phase transformation, grain size growth at the heat affected zone or solidification cracking was occurring during welding.

When examining austenitic stainless steel welds, grain size growth at the heat affected zone or carbide formation were not found. Delta ferrite content of the weld metal was between 5-15 %, which prevents the formation of the solidification cracking. Some microstructures are shown in Figs. 9-10.

When examining duplex and super-duplex stainless steels in as-welded condition no other secondary phase formation than secondary austenite was found. Secondary austenite does not have any effect on mechanical properties but reduces corrosion properties. All duplex and super-duplex stainless steel test welds were post-weld heat treated for dissolving the secondary austenite. Phase balance between delta ferrite and austenite in the weld metal and the heat affected zone was not significantly different when compared to the base material. Some microstructures are shown in Figs. 11-12.

Mechanical properties

Mechanical properties were examined using tensile, Charpy-V impact toughness and bending tests. In Table 5 is seen the mechanical properties of tested austenitic stainless steels and in Table 6 is seen the mechanical properties of tested duplex and super-duplex stainless steels. Table 7 shows the results of the 3-point bending tests of some austenitic stainless steel test welds.

Non-destructive testing

The non-destructive testing was done for the most of the test welds using ultrasonic or radiographic testing. When the inspection of austenitic stainless steels using the conventional ultrasonic testing was not able to provide accurate results, radiograghic testing was used. The results of the radiographic testing of austenitic stainless steels are shown in Table 8. Duplex and super-duplex stainless steel welds were tested using ultrasonic testing, which gives accurate inspection results. The results of the ultrasonic testing of duplex and super-duplex stainless steels are shown in Table 9.

The amount of welding defects detected by non-destructive testing was very small. Only problems encountered were in orbital welding, when welding the root runs of austenitic stainless steels but solutions were found by optimising welding parameters.

Base material	Inspected	Inspection method	Defects	Type of defect
TP 304	no	–	–	–
TP 304	yes	RT		
TP 304	yes	RT		
SA 376 TP 304	yes	RT	yes	porosity, undercut
TP 316 LNG	yes	RT	yes	root defect
347Mod	no	–	–	
347Mod	yes	RT		
347Mod	yes	RT	yes	inclusion
AISI 316 L	yes	RT	yes	root defect

RT = radiographic testing

Table 8. Non-destructive testing of austenitic stainless steels.

Base material	Inspected	Inspection method	Defects	Type of defect
PM Duplok 27	no	–	–	–
PM Duplok 27	yes	UT	–	–
PM Duplok 27	yes	UT	–	–
Avesta 2205 SRG	yes	UT	–	–
Avesta 2205 SRG	yes	UT	–	–

UT = ultrasonic testing

Table 9. Non-destructive testing of duplex and super-duplex stainless steels.

Conclusions

The aim of the study was to evaluate the possibilities of using the narrow gap GTA welding method to improve the quality and economic efficiency when welding austenitic, duplex and super-duplex stainless steels. Mechanical properties of tested welds were excellent, and the amount of welding defects detected by non-destructive testing was very small.

As a result it is shown that the narrow gap GTA welding method:

- is an excellent choice for welding thick wall austenitic, duplex and super-duplex stainless steel pipes,
- improves the weld quality,
- improves economic efficiency by lowering the joint volume and filler wire consumption,
- with pulsed welding current offers an easy way to control heat input, but
- requires more accurate joint preparation and pipe alignment and
- more expensive shielding gas.

Acknowledgements

The results are based on the results obtained in the project “Narrow gap GTA welding of stainless and creep resistant steels” during 1997-1998. The project was funded by Technology Development Centre of Finland, Rauma Materials Technology Oy, Valmet Oy, Teollisuuden Voima Oy, Imatran Voima Oy and YIT Power Oy.

An allround cored wire for an allround fabricator

by Ben Altemühl, Svetsaren editor, interviewing production management of SES TVP s.r.o, Slovakia.

SES TVP s.r.o. Zeliezovce, part of the Slovakian SES Group (Slovenské Energetické Strojárne a.s.), is a fabricator that has adapted successfully to the new economic climate that evolved after the decline of European Communism and the partition of Czechoslovakia.

In answer to the falling demand from former Comecon countries, the company diversified their product range by contracting a variety of projects from other countries, aided by the relatively low Slovakian labour costs. Meanwhile, they increased the efficiency of their production, amongst others by a wide scale introduction of manual flux-cored arc welding to replace stick electrodes. The PZ6113, an all-position rutile cored wire, is universally applied as a multi-purpose cored wire. Other ESAB solutions are utilised for SMAW, GTAW and SAW.

Acknowledgement

We thank Mr. Milo Kohút, MD of SES TVP, for giving us the opportunity to visit his company, and Mr. Gabriel Bagala and his welding department for providing us with the information to base this article on. We congratulate Esab Slovakia in general and Mr. Martin Janota in particular, with the marketing success achieved at SES.

SES

The SES group, with headquarters in Tlmace, consists of 15 companies, active in the field of steam boilers and equipment for power generation. The group had a 1998 turnover of 125 million Euro and is listed on the Bratislava Stock Exchange. The product programme includes various types of boilers, condensers, heat exchangers, fluidised bed boilers, waste incineration plants, sewage disposal plants, as well as general overhaul of power engineering equipment.

Although embedded in the structures of the SES Group, SES TVP functions independently with an own international marketing department, in-house engineering facilities, as well as a de-centralised production management. The company employs around 650 persons, of which 80 related to welding. The manufacturing lines are located in two halls of 18880 m^2. They are devided in three sections: material preparation, machining and welding/assembly.

Over the past years, the active marketing team has increasingly been able to land contracts from outside SES's traditional markets in Eastern Europe. This involved the delivery of condensers, heat exchangers, condensation pipelines and a variety of other products to countries like Great Britain, Denmark, Sweden, France, Germany, Egypt, Turkey, China, The Philippines and Argentina. The company's marketing successes were aided by a flexible attitude regarding the type of projects to be contracted, as well as the relatively low labour costs in Slovakia. Meanwhile, production facilities were gradually modernised by way of relatively small, but frequent investments. The most important improvement in the field of welding was undoubtedly the change from welding with stick electrodes to cored wire welding that took place over the past three years. It was supported by ESAB with training, products, and application help and provided SES with a dramatic increase in welding productivity.

Welding

SES TVP use the arc welding processes SMAW, GMAW, GTAW, FCAW and SAW. Apart from SAW, it all concerns manual welding. The cored wire used universally for manual FCAW is the FILARC PZ6113, together with a metal-cored type PZ6102 applied for rooting. Ar/CO_2 mixed gas is universally used as shielding gas.

PZ6113 hardly needs explanation, because it is the all-position cored wire for mild steel most applied in Europe. It combines superb all-position weldability with very high productivity, and it can be welded in mixed gas, as well as CO_2. It is classified

T 42 2 P C 1 H5 / T 46 2P M 1 H10 according EN 758-97.

When asked about the introduction of cored wire welding, Mr. Bagala answers the following: "the first project to use cored wire welding was the construction of condenser for a French client. It was in fact the client

Figure 1: Heat exchanger for hydro thermal water.

Figure 1a: Frame welded to cylinder in PC position. SAW joint partly visible.

Figure 1b: Waterbox attached to main construction.

himself prescribing the use of FCAW for this project. Having no experience with this process we referred to ESAB Slovakia who helped us setting-up a programme for welder training and procedure qualification. We started with a group of nine welders who were taught the ins and outs of cored wire welding by Carin Jansen, a female welding instructor from FILARC in The Netherlands.

Now three years later around 70% of all welding is done with FCAW. We educate our own welders here in Zeliezovce, as well as in the central welding school in Tlmace. We estimate that the production time for our major products has been reduced by 20–30%. This enables us to quote sharp prices and short delivery times and has helped us enormously becoming competitive and successful".

Figure 2: Welding of beams with PZ6113-1.2mm

Figure 2a: Weld appearance

Cored wire applications

During our visit at SES TVP a number of projects were under construction. Below they are briefly described, emphasising the role of cored wire welding.

Heat exchanger for Klaipeda, Lithuania

To fabricate this component, SES use SAW for the circumferential and longitudinal welds of the cylindrical parts. These are symmetric X-joints, which are double-sided welded with the Vamberk wire/flux combination A103/F103.

SMAW and GTAW are used for the root passes on this project. All fillet welds and a variety of other joints and attachment works are done with PZ6113-1.2mm. The details of cored wire weldments show the versatility of this wire for this kind of construction work. The waterbox shown is welded in three positions (PB, PF and PD) with the same parameter setting.

Goldisthal project, Germany

This project involves the fabrication of stop-logs and other steel construction modules for dam constructions for a hydro power plant. Double-sided, single layer fillet welds (a-size=5mm) in PB position are welded simultaneously by two welders.

Steam condensers, Ho ping, China

During our visit a project was in progress involving 4 modules. Figures 3 show a water box; each module has two of them. The water box is a fine example of the

Figure 3: Waterbox welded with PZ6113-1.2.

Figure 3a,b: Weld details. Outside + inside.

level of skill that SES welders have acquired in manual cored wire welding. The weld appearance resembles that of mechanised welding.

The primary welds are unsymmetrical X-joints with a complex geometry. Root (ground) as well as filling is done with PZ6113. Previously, these welds were done with stick electrodes. With FCAW, these specific components are now welded 4 times faster. Moreover, no stress relieve treatment is needed because of the lower heat input.

Another interesting project is reviewed below, showing the flexibility of SES TVP as a fabricator, while exemplifying the use of ESAB cored wire products. It was performed earlier in 1999.

Steel convertor vessel spigot for Dillinger Eisenhütte, Germany.

Two bearing rings for manouvring convertor vessels in the oxysteel process, diameter 9.5m weighing 145 tons each, were fabricated from mild steel with a minimum yield strength of 355Mpa. Plate thicknesses for the circular box structure were 65mm for the sidewalls and 80mm for the deck plates. Each ring consisted of two semi circular segments.

The complete structure was welded with PZ6113-1.2 (roots with PZ6102-1.2mm). This involved the welding of through thickness K-joints in the PC position for the bottom and deck plates, and through thickness X-joints in PA and PF position for connecting the ring segments. each ring consumed 2.5 tons of cored wire.

The whole project was performed with a very low defect rate, which, together with the fine weld appearance, once again, exemplifies the possibilities of PZ6113 when used by skilled welders.

Figure 4: Convertor vessel spigot.

Figure 4a: Close up of through thickness horizontal-vertical and vertical welds.

To conclude

Visiting SES TVP, we encountered a flexible fabricator in the sense of the variety of projects they can handle. Their welding is organised very efficiently, with a central role for manual FCAW, and based on a high level of welder skill.

The all-position rutile cored wire FILARC PZ6113, the standard in European shipbuilding, proofs its reputation as a multi-purpose FCAW consumable for other industrial segments as well.

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.

OK Autrod 12.50 and 12.63 EcoMig

the ultimate technological innovation in MIG/MAG welding

In the field of arc welding, there has never been a product that has been so widely used as copper-coated wire for MIG/MAG welding. This wire is sometimes commonly known — even if not this is not its correct name — as CO_2 wire.

Because of its reasonable flexibility and ease of use, together with its range of applicable mechanical properties, but mainly because of its high deposition rate, which is far higher than that of the welding process that signalled the start of arc welding, i.e. the SMAW process, MIG/MAG welding, which was introduced onto the market at the beginning of the 1960s, systematically increased its market share to become the leading process in the 1980s.

Nowadays, its use is still growing and this development is likely to continue — even if the rate of expansion is lower — as a result of cored wire. Cored wires offer additional productivity, flexibility and quality, but their sophisticated production technology involves costs — and therefore prices — that are definitely higher than those of solid wires.

It is strange to note that, in the course of almost four decades, MIG/MAG welding wire has basically retained the characteristics it was born with, notwithstanding the large-scale technological progress that has been made in almost every other segment during the same period. Now as then, it consists of a wire made of steel with a well-defined analysis, copper-coated and generally supplied on small reels or spools. Marathon

Pac is the only really significant innovation to be introduced on the western market by ESAB in the course of the last decade. The main advantage of Marathon Pac is that it allows the end user to deposit up to 300-400 kg of wire without interruption. It is therefore ideal for robotics and automated welding processes. to 300-400 kgs of wire, therefore it is ideal for robotics and automathized welding processes.

Why is copper coating needed?

Basically, a MIG/MAG wire must satisfy three main requirements.

- Metallurgical. The wire must have the correct chemical analysis.

- Electrical. The wire must have good electrical conductivity to enable the current to flow more easily through the contact tips and assure good arc stability.
- Mechanical. The wire must guarantee good feed through the feed system, from the feed rollers through the liner to the contact tips.

The copper coating on the surface of the wire satisfies the last two of these requirements in practical terms. Furthermore, copper coating protects the wire from environmental oxidation. Probably not all end users know that there is another reason why the copper coating is required. It permits an easier and faster drawing cycle, thereby enabling the wire manufacturer to obtain higher productivity and lower costs.

To be realistic, from an objective point of view, copper coating has to be regarded as a necessary evil, as it has some aspects that are negative.

Negative sides of copper coating

From a mechanical point of view, a factor that is regarded as one of the strengths of copper coating, i.e. that it acts as a lubricant to facilitate the passage of the wire during feeding, is also one of its weaknesses. In the short or long run, as a function of good or bad copper adherence to the wire surface, the continuous passage of the wire through feed rollers and liners causes the loss of copper particles which results in uneven feed and subsequent fusion problems, leading to total blockage. This results in welding defects, arc instability, the need for repairs, cycle interruptions, cost increases, the loss of productivity and so on.

To eliminate this problem, frequent, accurate maintenance is required and this once again results in cycle interruptions, extra time and costs and the loss of productivity.

From a metallurgical point of view, it is known that copper, when added to the weld pool, even if it comes from the wire surface, may produce negative effects such as:

- An increased risk of hot cracking
- Reduced impact properties

Another negative factor has been disregarded for too long. The process made its appearance in the 1960s and everyone now realises just how important it is. However, the copper which comes from the welding fumes is an environmentally negative factor. Moreover, when it comes to the manufacturing cycle for copper-coated wires, it is important to remember that this cycle involves the use of — and also generates — environmentally-harmful substances which can only be eliminated in a selected and controlled manner.

OK Autrod 12.50 and 12.63 EcoMig the ESAB solution

The above-mentioned factors were the starting point of the ESAB project in-volving the development of Eco-Mig wire. Its guiding principle was very simple: to eradicate the problem at its root or, in other words, to eliminate all the negative effects of copper coating without losing any of the ideal characteristics of a good MIG/MAG wire.

This apparently simple exploit required in-depth research, long-term experiments and sophisticated process technology and it has finally led to the design of OK Autrod 12.50 and 12.63 EcoMig. An exclusive production procedure has resulted in a wire which is not only comparable to but even better than a good copper-coated wire — as regards the positive aspects — while eliminating all the negative factors at the same time.

ESAB's EcoMig wire is not copper-coated. Compared with traditional copper-coated wires, it permits even, uniform feed through the feed system, without tears or interruptions, as there are no copper particles the wire can shed. This guarantees cleanness and a long service life for the liners and the entire feed system — up to two to three times longer than that when a standard copper-coated wire is used. As a result, the time wasted on cleaning and maintenance is reduced and productivity is improved.

Another peculiar and important characteristic of EcoMig is its arc stability. The weld is practically spatter-free, which results in enhanced quality and fewer welding defects. This is obviously a benefit in terms of time savings, while reducing repair costs at the same time.

Finally, the human factor should not be disregarded. There is often a tendency to forget that, where the arc is burning, there is also a welder handling the torch. EcoMig respects the welder's quality of life, because no harmful copper fumes develop from the wire surface during welding.

The following diagrams show the values for copper fume emission, as well as the total emission from OK Autrod 12.50 EcoMig, compared with a standard copper-coated wire.

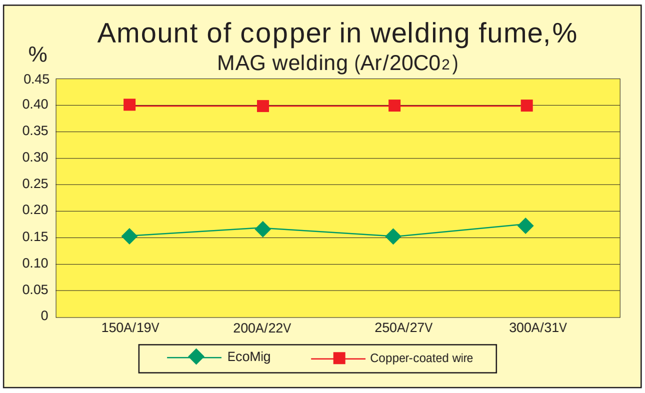
EcoMig's ease of use gives the welder enhanced comfort, satisfaction with the quality of his work and greater efficiency.

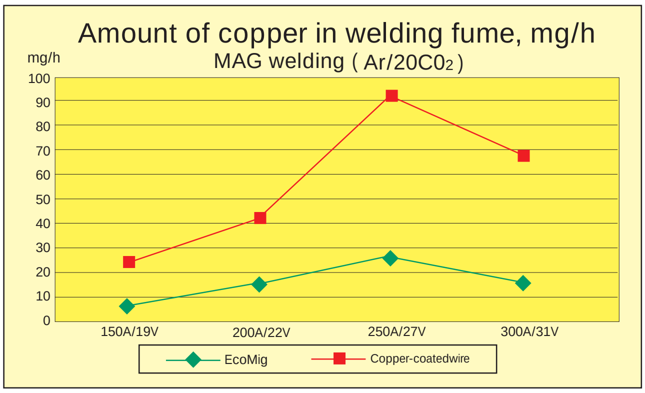
Moreover, the advantages of EcoMig appear to be never-ending.

The overall result is higher productivity.

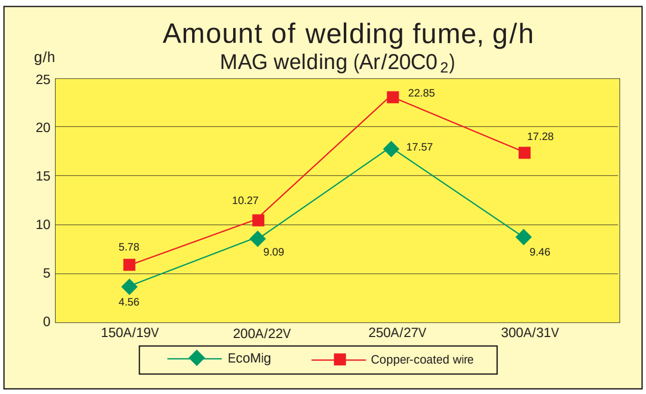
- EcoMig is suitable for robotic welding. Its arc-stability characteristics and the improved feed make it ideal for robotic or automated processes, where welding steadi ness and uniformity are essential in order to avoid welding defects and very expensive cycle interruptions.
- Less post-weld cleaning means less unpleasant grinding dust and distracting noise levels.
- The absence of copper on the wire surface results in a cleaner deposit and avoids the metallurgical risks that can be induced by the increase in copper in the weld pool.
- Finally, the EcoMig production process is environmentally-sound, because there is no need to use harmful substances for the copper coating. This results in greater respect for the environment.

OK Autrod 12.50 EcoMig has recently been introduced on the market and its success has exceeded all expectations, even if anything different was not really anticipated! After all, it is one of the few, more meaningful innovations to be introduced in the MIG/MAG wire sector since the process first made its appearance.





Diagrams showing a comparison of the copper content of welding fumes between the non-copper-coated EcoMig and copper-coated welding wire.



Stainless steel metal cored wires for welding automotive exhaust systems

by Stanley E. Ferree and Michael S. Sierdzinski, ESAB Welding and Cutting Products, Hanover (PA), USA

Over the past two decades, advances in stainless steel materials and the designs of automotive exhaust systems have led to longer life cycles and extended warranties. This paper will describe the development of stainless steel metal-cored (SSMC) wires and their expanded use for welding these improved automotive exhaust systems. Information on manufacturing methods, core ingredients, available alloy types and application data will be presented.

Background

In the past, automotive exhaust systems were expected to last for only three to four years. A major change occurred in the United States in 1970 with the Clean Air Act, which forced car makers to add catalytic converters to exhaust systems. In the mid-1970s, environmental mandates for catalytic converters with five-year/50,000-mile warranties forced car makers to abandon carbon steel systems in favour of 409 ferritic stainless steel (1). In addition, austenitic stainless steels and hot-dipped aluminium-coated ferritic stainless steels were used for some demanding applications. Because of competitive pressure and consumer demands, today's exhaust systems usually have life cycles and warranties of seven to ten years. Table 1 shows the major stainless steel alloy types that are now used to make automotive exhaust systems (2).

Although ferritic stainless steels have been used for certain automotive exhaust components since 1961 (3), their expanded use to include complete exhaust systems has only occurred over the past 10 years. Today's automotive exhaust systems can be divided into two parts: a hot and a cold end (4). The hot end includes the exhaust manifold, downpipe, flexible coupling and catalytic converter. The cold end includes the resonator, intermediate pipe, silencer and tail pipe. Important material properties and considerations for the hot end of the exhaust system include high-

Alloy	C	Mn	Si	Cr	Ni	Ti	Nb	Mo	Al
Aluminised steel type 1, Al409 and Al439				Carbon and stainless steels/aluminium- coated					
409	0.010	0.25	0.50	11.20	0.25	0.20	—	—	—
439	0.015	0.25	0.30	17.30	0.25	0.30	—	—	—
11 Cr-Cb	0.010	0.25	1.30	11.30	0.25	0.20	0.35	—	—
18 Cr-Cb	0.015	0.25	0.40	18.00	0.25	0.25	0.55	—	—
12 SR	0.015	0.25	0.60	12.00	—	0.25	0.50	—	1.2
18 SR	0.015	0.25	0.60	17.30	0.25	0.25	—	—	1.7
304L	0.025	1.75	0.30	18.10	8.50	—	—	0.20	—
321	0.040	1.30	0.60	17.25	9.75	0.40	—	—	—
409 Ni	0.010	0.75	0.35	11.00	0.85	0.20	—	—	—

Table 1. Typical alloy composition (wt%) of materials for exhaust systems (2).

temperature oxidation resistance, fatigue strength and the coefficient of thermal expansion. The important points when it comes to the cold end of the exhaust system are condensate corrosion and aqueous salt corrosion.

The ferritic 11% Cr alloys are popular choices for many exhaust components and systems. However, to comply with the long-term durability requirements, such as a 10-year/100,000-mile warranty, the higher chromium (17–20% Cr) ferritic stainless steel grades are often used.

A number of joining processes are used to fabricate these advanced automotive exhaust systems. They include high-frequency resistance welding, laser welding, resistant spot welding, gas tungsten arc welding, brazing and gas metal arc welding (GMAW) with solid or metal-cored wires. Welding stations may also be designed for semi-automatic, mechanised, or fully robotic welding applications. The process chosen by exhaust system fabricators depends on various factors. The complexity of the parts, the number of varieties and quantities produced, the required capital expenditure and production cost-profit analyses all play an important role in determining the process. However, the GMAW process using solid or metal-cored stainless wires has evolved as one of the favourites for welding the new automotive exhaust systems. In addition, it soon became apparent to exhaust system fabricators using the GMAW process that it was much easier and less costly to obtain customised stainless steel metal-cored wires than solid wires for welding the modified or new stainless steels which are used in these systems. Along with the availability of a wider range of alloy modifications, the SSMC wires also offered welding fabricators advantages in terms of improved quality, increased productivity and reduced costs.

Figure 1. Automotive exhaust components welded with 1.2 mm Arcaloy 18CrCb showing joint complexity and

a) Cut-away view of flexible exhaust decoupler showing complexity of joint and variety of thicknesses. Weld joints are near the top on the outside, joining four parts, and on the bottom inside, sealing two parts to the flange

b) Flexible exhaust decoupler showing weld joining decoupler to tube

c) Bottom view of b) showing the inside of the flange weld

d) Example of flexible exhaust connector

Design of stainless steel metal-cored wires

Some of the advantages of SSMC wires are a result of their tubular design. SSMC wires are made by forming a steel sheath into a U-shape, filling it with ferroalloys and other core ingredients, closing the sheath into a tubular shape and then drawing or rolling the formed tube down to the required size. A low carbon mild steel sheath is commonly used to make ferritic stainless steel alloys, while a 304L grade of sheath is usually used for making the austenitic alloys (5).

The tubular structure of SSMC wires offers several advantages compared with solid wires. As previously mentioned, many alloy types are easily made by changing the ferroalloys in the core ingredients. Some automotive exhaust system manufacturers want 409 types stabilised with Ti or Nb and/or with Ni additions, while others prefer modified 17–18% Cr alloys with similar al-

Wire	ESAB Arcaloy 18CrCb	Solid 439Ti
Size	1.2 mm (0.045 in.)	0.9 mm (0.035 in.)
Current (A)	245	245
Voltage (V)	23	23
Wire feed speed	8.6 m/min (340 ipm)	8.6 m/min (340 ipm)
Travel speed	1.5 m/min (60 ipm)	0.7 m/min (26 ipm)
Deposition rate	18.9 kg/h (8.6 lbs./h)	11.7 kg/h (5.3 lbs./h)
Arc time per weld	12 seconds	30 seconds
Shielding gas	95 Ar/5 CO_2	95 Ar/5 CO_2

Table 2. Application data for Arcaloy 18CrCb SSMC wire and a solid 439Ti wire.

loy additions. Customised austenitic alloys are also easy to make using a tubular designed metal-cored wire.

Potassium, sodium or lithium arc stabilisers are often added to the core ingredients to reduce welding spatter and/or to produce good arc stability at the low welding currents required for thin-gauge applications. Small amounts of fluoride compounds and/or oxide compounds also may be added to improve weld metal wetting. In general, a spray transfer with lower spatter levels and a wider bead flow can be achieved at lower current settings than is possible with solid wires. SSMC wires are therefore less prone to burn-through problems on thin-gauge sheet metal and are more tolerant of joint gap variations. In overall terms, a higher level of quality, with fewer defects and lower part rejection rates are often achieved with SSMC wires.

Application information

In many applications, faster welding travel speeds are attainable with SSMC wires than with solid wires because of the tubular design of SSMC wires. Their inherent higher current density characteristics produce faster wire melt-off rates than solid wires. Some exhaust system fabricators have doubled their welding travel speeds when changing to SSMC wires because of their faster melt-off rate. Table 2 shows the improved productivity results for an SSMC 18CrCb wire compared with a solid 439Ti wire, when welding flange joints on decouplers. The arc time per weld was reduced from 30 seconds with the solid wire to 12 seconds with the metal-cored wire. Less penetration and better bead profiles were also found with the SSMC wire.

Some of the components in the newer exhaust systems also have complex joints containing a variety of stainless steel alloys and sheet thicknesses (Figure 1). The SSMC wires appear to be more tolerant than solid wires of the complexities involved in welding these joints. The special additions made to their core ingredients and their tubular design produce this advantage.

The optimum wire diameter for welding most joints on exhaust systems is 0.9 mm (0.035 in.) for solid wire and 1.2 mm (0.045 in.) for SSMC wires. However, on some very thin-gauge parts (< 1 mm), 1.0 mm (0.040 in.), SSMC wires may be used to prevent burn-through problems. For the same reason, the pulsed-arc transfer mode is more commonly used than a spray transfer, except on thicker tube-to-flange joints.

The shielding gas for solid and SSMC wires is usually a mixture of argon and oxygen or carbon dioxide (95-98% Ar/Rem. O_2 or CO_2). Sometimes, tri-mixes that include hydrogen or helium are used in these applications. The shielding gas is selected to optimise the welding operability or performance characteristics. However, the proper Ti:C or Nb:C ratios must be maintained in the weld deposit to tie up the free carbon and nitrogen and reduce the formation of Cr carbides. Sensitisation or the formation of Cr carbides reduces wet corrosion resistance and leads to intergranular attack (1).

Any change in gas composition requires a weld metal analysis to ensure acceptability. Table 3 shows the typical effects of the most common shielding gases on the weld metal composition of an SSMC 18CrCb wire. As expected, the carbon content increases slightly when using a shielding gas containing CO2. The shielding gas composition has little effect on the other elements. A similar trend is found with solid wires (6, 7).

ESAB’s stainless steel metal-cored wires

Ferritic grades

Five ferritic SSMC wires are being produced for the automotive exhaust system industry: Arcaloy 409Ti, 409Cb, 436, 439 and 18CrCb. The choice of filler metal depends on cost, availability and performance, such as superior corrosion, oxidation and creep resistance. A description of each product now follows and Table 4 shows the typical weld metal analysis.

Arcaloy 409Ti (AWS A5.9-93, EC409) Arcaloy 409Ti is a 10.5–13.5% Cr alloy stabilised with Ti for arc

	C	Mn	Si	P	S	Cr	Ti	Nb
98 Ar/2 O_2	0.017	0.53	0.48	0.011	0.013	18.6	0.34	0.40
95 Ar/5 O_2	0.016	0.49	0.43	0.011	0.013	18.0	0.27	0.40
95 Ar/5 CO_2	0.032	0.54	0.47	0.011	0.013	18.2	0.35	0.43

Welding conditions 235 A, 24 V, DCEP, 7.9 m/min wire feed speed, 12.5 mm contact tip to work distance.

Table 3. Effects of shielding gas composition on the weld metal composition of 1.2 mm Arcaloy 18CrCb SSMC wire.

	C	Mn	Si	P	S	Cr	Ti	Nb	Mo
Arcaloy 409Ti	0.020	0.48	0.55	0.010	0.008	11.6	0.90	—	—
Arcaloy 409Cb	0.015	0.45	0.55	0.011	0.010	11.7	—	0.60	—
Arcaloy 436	0.020	0.60	0.50	0.010	0.009	17.3	0.60	—	1.20
Arcaloy 439	0.020	0.50	0.45	0.010	0.010	18.0	0.60	—	—
Arcaloy 18CrCb	0.018	0.50	0.45	0.011	0.011	18.5	0.25	0.50	—

Table 4. Typical undiluted weld metal analysis (%) with 98 Ar/2 O_2 shielding gas for ferritic SSMC wires.

	C	Mn	Si	P	S	Cr	Ni	Mo
Arcaloy MC308L	0.027	1.50	0.50	0.015	0.006	20.1	10.3	0.1
Arcaloy MC309L	0.014	1.53	0.51	0.016	0.006	24.1	12.6	—
Arcaloy MC316L	0.026	1.43	0.55	0.024	0.006	18.8	12.5	2.5

Table 5. Typical undiluted weld metal analysis (%) with 100% Ar shielding gas for austenitic SSMC wires.

stability and to form carbides to improve corrosion resistance, increase strength at high temperatures and promote the ferritic microstructure.

Arcaloy 409Cb (AWS A5.9-93, EC409Cb) Arcaloy 409Cb is the same as Arcaloy 409Ti, except that Cb(Nb) is used instead of Ti to achieve similar results.

Arcaloy 436 (no AWS classification) Arcaloy 436 is a 16.5–18% Cr alloy stabilised with Ti and with a 1–1.5% Mo addition for improved resistance to condensate corrosion and aqueous salt corrosion.

Arcaloy 439 (no AWS classification) Arcaloy 439 is a 17–19% Cr alloy stabilised with Ti. The higher chromium content provides an increased level of oxidation and corrosion resistance compared with the 409 grades.

Arcaloy 18CrCb (no AWS classification) Arcaloy 18CrCb is a 17.5–19.5% Cr alloy similar to Arcaloy 439 but stabilised with both Ti and Cb(Nb). The dual stabilisation helps to prevent carbide sensitisation during welding and high-temperature exposure.

Austenitic grades

Three austenitic grades are also available for these applications: Arcaloy MC 308L, MC309L and MC316L. A description of each product now follows and Table 5 shows the typical weld metal analysis.

Arcaloy MC308L (AWS A5.9-93, EC 308L) Arcaloy 308L can be used to weld AISI types 301, 302, 304, 304L, 308 and 308L.

Arcaloy MC309L (AWS A5.9-93, EC 309L) Arcaloy 309L is designed for welding dissimilar joints between carbon steels and various stainless steels.

Arcaloy MC316L (AWS A5.9-93, EC 316L) Arcaloy 316L is used to weld AISI 316 and 316L grades of stainless steel when pitting corrosion is a problem.

Packaging

The Arcaloy family of ferritic and austenitic SSMC wires is sold to major car manufacturers and their suppliers of exhaust components or assemblies. They are packaged in 15-kg (33 lb.) and 20-kg (44 lb.) spools and 227-kg (500 lb.) Marathon Pacs. The Marathon Pac has become the preferred package for many exhaust system fabricators. Down time is reduced as fewer changeovers are needed with this larger package size.

Summary

Advances in the design of automotive exhaust systems have led to a new family of stainless steel metal-cored wires that are rapidly becoming the favourite choice of welding fabricators in this industry. They offer the following advantages compared with solid wires:

1. Customised chemistry requirements are readily available
2. Increased travel speeds and deposition rates help reduce costs
3. More tolerant to poor fit-up with better wetting characteristics
4. Higher level of quality — fewer weld defects
5. Overall welding costs are usually lower

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About the authors

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AP Parts Torsmaskiner AB — supplier to the automotive industry

by Mats Persson, empe consulting & service, Sweden

For almost 50 years, this company has been producing components for the exhaust system for vehicle engines. The name and owners may have changed, but it has nonetheless always been clear that the company is based in Torsås, a town in an historical part of south-eastern Sweden.

It all began with the production of the pipe that connected the cast manifold and silencer on Volvo's post-war models. Compared with the complexity of current components, this was a very simple part. It was made of soft carbon steel and welding was performed using traditional gas welding. However, as welding technology developed, gas metal arc welding was introduced and the process was subsequently mechanised.

Cast manifold replaced with a welded version

Cost-cutting by vehicle manufacturers affected developments in every area. Interest eventually focused on the cast manifold in the engine. SAAB was one of the first customers to envisage a change and a far-sighted management team and skilled technicians at Torsmaskiner AB, as the company was known at the time,

Figure 1. Manifold for a 5-cylinder engine.

accepted the challenge and developed a manifold made of bent pipes which were welded to a joint connection flange. Welding immediately became an advanced part of the production process and robot welding was soon introduced. The welding fixtures were designed in house and the company's skills and expertise developed very rapidly.

When the new manifold was tested in the engine, an unexpected bonus was discovered. Engine output increased as a result of improved gas flow.

At the end of the 1980s, the welded manifold experienced a major breakthrough. SAAB decided to introduce it and Volvo quickly followed, incorporating the new manifold in its 850 model. Renault hesitated for a while, but eventually it, too, placed a large order. It then took only a few years for Volkswagen and Ford to follow suit.

Over the past three years, Torsmaskiner has invested a total of some SEK 170 million in extending production capacity to include new production lines to keep pace with large new contracts. The company now has a potential annual capacity of around two million manifolds on seven production lines, each of which is adapted to its individual model. The pipes are bent and shaped in fully-automatic pipe-bending machines. In 1999, more than one million manifolds were produced.

Higher temperatures require stainless material in the exhaust system

The exhaust temperature generated by modern engines is far higher than before and, as a result, the manifolds are now made from ferritic W1.4509 stainless steel with a chromium content of 17%. The scaling temperature is 950-975° C.

Hans Nyström, a welding engineer, explains that some joints are welded with OK Autrod 12.64, which is classified as AWS A5.18:ER70 S-6, but that equivalent filler metal such as OK Autrod 16.81 in accordance with W1.4502 is frequently used, while other joints are welded with OK Autrod 19.82, SFA/AWS A5.14-89 ERNiCrMo-3 (see the data box for more information).

The robot welding stations are equipped with double welding pistols and wire-feed units to switch between different filler wires. It goes without saying that the changes take place automatically during the operating cycle. Short-pulse welding with 0.9 mm wire has virtually eliminated finishing, as the "spatter" is almost non-existent. Car owners have probably noticed that their exhaust systems last far longer nowadays, in spite of the higher exhaust temperatures. An improvement which can be attributed to the stainless material.

Very little transport is performed by warehouse trucks inside the production facility. Most of the parts and welded components are instead transported on conveyors, thereby making optimum use of floor space.

Quality inspections automated

Quality inspections take place at fully-automatic stations using software, in accordance with the standards stipulated in the contracts. Checks are made to ensure that the material is correct, that the welded joints are airtight and that the measurement tolerances have been complied with. A handling robot moves the components from one inspection station to the next. After labelling, the robot places the approved components on a conveyor belt, ready for delivery. Components that are not approved are put on a different conveyor and are taken back to be adjusted.

The company has developed a completely new manifold for the Volvo S80 Series with its five-cylinder engine. It consists of two halves of a sheet metal shell that are pressed together.

Figure 2. Manifold made up of bent tubes.

It goes without saying that product development takes place in close collaboration with the different car makers. The development, production system organisation and design of all the fixtures that are needed for production take place at the company's technical centre. Since the mid-1980s, AP Parts Torsmaskiner has had its own engine laboratory where it tests its products and conducts its own evaluations.

Catalytic converters — a new product in the range

At the end of the 1980s, the21 company entered the emission control sector. It is currently producing catalytic converters for all Volvo's five-cylinder engines in the S/V70 and S80 models. The assembly process has been completely robotised. Two catalytic converter inserts, one made of stainless material and one made of ceramic, are placed in one half of the casing. Before the ceramic insert, which is sensitive to bumps and vibrations, is fitted, it is covered with fibre material which ensures that it is firmly fixed inside the casing. The other half of the casing is then fitted and the two halves are welded together using gas metal arc welding, before the catalytic converter leaves the assembly station.

The two halves of the casing are compression moulded from thin stainless material. There is a rebate on each side to make room for the weld. When it came to the selection of the welding method, the choice fell on laser welding for a number of reasons. The heat that is generated is relatively limited and yet highly concentrated, which helps to ensure that no changes in shape occur. The laser beam provides excellent access to the catalytic converter connections and the welding speed is high. Hans Nyström explains that the Institute of Technology in Luleå has been a great help in developing the laser welding method to suit the company's products.

Torsmaskiner is now part of a global car component producer

At the beginning of this article, mention was made of various changes of ownership. Originally, the company was owned by the family that founded it. It has expanded powerfully under the guidance of target-oriented leaders and technicians, who have developed its products and adapted the company to comply with the increasingly demanding customer call for improved products at lower prices. Continuous production rationalisation at every level has cut costs, while maintaining or enhancing the level of quality.

AP Parts Torsmaskiner AB with its 550 employees is currently part of the French Faurecia Group, a global car component manufacturer, with a total of 32,500 em-

About the author

Mats Persson has been engaged in welding for 50 years. During the first 25 years in service and sales of resistance welding machines with ASEASVETS and ESAB. 1975–77 he was technical manager at ESAB Australia. Thereafter area sales manager and later technical manager at ESAB International.

Welding consumables

The filler wire has been chosen to take account of the material that is being welded and the environment in which the weld is going to be used. The following table presents four different types of wire, ranging from a simple carbon-steel wire with a slightly increased manganese content to a high-alloy nickel-chrome-molybdenum wire.

Classification	ESAB designation	Alloy type
AWS A5.18ER 70 S-6	OK Autrod 12.64	Mn/Si alloyed
AWS A5.9ER 308 L Si	OK Autrod 16.12	18%Cr 8%Ni 0.5%Mo, low C
DIN 8556 SGX8 CrTi18	OK Autrod 16.81	18%Cr-0.5%Ti
SFA/AWS A5.14-89 ERNiCrMo-3	OK Autrod 19.82	Min.60% Ni, 22% Cr,9% Mo, 3.5% Nb (austenite)

OK Autrod 12.64, 0.9 mm in 250-kg Marathon Pac is used at several welding stations.

FILARC PZ6105R The robot-friendly cored wire

by Klaus Blome, ESAB GmbH, Germany and Tapio Huhtala, FILARC Welding Industries B.V., the Netherlands.

Fully mechanised welding imposes rigorous requirements on both the process and the welding consumables.

FILARC PZ6105R, a metal-cored wire for robotic welding, has been developed in co-operation with end users to meet these very specific demands which are summarised below:

- dependable feedability at high process duty cycles
- excellent start/stop characteristics
- no porosity and no spatter
- a wide parameter box
- flat welds with round penetration and smooth tie-in.

Dependable feedability is obtained through improved surface condition of the wire in combination with optimal spooling on reels or in MarathonPac. The feedability of the wire at high duty cycles is consistently good, even with long cable assemblies, providing a stable, spatter-free arc resulting in excellent weld quality. Sharp turns of the robot arm, which are often encountered when welding smaller components, do not present a problem either.

The force required to feed the wire through the liner is substantially reduced compared with conventional metal-cored wires (Figure 1).

The striking behaviour is optimised through the formulation of the wire, providing a dependable, soft and virtually spatter-free arc ignition up to current levels of 450A. Figure 2 shows the results of high-frequency current transfer measurements. The arc equilibrium at a given parameter setting is obtained more rapidly and without the current peaks often observed with solid wires or conventional metal-cored wires. This feature enables the welding of relatively thin components at high currents and high travel speeds.

In Svetsaren issue 3, 1998, we introduced PZ6105R, the metal-cored wire for robotic welding, describing its use in the fabrication of excavator frames involving medium to thick steel components. In this publication, we will discuss the utilisation of this new product for the robotic welding of thin plates, as a very productive, high-quality alternative to solid wire. The applications are quite remarkable, with components as thin as 1mm being welded with 1.4mm cored wires at very high travel speeds.

Firstly, however, we will review the most important features of PZ6105R.

Shielding gases

Various gas mixtures are used to improve results with solid wires. Mixtures such as 92/8 and 90/10 Ar/CO_2 are quite common as an alternative to the standard mixed gas 82/18 Ar/CO_2; also 96/4 or 92/8 Ar/O_2. FILARC PZ6105R can also be applied with all these shielding gases. The best results are obtained with 92/8 Ar/CO_2, followed by 82/18 Ar/CO_2 and 96/4 Ar/O_2.

Productivity

A diameter of 1.4mm is the optimum size for PZ6105R. With this versatile size, a wide range of plate thickness and fillet weld sizes can be covered. Fillet welds with a throat thickness of 2.0 to 6 can be welded in one pass. With very small throat sizes, travel speeds of up to 3.8m/min. are obtained.

Between 350 and 450A, the most frequently used current range (wire feed speed 11-16m/min.), deposition rates are 7 to 10 kg/h at a 100% duty cycle.

A reduction in downtime resulting from wire feed problems is another important improvement which has been brought about by PZ6105R. The improved surface condition and optimal spooling of the wire provide trouble-free feed for substantially longer periods than coppered solid wire or conventional metal-cored wires. In combination with the regular maintenance of liners and contact tips, this can produce substantial cost savings.

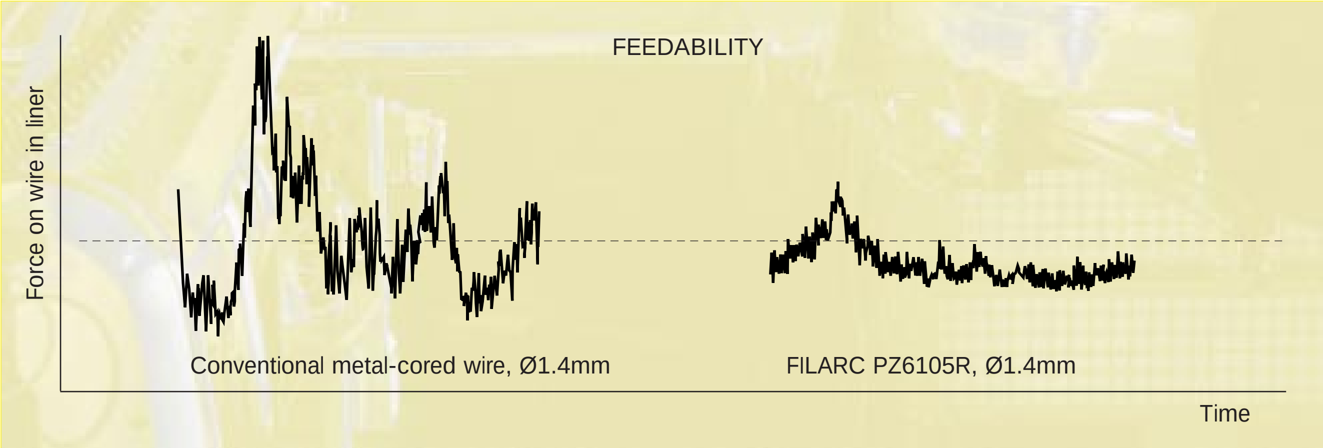


Figure 1: Force on the wire in the liner.

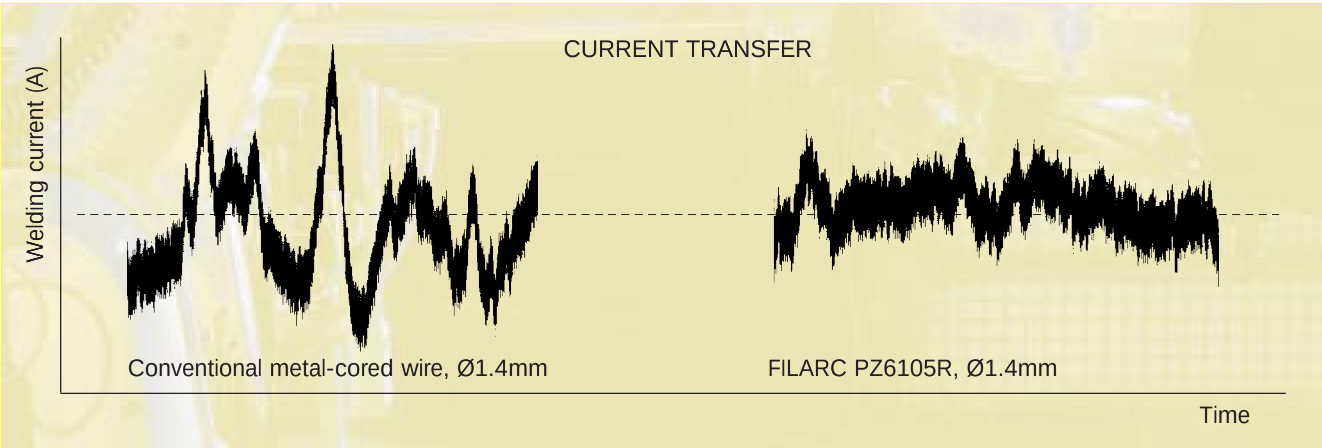


Figure 2: High frequency measurements of the current transfer between wire extension and contact tip.

Applications

We will now review selected applications of PZ6105R in the field of thin-plate welding; a new market for this product that has developed in parallel with more traditional cored wire market segments such as shipbuilding and the fabrication of earth moving and road construction machinery.

Circumferential welds in boilers

The requirements for the characteristic joggled circumferential joints in boilers are very high. Secure penetration in the root area is essential, as is the capability of the welding process to cope with fit-up variations.

The boiler in Figure 3 has a diameter of 500mm and a wall thickness of 3mm. Both joggled circumferential joints are welded simultaneously. Previously, this was carried out with 1.2mm solid wire with a welding time of 2.5min. The use of PZ6105R resulted in an arc time of only 1 min. As a result, the cost price of these boilers was reduced by 15%, notwithstanding the higher purchase price of the cored wire.

Car seat rails

In the production of car seat rails, an attachment strip is connected to the rail profile using two short welds (30–50mm) by robotic welding. The material thickness is 2mm. The enclosed fillet weld and the outer corner weld are normally welded with 0.8 or 1.0mm solid wire. The weld quality requirements are:

- flat beads
- no undercut
- round, full penetration
- no spatter

Taking account of these demands, 1.0mm solid wire cannot be welded at currents much higher than 180–190A. Beyond this level, spatter occurs with arc striking, as well as undercut due to the increased voltage. The maximum welding speed is 60–70 cm/min. with a welding time of 16–17s (Figure 4).

Figure 3; Boiler with two joggled circumferential joints, welded with PZ6105R-1.4 mm in 60s. Mechanised welding.

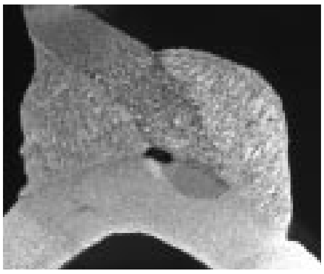


Figure 4: Strip attached to car seat rail, welded with 1.2 mm solid wire. Welding time 16.5 seconds.

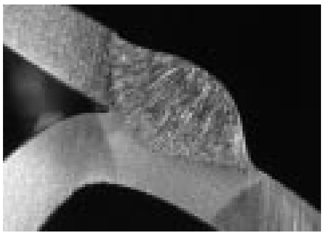


Figure 5: Strip attached to car seat rail, welded with PZ6105R-1.4 mm. Welding time 14 seconds. Note the full penetration and improved weld appearance.

Figure 6: Overlap joint 2×2 mm plate thickness, welded with PZ6105R-1.4 mm at 150 cm/min.

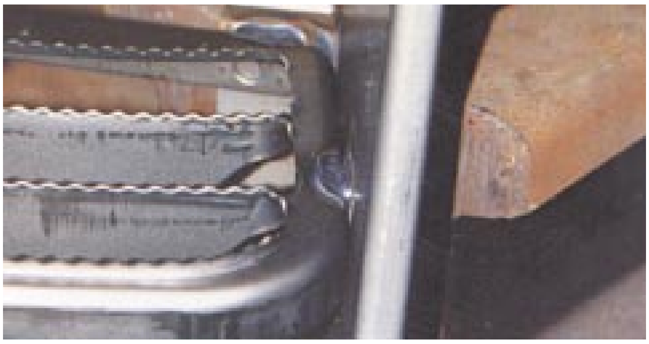


Figure 7: Attachment welds on vehicle stairs in 2 mm thick sheet metal. Spatter free welded with PZ6105R-1.4 mm.

Figure 8: 1 mm thick tubes, joined with PZ6105R-1.4 mm.

The use of PZ6105R-1.4mm leads to a welding time of 14s, a reduction of 15%. The welding current is set at 290A with a welding speed of 120-130 cm/min. All the weld quality requirements are met, as can be seen from Figure 5. The cost price of these components was reduced by 15%.

Overlap joints

In the fabrication of farming and construction equipment, it is very common to weld overlap joints from 1.5 to 2.0mm thick strip, for the cabins of tractors, the bodies of combine harvesters, mounting stairs and motor consoles, for example. Flat beads without spatter and a low heat input are required for this kind of work, to avoid excessive distortion and subsequent post-weld rectification.

Due to the excellent arc striking and the wide, stable arc of PZ6105R, it is possible to weld overlap joints in 2mm thick strip at a travel speed of 150 cm/min. The bead is flat with good tie-in with a round weld profile and good penetration (Figure 6).

Joints with fit-up variations

The capability of this wire to cope with fit-up variations is ideal for fillet welds in sheet metal constructions or pressed parts. When the opening exceeds 1mm or is variable, solid wire normally requires the deposition of two layers, whereas with PZ6105R one layer is usually enough to obtain a sound weld. Additionally, welding speeds are higher with a reduced heat input, while the amount of spatter is significantly lower (Figure 7).

The welding time for this component (mounting steps for agricultural and construction vehicles) is reduced from 60 to 40s. The absence of spatter reduces the amount of weld dressing substantially. In all the cost price of this component is reduced by 15%, compared with solid wire welding.

The robotic fabrication of car seats is another application in which the suitability of PZ6105R to bridge root gaps plays an essential role. Tubes of 1mm thickness are joined by a number of short welds. The increased welding speed is beneficial, as the heat input is reduced and with it the risk of distortion (Figure 8).

To conclude

FILARC PZ6105R is a versatile metal-cored wire for fully mechanised or robotic welding applications. It can be used for welding construction steel with a thickness of 30mm or more, down to sheet or tube with a thickness of 1mm; all with a single diameter of 1.4mm. It can be used with all the common Ar-based mixed gases. Advantages compared with solid wire or conventional metal-cored wire include more reliable feedability and improved weld quality.

In many applications, the welding process is more effective, leading to an overall cost reduction for welded components.

About the authors

Tapio Huhtala is a product manager for unalloyed cored wires at ESAB B.V. in Utrecht in the Netherlands. He joined ESAB in 1993 and worked as a research metallurgist in Goteborg until 1998.

Klaus Blome obtained an MSc from the Technical University RWTH of Aachen. He joined ESAB Germany in 1990 as a product manager for welding consumables. Between 1992 and 1997, he was international product manager for cored wires at Filarc Welding Industries in Utrecht. He returned to ESAB Germany in 1997 and has since been involved in various projects. Klaus Blome recently assumed responsibility for the sale of all ESAB products in southern Germany.

Stub-ends & Spatter

Automation for shipbuilding

In hull constructions such as double bottoms and bulkhead sections, vertical welding is both a time-consuming and labour-intensive process. It is normally performed by a large number of manual welders using semi-automatic MIG welding equipment. The working conditions are generally very unpleasant for the welder; cramped, dirty spaces, often with insufficient fume extraction.

In close co-operation with shipyards, ESAB's partner, the Finnish automation specialist PEMAMEK Oy Ltd, has designed and constructed an automaton to mechanise this difficult welding process.

The new PEMA-VWS vertical welding system is assembled on a movable portal and can be used for welding various vertical welds in ship's hull constructions.

Typical examples of these constructions include egg-boxes in double-bottom/bulkhead structures.

The main features of the machine are:

- ability to weld four vertical seams simultaneously
- user-friendly operating menu using PLC programming
- motorised adjustment of platform height and position
- four MIG welding torches supported by a sluing ring, with motorised rotation of ± 45º
- freely programmable oscillation system for different throat thicknesses
- automatic, programmable jump over horizontal stiffeners
- accurate positioning above the cross-section by laser light cross-beam
- efficient fume extraction system for each torch

The welding system normally includes four water-cooled (OCE-2) ESAB LAW-520 power sources with the MEK 4 wire-feed system. Using the advantageous oscillation system and flux-cored wire, it is possible to obtain a throat thickness of up to 7 mm in one run and 12 mm with two runs. When very strong welds are needed, such as those on engine frames, the system permits the welding of throat thicknesses of up to 16 mm. The welding speed varies from 10 cm/min to 35 cm/min, depending on whether or not oscillation is used.

The payback time calculations which PEMAMEK has made with its client show that the VWS vertical welding automaton easily replaces the work of 8 – 10 welders and the investment is normally paid back in less than a year.

Yards including Kvaerner Warnow Werft and Kvaerner Masa Yard are currently working with this equipment. Several other yards in Europe and the USA have already ordered equipment of this type for their production operations.

ESAB Aluminium 2000 Seminar on aluminium welding

The industrial use of aluminium is increasing sharply. New alloys have resulted in improved mechanical and physical properties, such as higher strength and improved weldability. Other obvious benefits include the low weight of the material and its fine corrosion resistance.

New welding and cutting methods and machines with improved characteristics are also helping aluminium to replace other materials in many structures within the transport, marine, aircraft, offshore and construction sectors.

In conjunction with The Welding Institute's (TWI) seminar on Friction Stir Welding in Göteborg on 27-28 June 2000, ESAB will be organising a two-day aluminium seminar covering the most important welding and cutting methods at the Quality Hotel 11 in Göteborg. This seminar will be held in English on 29-30 June 2000, and includes lectures by leading experts in the fields of material development, welding methods, mechanical equipment, shielding gases, various cutting methods and interesting applications in different areas. A number of demonstrations, including Friction Stir Welding, will be conducted at the nearby ESAB Process Centre.

This seminar is aimed at everyone who is involved with the welding and cutting of aluminium. People who would like to attend should contact Mrs. Märit Olsson by phone, fax or e-mail at
ESAB AB in Göteborg, Sweden,
phone +46 31 509 479
fax +46 31 509 436
e-mail marit.olsson@esab.se

A complete programme and additional information about this seminar can be found on the Internet at: **http://www.esab.com/europe**

OK 83.53 with EWR properties

A newly-developed ESAB hardfacing electrode, OK 83.53 EWR, is now being introduced after successful field tests. EWR stands for Extra Wear Resistance. This electrode is of the basic type and complies with the DIN 8555 E6-UM-60 standard. It is available in 3.25, 4.0 and 5.0 mm.

OK 83.35 EWR features:

- good arc stability, especially with DC+
- superb arc striking capabilities
- good slag detachability
- all positional welding

OK 83.35 EWR is recommended for applications in which extreme abrasive wear and moderate impact conditions apply, such as rock crushing machinery parts, drilling equipment, forestry tools, conveyor screws and so on.

Typical weld metal composition:

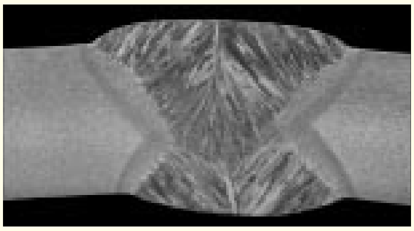
	C	Si	Mn	P	S	Cr	Mo	Nb
Min.	0.40	0.6	1.0	–	6.9	1.0	0.4	–
Max.	0.60	1.0	1.5	0.030	0.030	7.5	1.5	0.7

Eurospool – a new concept in spool design

The new octagonal Eurospool wire basket is designed to flush-fit European pallets without overhang to increase loading capacity from 660 kg to 900 kg with a flat top. The basket has the following dimensions: a width of 100 mm and octagonal diameters of 390/415 mm. Spools will be available with weights of 30, 25 and 15 kg and stacked in five, six and 10 layers respectively.

The carton has a push-through carrying handle with the wire visible for inspection through the transparent shrink-wrapped plastic prior to opening. The octagonal carton reduces waste by more than 40% and the octagonal basket prevents the spool from rolling when placed on sloping surfaces. The Eurospool wire basket has a patent pending.

OK Flux 10.74 – for welding longitudinal pipes



Picture of inside/out bead cross-section on 16 mm pipe wall thickness

OK Flux 10.74 is a basic, moderately Si and Mn alloying flux designed for the longitudinal welding of line pipes with multiple electrodes where a low weld bead profile (reinforcement) is desirable for coating applications.

This is achieved at high current levels with excellent impact toughness and reduced hardness in the weld metal.

ESAB Introduces the “Other” T-8 in a 1.6 mm Diameter!

Under the AWS A5.20 specification, the EXXT-8 classification umbrellas two types of slag systems the traditional barium fluoride based system found in the Coreshield® 8Ni1 and a high lithium oxide system in our new Coreshield® 8. The new Coreshield® 8 flux cored wire is intended to simplify welding.

The wire is used “open arc” in all positions with straight progression. The all-weld-metal deposit is ductile and tough and will meet 27 J at –29°C nearly independently of the welding procedure. It meets the strength and toughness requirements of AWS A5.20 E71T-8 and ABS 3SA, 3YSA. It is intended for plate assemblies and joints. The 1.6 mm diameter is ideal for achieving high deposition rates.

What’s more, the Coreshield® 8 wire contains a very low level of barium (less than 0.5% by weight). As a result, the fume exposure limit for barium will not be reached before the overall limit for welding fumes of 5 mg/m3 is reached. These advantages make the Coreshield® 8 the ideal choice for all-position welding in the construction of steel frame buildings.

ESAB has taken a market-leading position by successfully manufacturing a 1.6 mm diameter, the smallest marketed for this type of wire. The smaller size concentrates the heat, making it easier to achieve cleaner x-rays and at the same time offering improved operator appeal. The welding arc reflects a deep purple hue that has given rise to the nickname of “purple arc.”

The new Coreshield® 8 and the traditional Coreshield® 8Ni1 are recommended for nearly all construction jobs in which a self-shielded all-position wire is required or preferred.

Stainless steel wire – Marathon Pac

At the beginning of 1999, ESAB introduced stainless steel welding wire in an octagonal Marathon Pac as a result of increasing demand on the market, especially from the automotive and related industries.

The concept of packing non-alloyed welding wire in an octagonal drum has been on the market for a few years and is now well known. It was therefore only natural for ESAB to extend the available product range to include stainless steel wires. The main benefits of the octagonal Marathon Pac are:

- Higher productivity – less downtime
- Higher weld quality – consistent feed
- Environmentally-sound – 100% recycling package

To date, most of the ESAB Marathon Pacs that have been delivered are used for robotic welding, where productivity, downtime and feed consistency are essential factors. ESAB Marathon Pac is the solution in these areas.

The range of stainless steel wires in Marathon Pac comprises OK Autrod 16.12, 16.32, 16.51 and 16.95 in diameters of 0.9, 1.0 and 1.2 mm.

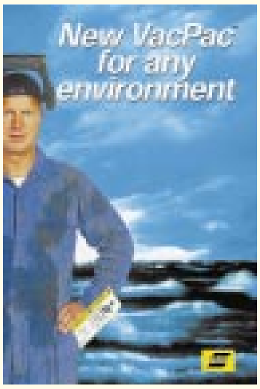
Now released:

The cored wire product brief on CD-ROM

The 1999 edition of the OK Tubrod Cored Wire Product Brief is now available on CD-ROM. It covers the full range of products for flux-cored arc welding, as well as the cored-wire/flux combinations for submerged arc welding. The CD-ROM has been developed for use with Acrobat Reader 3.0 software.This software has been incorporated on the CD-ROM.

The CD-ROM can be ordered with a fax or a mail to:
ESAB. B.V.+31 30 241 15 35,
ben.altemuhl@esab.nl

New ESAB VacPac™



The use of low-hydrogen electrodes in a ready-to-use package has attracted increasing interest over the past few years. ESAB VacPac™ is the package used in applications where the lowest possible moisture content and the best possible quality assurance are a must.

This way of packing low-hydrogen electrodes is the ultimate delivery method for these electrodes, as the troublesome storage and rebaking procedures are eliminated and the existence of a vacuum in the package shows that the ESAB OK electrodes are okey.

ESAB is now introducing a new type of VacPac™ with a number of improvements.

- The package contains less plastic, thereby imposing a smaller environmental load.
- The protection from punctures has been improved, thanks to a corrugated plastic inner box.
- Complete marking information is printed directly on the laminate.

Initially, two sizes will be available. One is a half-pack, containing about 2.5 kg of electrodes. This package will be the standard size for dimensions smaller than a core-wire diameter of 4.0 mm. There will also be a 3/4-pack, containing around 4 kg of electrodes. This size will be the standard packing size for dimensions larger than a core-wire diameter of 4.0 mm. The 4.0 mm electrodes come in both sizes, depending on the type of electrode.

The new VacPac™ will gradually replace the present type. It will be available for all moisture-sensitive electrodes.

6th World Duplex Stainless Steel Conference and Expo

Duplex stainless steels have been used increasingly by industry as a result of specific mechanical and physical properties such as hardness, high yield strain, good weldability and resistance to corrosion and pitting.

The characteristics of duplex stainless steels have made them very interesting for many applications in the oil and gas industry, chemical industry, marine industry, paper industry, engineering and architecture.

Associazione Italiana di Metallurgia, AIM, has been designated to host the 6th World Duplex Stainless Steel Conference and Expo which will be held in Venice, at the prestigious Fondazione Cini on the island of San Giorgio Maggiore, in front of San Marco Square, from 18 to 20 October 2000.

The congress will offer an opportunity to make an evaluation at world level of the current situation for duplex stainless steels. It will focus on structure and properties, application and service experience, fabrication, forming and welding. The conference will also feature a specific exhibition for manufacturers, end users and service companies.

All information and updates on Duplex 2000 will be available at the following Web address: www.duplex2000.gpa.it

For further information, please contact:
Associazione Italiana di Metallurgia Piazzale R. Morandi 2
I-20121 Milan, Italy
phone +39 2 7602 1132
fax +39 2 7602 0551.

Vego Svejse- og Valseindustri improving productivity using the A6 Synergic Cold Wire process

Figure 1.

Vego Svejse- og Valseindustri is a large Danish manufacturer of heavy steel structures. As a supplier to the wind power industry, the company keeps a close eye on developments in a number of welding processes and is constantly looking for systems to improve quality and speed up production. In recent years, Vego has optimised its welding using the Twin-wire process, but it still needs to increase the deposition rate.

The company has now decided to use the new Synergic Cold Wire process (SCW), which has been developed by ESAB, to produce the towers for wind power stations. Welding tests using cold wire consumables at the ESAB Process Centre in Göteborg revealed an increase of 50% in the deposition rate compared with standard Twin-wire welding at the same welding current. The same increase in deposition rate was obtained for both solid wire and flux-cored wire. This represents a significant improvement in productivity which reduces the number of runs while maintaining the welding speed. In addition, distortion and flux consumption are both reduced.

In this case, the cold wire was a 3.0 mm solid wire, fed by an “A6 Dual Gearbox“. The cold wire is fed in front of the two twin wires and melts in the joint molten pool, see Figure 1.

The SCW process does not require any additional control or feed devices as the choice of cold wire diameter determines the increase in productivity. Cold wire can also be used to change the chemical composition of the weld in a predetermined manner.

The Weld Procedure Report, Figure 2, shows the deposition rates for different test welds. It varies from 6 kg/hr with a single wire to 25.4 kg/hr with SCW consumables, with good X-ray quality and fine mechanical properties when welding with OK Flux 10.71 and OK Autrod 12.22.

ESAB — WELD PROCEDURE REPORT

Base Metal

WELDOX 450

Filler Material

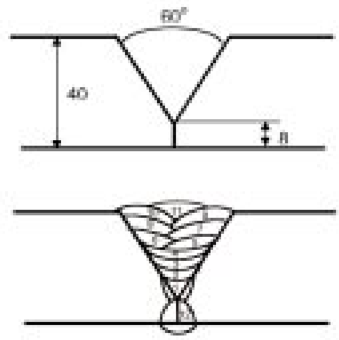
OK FLUX 10.71
Arc wire: OK AUTROD 12.22, Ø 3.0 mm
Cold wire: OK AUTROD 12.22, Ø 3.0 mm

Process

TWIN WIRE SCW - SAW

Position	Current
1G	DC+

Joint



WELDING PROCEDURE

Run No	Wire Ø mm	Parameters Amps	Parameters Volt	Speed cm/min	Dep. rate kg / hr	H.I. kJ/mm
1	1x3.0 mm	500	28	50	6.0	1.7
2	3x3.0 mm	1000	33	100	18.8	2.0
3	- - -	1250	34	90	25.4	2.8
4	- - -	1250	34	80	25.4	3.2
5-8	- - -	1100	33	80	21.3	2.7
9	- - -	1100	33	70	21.3	3.1
10	- - -	1200	33	75	24.0	3.2
11	- - -	1200	33	60	24.0	4.0
12	2x3.0 mm	1250	33	75	16.9	3.3

Procedural comments

Bead No 1 — Single wire
Bead No 2-11 — Twin wire + cold wire
Bead No 12 — Twin wire
ESO = 30 mm

TEST RESULTS

Tensile test

UTS : 533 MPa
YS: 414 MPa
Elong. 27 %

Impact test

Loc.	Temp.	Values
TOP	-20°C	108 J
	-30°C	66 J
MID	-20°C	69 J
	-30°C	64 J
ROOT	-20°C	69 J
	-30°C	56 J

Figure 2.

OK Flux 10.80 with new formula

OK Flux 10.80 has been redesigned for improved weldability, smoother bead shape and wettability with increased resistance to pockmarking and can now be redried. OK Flux 10.80 is a neutral Si and Mn alloying flux for the single and multi-pass butt welding of mild and medium tensile steels where the impact requirements are moderate and the surfacing of marine engine piston tops is required. It is of the calcium-silicate type which permits very high current capabilities, up to 1,500 A on single wire, thereby improving productivity.

Quality assurance in automatic welding

by Stefan Berglund and Urban Strand, ESAB Welding Equipment AB, Laxå, Sweden

Since 1984 when the ISO 9000 regulations were first issued, progress towards quality assurance has attracted increasing interest and is becoming increasingly important in general welding. The statement that welding was to be regarded as a special process led to the development of the EN 729 standard "Quality requirements for welding" approved by CEN 1994 (CEN stands for European Committee for Standardisation). At this point, ISO 9000 regulations were improved by a revision.

For automatic welding, the move towards quality assurance was made at an early stage by industry in the form of regulations specified in contracts depending on the application. For applications such as pressure vessels, national standards have been valid for a long time and the same thing applies to welding in the construction industry (such as bridges), offshore and nuclear plants. The automotive industry and industry in general were not regulated in this sense, but they saw economic incentives in quality assurance. Manufacturing and after sales costs can be reduced and market image can be improved by quality assurance. Now and then, we hear about car companies recalling thousands of cars for adjustments.

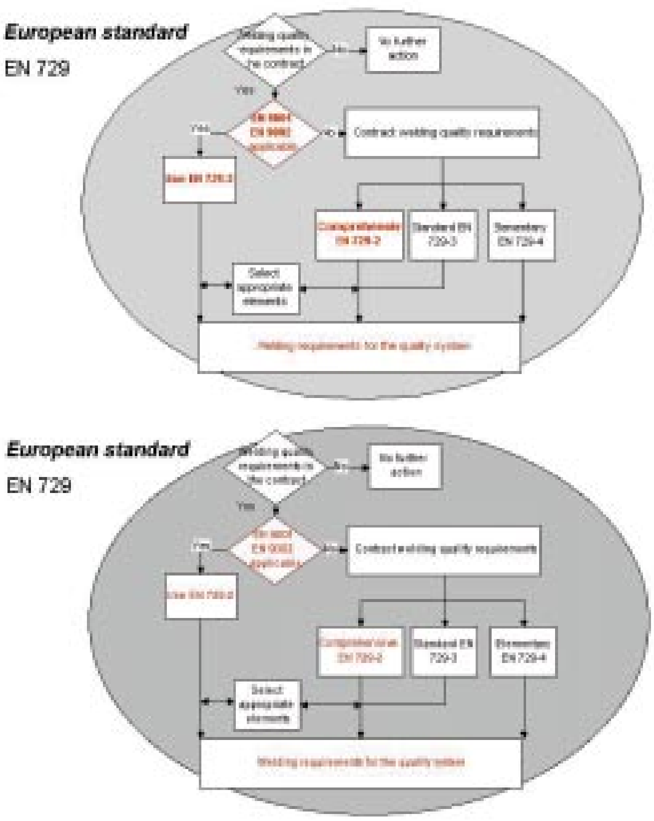


Figure 1. Interaction of welding standard EN 720 classes and ISO 9000.

Figure 2. Welding standard for quality assurance.

Welding standard for automatic welding

ISO 9000. The ISO 9000 standard is general for all welding. The welding is defined as a "special process" in 4.9, because, as it says, "Where the results of processes cannot be fully verified by subsequent inspection and testing of the product… … .., the processes shall be carried out by qualified operators". It is also said that "and/or shall require continuous monitoring and control of process parameters to ensure that the specified requirements are met". So even the top-level standard specifies process control and process records (4.16) for stated applications in industry instructions or business

Figure 3. Power source validation and standard verification.

contracts. Most automatic welding today is well prepared for this requirement, as the control systems are frequently flexible and easy to interface with computers.

It should also be noted that element 4.9 specifies many requirements for a preventive maintenance programme. This should result in less downtime and lower manufacturing costs.

EN 729/EN 719. As the ISO 9000 standard is not specific to welding, the need for more details was met by the EN 729 standard "Quality requirements for welding", with the subtitle "Fusion welding of metallic materials", and the EN 719 standard "Welding coordination – Tasks and responsibilities". In the case of automatic welding, the second of these standards relates to the technical knowledge of welding and interfaced equipment. In ISO 9000, knowledge is identified as one determining factor for successful welding. Enclosed with the standard are recommendations on technical knowledge for welding co-ordination staff from the EVF, the European Welding Federation. The EN 729 standard is divided into three classes 2, 3 and 4 (Figure 1). Class 2 is the most demanding and calls for supplementary standards like EN 287 and EN 1418, which deal with welding operator approval for manual and automatic welding respectively. EN 288 is also compulsory and describes how a WPS (Welding Procedure Specification) should be prepared. The method of approval must comply with the relevant application standards or as stated in the contract.

Other main issues in EN 729 include weld object identification and traceability and welding quality records, all points of vital importance for the quality assurance of welding.

The interaction of these standards is shown in Figure 2.

The future is already here when it comes to increasing the focus on quality assurance. The developments in society necessitate improved control of quality and welding quality. In the current economic climate, most companies are highly motivated to pursue this course. The ISO 9000 standard will be revised late in 2000. The key words for this revision are continual improvement, more rigorous management review, quality objectives at each function and level, defined customer communications, process monitoring for improvements and preventive action to avoid potential non-conformity.

Quality supervision system for automatic welding with TIG and SAW for standard application welding equipment

When welding products with rigorous strength requirements, where an incorrect weld joint could cause an accident or personal injury, the company doing the welding must be able to guarantee the quality of the welding in a satisfactory manner. One method that is used is a post-weld inspection to identify possible defects using different technical systems including X-ray. This is a labour-intensive , expensive method which also extends production times. What is more, it is not possible fully to guarantee the material properties and strength in the heat affected zone without using extremely detailed tests. In this case, the above standards specify a method for assuring the quality of welding by qualifying the

Figure 4. Quality assurance application for Protig 450, TIG welding tool PRC and PC computer.

welding process and production in accordance with the WPS. This means that the best application is tested for welding (WPS) using the procedure specified in EN 288. During production after a WPS. it is necessary to have a system that registers critical process parameters and stores information in such a way that it can be retrieved on the basis of the welding designation. A large number of monitoring systems for welding are available. In the past, they have been independent analogous measurement systems which it has been possible to connect whenever necessary. Handling has been complicated when it comes to both connection and use. However, the use of industrial computer systems has made significant improvements possible.

Modern power sources are computer controlled and developments are moving towards monitoring these power sources using integrated 'computers' which utilise the standardised data systems that are available for storage, securing back-up and handling in standard operating systems. As a result, the previous independent measurement systems have to be replaced by the quality assurance of power source function.

The prENV 50184 standard specifies how validation is to be performed on power sources to ensure the correct integrated surveillance (Figure 3).

Weldoc/WMS 4000

ESAB has a monitoring system for welding with the modern, programmable power sources in the Aristo Series and Protig 450/Prowelder 320 for tube-welding using the TIG method. The same system can be used for automated welding with the PEH control box for the power sources in the LAF and TAF Series which are used for products such as welding tractors, automatic beam welders, seamers and columns and booms. The computer program is known as Weldoc/WMS 4000 and a general description can be found in Svetsaren No.1-2, 1997(Strand 1997).

WMS 4000 has been designed as a PC standard program for the above-mentioned products. The idea is to comply with the current welding standards and offer systems for quality assurance to the welding industry without necessitating too much training. It goes without saying that computer skills are required, but the basic aim has been simplicity, adaptation to the functions that are included in Windows and on the Internet, flexibility and safety.

Transfers to the computer take place using serial optical signals in a plastic cable for interference-free operation. The high-frequency striking of the TIG arc and other high-frequency signals in a welding workshop could otherwise disrupt signal transfer.

TIG welding

The flexibility of this computer program is illustrated by the fact that it is able to monitor the automated TIG welding of tubes with sectorisation, in which each sector can be allocated separate limit values for the five welding parameters which are being monitored (current, voltage, output, wire-feed speed and welding speed). Vertical markings on the diagrams for analysing the welding parameters indicate the limits of the welding sectors.

SAW – MIG/MAG welding with LAF/TAF power sources

When welding with LAF and TAF power sources, the welding process is controlled by the PEH control box. Input data and welding parameters can be transferred from the PEH box to a computer. Four welding parameters, current, voltage, wire speed and welding speed, can be monitored the whole time. In addition, the heat supply for the entire weld is calculated as a mean value.

Quality assurance

As the demands that are imposed on welding equipment are stepped up, increasingly rigorous requirements are being set for weld quality. In the majority of more complicated welding jobs, there is a WPS (Weld Procedure Specification) to follow and it gives detailed information about the standards that apply to the job and the most suitable welding procedure.

Automation normally involves the automatic positioning of the welding electrode and this imposes truly rigorous demands in joint preparation, as corrections to welding parameters or positioning are not automatically made if there are deviations in the weld joint.

ESAB has developed a welding system which reacts to changes in the weld joint. The joint is analysed with the assistance of a "smart optical sensor" which consists of a CCD camera and a line laser. The camera registers the line of the joint configuration on a matrix which informs a computer about the joint geometry. The laser line itself produces an exact image of the cross-section in the weld joint at the precise position in which the laser finds itself at that point. You could say that the camera and the line laser combine to act as the welding operator's eyes.

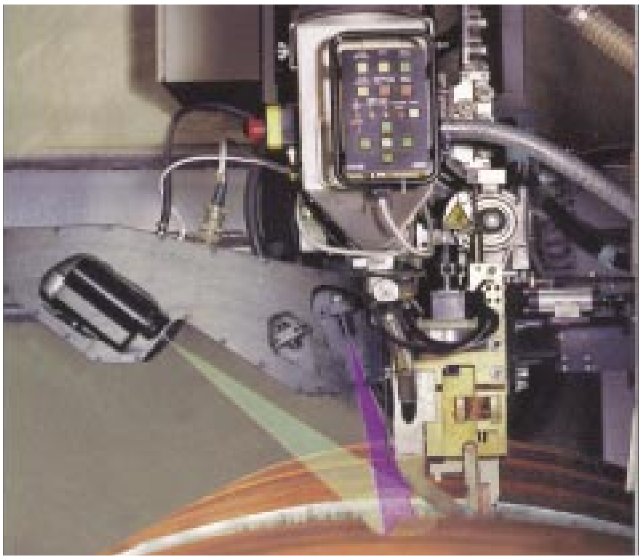


Figure 6. The ABW welding head and its smart camera and linear laser.

Using a computer with programmed logarithms, the welding parameters and positions can be changed when changes take place in the weld joint. This could be called the operator's brain.

The advantage of a system of this kind is that the set parameters are automatically changed if the joint makes this necessary. In the case of manual or automatic welding, this would be difficult if more than one parameter needed to be changed.

One way of securing weld quality is to register as many welding parameters as possible in detail. Current, voltage and welding speed can normally be registered, but it has not previously been possible to register run positioning. ESAB's highly-automated ABW (adaptive butt welding) welding systems make it possible to register the exact position of the welding runs.

Figure 5. ABW is suitable for joints with slight variations.

As the ABW system has the intelligence to use the shape and variation of the weld joint as the basis for changing the welding parameters and the position of the welding electrode in order to comply with predetermined requirements, the need to register the position of the welding electrode, in addition to the welding parameters, has become apparent. This makes it possible to identify where in the joint the problem has occurred with millimetre precision.

ABW registers all the data in what is known as a log file. As a log file is so large and difficult to handle, a so-called welding report is used. It mainly specifies the programmed limit values that have been exceeded. This means that all that data within the report (tolerance) limits is not registered, but the moment the data touches the programmed report, it is stored in the welding report. This makes it possible to control with millimetre precision the weld metal in the area in which the welding parameters reach the predetermined limit for reporting.

A welding report contains the following information:

- Specification of work for the item in question
- Specification of the programmed welding parameters
- Table of the number of runs in each layer
- Event list including identified critical data

Predetermined limits for the permissible welding parameters and the period during which these limits can be exceeded are also programmed in the system. If this limit is reached and the set time is exceeded, the welding system makes a controlled welding stop. This gives the operator the chance to check the reason why the values were exceeded before any welding defects occur.

With the ABW system, ESAB has taken yet another step towards total welding quality, as the system offers the user an even better chance to improve the quality of his production and to obtain complete documentation on the work that is done.

As it is now possible to register not only the welding and positioning values but also the movements of the workpiece (vessels on a roller bed), ESAB has been able to simulate and solve customer problems relating to the use of vessels on roller beds of other makes, using log data transmitted by e-mail.

The new ABW system has replaced the old PC control system for narrow-gap welding units. Not only is ESAB now able to control narrow-gap welding units using a PC-controlled node system, the company has now also made it possible to register the welding data during narrow-gap welding. The position of the electrode in the weld joint is not, however, measured by the system, but there are only two runs per layer in narrow-gap welding and the positions are controlled by an electromechanical joint-tracking unit. The system does, however, register the position along the joint (in the welding direction) and whether the run is a left-hand or a right-hand one and this is perfectly adequate, should the operator wish to attribute an incident in the welding date to a position in the weld joint.

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Submerged arc welding with fused flux and basic cored wire for low temperature applications

no re-baking of fluxes necessary

by Neil Farrow and Shaun Studholme, ESAB UK, Ltd.

ESAB introduce a basic cored wire/fused flux SAW package, OK Tubrod 15.24S/OK Flux 10.47 for use in offshore fabrication. Rebaking of the flux is avoided.

Introduction

Today, the commonly applied fluxes for high strength/low temperature applications are agglomerated basic types, to provide dependable CVN and CTOD toughness properties at sub-zero temperatures. The greatest disadvantage of agglomerated fluxes, however, is that they are hygroscopic and must be re-baked prior to welding in order to avoid potentially high weld metal hydrogen contents with the inherent risk of cold cracking. The routine of removing flux from bags into ovens and re-baking it for several hours is time consuming and costly for fabricators. Fused fluxes, although non-hygroscopic, never became established in offshore fabrication, mainly because of poor mechanical properties with solid wires. This is overcome by the use of a basic cored wire with active agents in the flux to improve the mechanical properties.

ESAB have now introduced a basic cored wire/fused flux consumable package, OK Tubrod 15.24S/OK Flux 10.47, fulfilling low-temperature weld metal requirements down to –40ºC and CTOD-tested at –10ºC, but without the necessity to re-bake the flux before welding. In the field of submerged arc welding, this is as much a breakthrough as the introduction of

Table 1: Classifications	
OK Flux 10.47	EN 760: SF AB 1 65 AC
Combination	AWS A 5.23: F8A4-EC-G

Table 2: All weld metal chemical composition and mechanical properties (as welded).

%C	%Si	%Mn	%Ni	%P	%S
0.05-0.10	0.10-0.40	1.50-2.00	0.60-0.90	<0.025	<0.025

Rp 0.2	(MPa)	>470
Rm	(MPa)	550-700
A5	(%)	>20
CVN at –40ºC	(J)	>47

Table 3: Typical CTOD values at –10ºC for OK Tubrod 15.24S/OK Flux 10.47.

	Single-V	Double-V	K-prep.
1st	>0.934	0.731	>0.916
2nd	>0.934	>0.893	0.866
3rd	>0.919	0.753	–

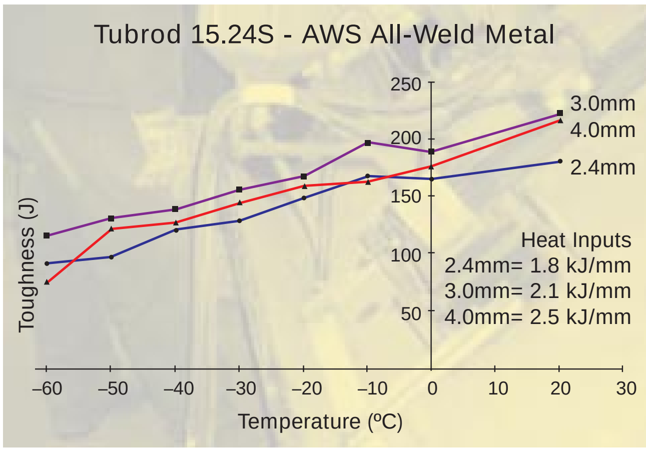

Figure 1: CVN transition diagram.

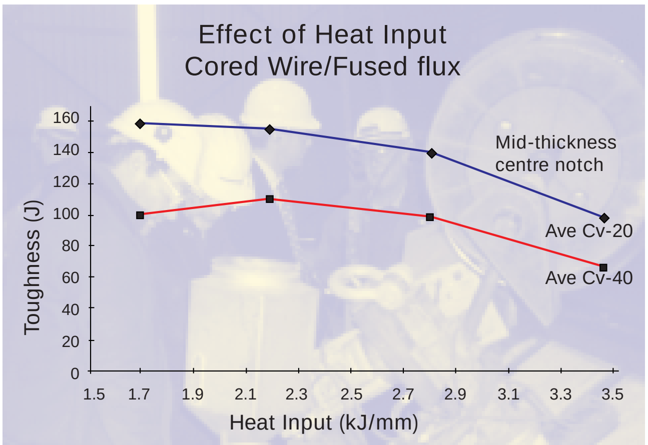

Figure 2: Influence of heat input on CVN properties.

vacuum packaging for stick electrodes in the eighties. It simplifies storage and handling procedures enormously.

In addition, fabricators get a bonus in the form of an increased welding economy, due to the use of a cored wire. Deposition rates may be 20 to 30% higher than with solid wire SAW, depending on the type of application. More benefits in the area of weldability are discussed below.

In the near future, ESAB will launch other consumable packages with basic cored wires and fused flux for general construction and other segments where the low-hydrogen weld metal is a factor for consideration.

Next, the new SAW consumable package is introduced and product characteristics are reviewed. In addition, we discuss its successful implementation for the fabrication of components of the Saga Petroleum Snorre B oil and gas platform by two UK subsidiaries of Kværner Oil & Gas.

Mechanical properties of OK Tubrod 15.24S/OK Flux 10.47

The objective of the development was to create a consumable package based on a basic cored wire and fused flux meeting the following weld metal requirements (as welded) for structural welding in the offshore segment:

- Yield strength >470MPa
- CVN toughness >47J at –40ºC
- CTOD >0.25mm at –10ºC

The use of a basic cored wire, instead of a solid wire, allows the weld metal toughness properties to be engineered through the cored wire rather than through the flux.

A highly basic flux is no longer a prerequisite and this opens the way to the use of a lower basicity fused flux with very distinctive advantages for offshore welding applications.

OK Tubrod 15.24S is a 1% nickel alloyed basic cored wire meeting the all weld metal mechanical requirements stated above in combination with the fused flux OK Flux 10.47. Table 1 gives the classifications and Table 2 shows the chemical composition and mechanical properties. It is clear that the combination exhibits the required tensile properties as well as sufficiently high CVN toughness, even down to -50ºC.

CTOD properties have been tested for single-V, double-V and K-joints in 50mm wall thickness with excellent results (Table 3).

Figure 1 surveys the CVN temperature transition curve, showing a gradual decrease down to a level of –60ºC for all three wire diameters. Figure 2 shows that the CVN toughness decreases with increasing heat input, but stays well above the 47J level at –40ºC.

These results establish that the SAW consumable package OK Tubrod 15.24S/OK Flux 10.47 clearly provides the mechanical properties needed for offshore fabrication. Additional benefits are found in the use of a fused flux, described below.

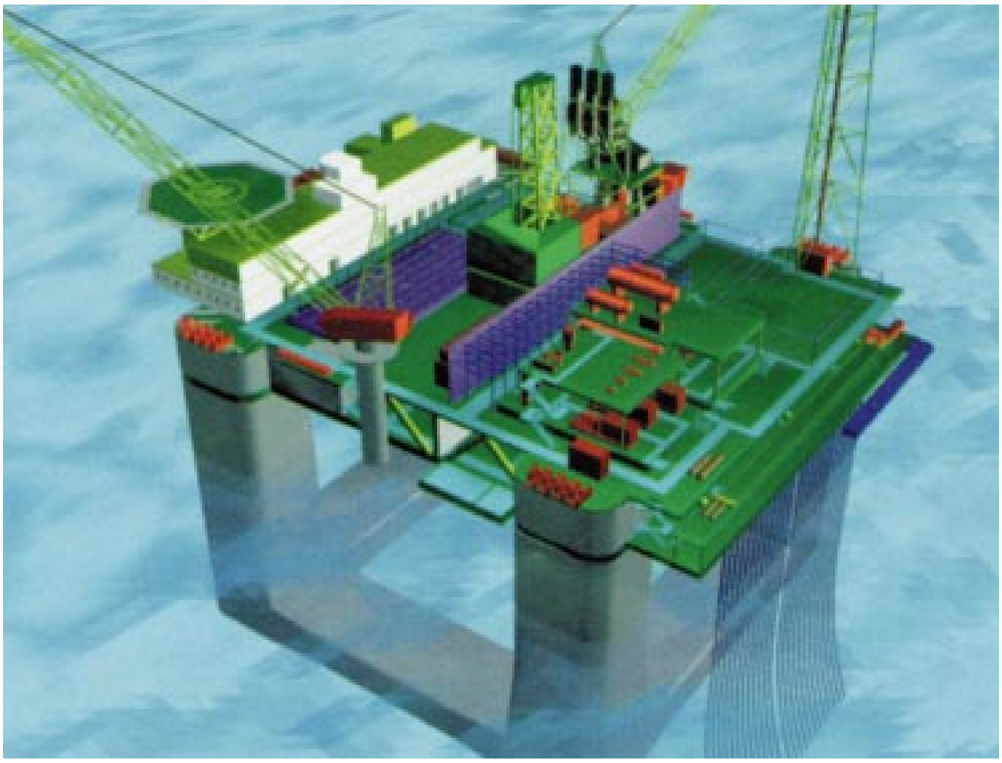

Figure 5: Snorre B. Artist's impression.

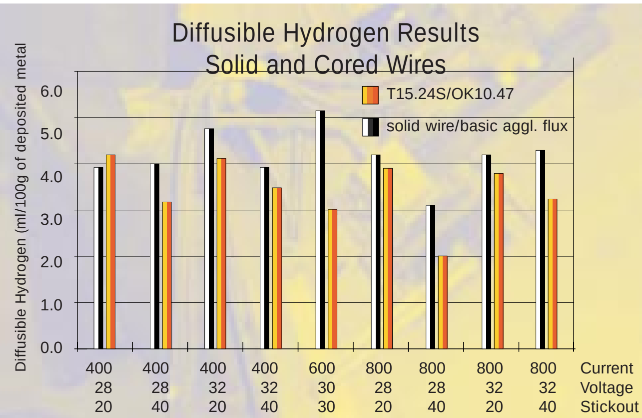

Figure 3: Diffusible hydrogen results for competitor EN 760: SA FB 1 55 AC type agglomerated basic flux used with solid wire and OK Tubrod 15.24S/OK Flux 10.47.

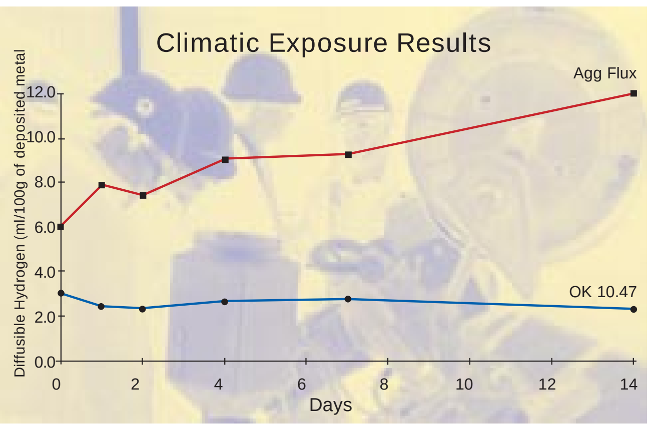

Figure 4: Climate exposure tests at 80%RH and 25ºC for EN 760: SA FB 1 55 AC type competitor agglomerated basic flux and fused flux OK Flux 10.47 with OK Tubrod 15.24S. Diffusible hydrogen determined at 600A/30V/ 30 mm stickout.

OK Flux 10.47

The fact that this fused flux has a very low moisture content and a moisture re-absorption rate close to zero is, undoubtedly, the biggest advantage for applications where low weld metal hydrogen contents are crucial. This enables the flux to be used without the costly, and time-consuming procedure, of re-baking.

Figure 3 compares the hydrogen performance of the consumable package OK Tubrod 15.24S/OK Flux 10.47 with a well established competitor basic agglomerated flux/solid wire combination. Diffusible hydrogen tests have been carried out at increasing current levels covering the work range of the flux, for various stick-out lengths. Both wire/flux combinations gave values below 5ml/100g with OK Tubrod 15.24S/OK Flux 10.47 tending below 4ml/100g. Note that the agglomerated basic flux has been re-baked according to the manufacturer's instructions whereas OK Flux 10.47 has been used directly from the original bags.

The moisture re-absorption characteristics of both fluxes have been tested by means of climatic exposure tests in a humidity cabinet at 80%RH and 25ºC for up to 14 days. It shows that OK Flux 10.47 is not sensitive to moisture re-absorption, due to its non-hygroscopic character and can be used safely without re-baking.

The basic cored wire OK Tubrod 15.24S hydrogen values and re-absorption behaviour is comparable with that of solid SAW wire. When stored and used according to the manufacturer's instructions it does not regain moisture.

The second big advantage for fabricators is an increased deposition rate due to the use of a cored wire as a consumable. As with cored wires used for FCAW, the current is conducted by the metal sheath, instead of the complete wire cross section resulting in a higher current density. In combination with the fused flux this higher current density is converted to increased deposition rates and higher applicable travel speeds. How much fabricators can benefit from this depends, of course, on the type of application. Our experience with cored wire/flux combinations in general, is such that an increase in welding productivity can be expected in the order of 20–30%.

Weldability characteristics are excellent; comparable to the best basic agglomerated fluxes available on the market. Slag release is very good even in the bottom of butt joints near the root area and even narrow gap applications are possible. Due to the glass nature of the flux, the grain strength is significantly higher than that of the fully basic agglomerated fluxes. This results in less breakdown and hence no problems with "dusting" and therefore allround improved recyclability. The finished weld appearance is very good, both in butt and fillet welds.

Next we will describe the use of OK Tubrod 15.24S/OK Flux 10.47 for offshore fabrication by two UK based yards who were the first customers for this new combination.

Fabrication of deck modules for Snorre B

The Snorre B oil and gas platform for Norway's Saga Petroleum (Figure 5) is currently under construction for delivery in the Spring 2000. Aker Stord of Norway is the main contractor. Part of the deck was sub-contracted to Kvaerner Oil & Gas (KOG) Methil, in Scotland, which in turn sub-contracted parts to KOG Teesside in England.

Applications at both UK yards are very similar. They consist of box structures and beams in BS 7191-450 EMZ steel with a minimum weld metal CVN toughness requirement of 47J at –40ºC. Figure 6 shows the fabrication of beams at KOG Methil. Fillet welds with a throat thickness of 8.5mm were made in one pass with OK Tubrod 15.24S/OK Flux 10.47 at 630A/31V/36cm/min. In this application, the cored wire/fused flux combination welds 25% faster than the competitor solid wire/basic agglomerated flux combination used previously for similar work.

KOG Teesside also reported impressive productivity improvements in the welding of box structures, involving V-joints in 35mm thick plates (Figure 7). Compared with the solid wire/basic agglomerated flux combination used previously with metal powder addition, the number of passes was reduced from 23 to 15 (-35%) while maintaining good mechanical properties. Note that OK Tubrod 15.24S/OK Flux 10.47 is used here without metal powder addition. They also reported marked improvements in actual flux consumption as the basic cored wire contributes its own fluxing agents to the weld pool.

Both yards benefitted from not having to re-bake the flux prior to welding, which enables easy handling procedures and is very time and cost efficient. Additionally, the improved slag release and cosmetic appearance of the completed welds was highly appreciated.

Figure 6: Fabrication of beams at KOG Methil.

Figure 7: Fabrication of box structures at KOG Teesside.

To conclude

Summarising, the basic cored wire/fused flux combination OK Tubrod 15.24S/OK Flux 10.47 introduced by ESAB has been developed for low temperature applications such as offshore fabrication. Product benefits are found in easy storage and handling without re-baking of the flux, increased welding productivity, very consistent mechanical properties, and an excellent weld quality. The SAW combination has been used successfully for the fabrication of critical components on the Snorre B project.

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Neil holds a BSc in Metallurgy and Materials Science and an MSc in Welding Technology from Cranfield University. He has recently been very active in the development of cored wires for submerged arc welding.

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Tandem MAG welding with the PZ 6105 R

by Hansjörg Cerwick, ESAB GmbH, Solingen, Germany

In 1998, Kvaerner Warnow Werft dockyard in Rostock decided to make further investment into modernising production. With the support of ESAB, Germany, who assumed responsibility in particular for the MAG tandem welding process, a process in which fillet welds are welded to braces, Pemamek Oy, Finland, was able to justify itself as the main contractor for the supply of complete panel welding equipment.

Fillet portal (KWW).

The panel range for plates up to 12 m wide comprises the butt seam portal for the submerged three-wire technique, the ESAB-Hancock marking and gas cutting portal, the reinforcing pile weld portal and stiff tack welding portal, the fillet weld portal using the tandem MAG technique, the associated roller panels, transport equipment and robot welding equipment as detailed below.

The fillet portal involves HP profiles and equivalent with thicknesses of 7–15 mm and lengths of 2–12 m being welded onto the 12–25 mm-thick braces using two tandem MAG torches simultaneously. In addition, two LAF 635 rectifiers, i.e. not pulse welding equipment, and two A2/MEK wire feed units are used with each torch. Each wire electrode is individually controllable and adjustable. Parameters which are separate for each wire are selected using the PEH A6 process control unit.

The two wire electrodes are fed into the weld pool separated from each other in a gas nozzle. Free wire length and angles are adjustable within a narrow range.

Filarc PZ 6105 R cored wire with a diameter of 1.4 mm is used to achieve high speed while maintaining a high quality weld. Welds were made at a speed of 150 cm/min and achieving a throat thickness of 4 mm with a relatively spatter-free weld. The mixed gas contains 92% argon and 8% CO_2. The leading wire in the burning torch is set to approx. 450 A with the following wire at 340 A. Primer is removed as much as possible to avoid pores.

For stronger metal sheets, e.g. for the offshore industry, fillet thicknesses of 5–5.5 mm are aimed for, reaching a welding speed of approx. 120 cm/min which can definitely be optimised further.

Tandem MAG welding has proved to be a promising high-performance welding process in which relatively thin sheets can be welded at high speed while maintaining high quality. This process requires the torch to be guided over the weld with 100% accuracy and uniformity; variations in the arc length and angle setting result in errors. The growth in experience in the use of this process will ensure its introduction in other industries too.

Tandem MAG torch, right, with guide, supports and extraction arm.

Tandem MAG torch.

A high-productivity welding production line of towers for wind mills

by Per Ivarsson, ESAB Welding Equipment AB, Laxå, Sweden

The promotion of renewable “green” energy has recently been stepped up by quite a number of governments. There is no question that the genuine cost of producing wind electricity is far higher at present than that of the electricity generated by non-renewable energy sources like fossil and nuclear energy.

Needless to say, there are aspects other than the purely commercial ones when pushing for wind power; they include safety, purity and, fundamentally, renewability. At the end of 1998, wind power capacity worldwide amounted to roughly 10,000 MW, 25% of which was installed during that year. The predictions are that the growth rate will be 20% annually in 1998-2003. Consequently, this energy segment is expected to experience extremely powerful trends in the years to come.

Denmark is the leader in Europe and is expanding the segment. Capacity here is already approaching 10%, while the target is 50% wind-powered electricity consumption by 2030, including pioneering the development of offshore wind power. Danish industry is also concentrating heavily on the production of wind mills, primarily to satisfy the domestic market, but even with successful exports to countries far and near, with the focus on the United States.

Need for high-efficient welding equipment

There are two main manufacturers of complete wind mills in Denmark, NEG Micon and Vestas Wind Systems. They purchase most of what they need for the foundations, i.e. the steel towers supporting the rotor and generator, from sub-suppliers in Denmark and other countries in Europe.

Tower production by these sub-suppliers has necessitated an increase and improvement in machinery facilities and interest has focused on high-productivity welding equipment in order to reduce door-to-door times, not to mention the rigorous quality and environmental requirements.

ESAB has recently delivered quite a number of mechanised welding stations to sub-suppliers in Europe in general and in Denmark in particular.

One of the largest sub-suppliers of these towers is Sönderjyllands Maskinfabrik A/S, located at the south of the Danish peninsula of Jylland.

In the contract between this customer and ESAB Engineering, it was agreed that ESAB would plan, design, deliver, install and commission a complete welding production line to meet the customer’s demands.

Huge workpieces

A complete wind tower consists of two to three sections, giving a hub height of up to 78 m, and each section has a maximum weight of 50 tonnes, consisting of 10-15 shells with a width of 1,500-2,400 mm. The diameter of the bottom shell is 4,800 mm at its maximum and 1,700 mm at the top. Plate thickness is 12-35 mm, joint-prepared for I , Y and X joints.

Efficient production flow

From the bending machine or buffer, one shell is placed in one of the 10T roller beds to position it for internal and external longitudinal submerged arc welding carried out by the CaB 460 column and boom. While one shell is being welded in one roller bed, another shell is prepared in the other roller bed set. This procedure definitely increases the arc time factor. In addition, each shell at the end of a tower section has a mounting flange. The flanges are also welded to these shells at this station.

At the next station, a head and tail stock positioner, one sub-arc welding head for internal circumferential welding and one CaB 460 column and boom for external circumferential welding are integrated. Furthermore, there is a support roller bed and a rounding jig. The tower section is built up here until it reaches its full length. The first shell with the flange is clamped into the withdrawn tail stock, while the second shell is clamped into the head stock in the corresponding manner. The two shells are tightened by pushing the movable tail stock towards the head stock, whereupon tack welding takes place. The ESAB A2 welding head carried by the support arm performs the internal welding and, finally, the external circumferential welding is performed by the A6 head of the CaB 460 station. Step by step, the tower grows, as shell by shell is added, until the last shell with its flange completes the tower section. In order to maintain the roundness of the gradually extended tower, a rounding jig adapts the tower ends, using hydraulically operated pressure arms with rollers, in order to make them fit the shells that are added.

Specification for complete production line

Station 1

One movable CaB 460 ArcCenter 6x3 column and boom is used for external and internal longitudinal submerged arc welding and for the circumferential welding of flange to shell. The vertical column is connected to the boom in a saddle using guide rollers to provide maximum load-bearing capacity with ample safety margins for reliable operation. The lift drive has a reliable safety factor and is equipped with a security device which, regardless of boom position, immediately locks the boom to prevent it travelling downwards in the event of a breakdown. The horizontal boom can be positioned in both the vertical and horizontal direction. The rack and pinion drive secures an even, stable welding speed. The control system has been designed with totally integrated functions; welding head manipulation and operation of the column and boom — all handled from a remote control.

The A6S ArcMaster SAW welding head is used for the productive twin-wire process, incorporating the microprocessor controller. There are two 100-kg wire reels at the rear of the boom. An electro-mechanical sensor with photo transistors ensures accurate joint tracking in the V joints — exact corrections are made by the motorised ball-bearing slides.

Furthermore, a colour TV-monitoring system including a distinct hair-cross generator deals with the I-joints. There is an operator's platform at the foot of the column for control and supervision. The improvement in continuity and savings in material costs that result from a rational flux handling system make it a wise investment. At the same time as flux consumption is reduced, the workplace is kept clean and free from flux spillage. This flux feed and recovery system is powerful, 3 kW, and reliable, to correspond with the requirements in every respect.

Last but not least, the welding rectifier with its very high capacity and properties designed for twin-wire welding — LAF 1250 ArcPower — complies with the customer's requirements in every way.

There are two self-aligning roller bed sets of the 10 T size, each consisting of an idler and a powered unit to operate in conjunction with the CaB welding station.

Taken as a whole, this is an advanced piece of equipment for high productivity and consistent weld quality.

Station 2

It comprises one movable CaB 460 Arc Center column and boom, identical to station 1, which is used for external circumferential submerged arc welding.

There is one head and tailstock positioner of the 20000 HTLM type, with motorised rotation and hydraulic height adjustment of the centre height. The head stock has an hydraulic stroke and the tailstock can be moved on rails using a motor. The maximum weight of the section is 50 tonnes, 25 tonnes a side. The unit features an hydraulic clamping cross-unit for workpiece clamping with outer diameters of 1,020-5,060 mm.

This is an outstanding handling tool, designed for applications requiring purposeful solutions.

There is one A2S Minimaster SAW welding head for the internal circumferential, single-wire process welding mounted on the movable support arm supplied with the head stock. There are motorised telescopic slides for sufficient accessibility. Accurate electro-mechanical joint tracking is also featured, together with a powerful flux feed and recovery system and a colour TV-monitoring system. The operator's platform is connected to the head stock. The system also includes an LAF 800 ArcPower welding rectifier. This mechanised constellation eliminates the need for an automatic tractor with another operator to work inside the workpiece — a major advantage in terms of productivity and the environment.

In addition, there is one idling support roller bed of 60 TNE type equipped with an hydraulic height adjustment system. The roller bed is assembled on motorised rail bogies of the 60 RBVS type. Maximum capacity is 30 tonnes.

Finally, there is one rounding jig with seven hydraulically-adjustable roller pairs to compensate for the ovality of the workpiece. It can be adjusted to suit different plate thicknesses. There is also a rail bogie with motorised movement to obtain proper access to the workpiece.

This is an indispensable piece of equipment, which fundamentally reduces the time that is used for handling in the workshop to a minimum.

New production line

Sönderjyllands Maskinfabrik A/S has now decided to invest in another production line and ESAB has once again been favoured to continue the excellent partnership by delivering this new line.

About the author

Per Ivarson joined ESAB in 1983. Since 1994, he has been with ESAB Engineering in Laxå as area sales manager for applied automation solutions with the emphasis on European markets.

Figure 1.

Advanced process control could be the difference between successful and unsuccessful welding results

by Billy Höög, ESAB Welding Equipment AB, Laxå, Sweden

A successful weld is dependent on a number of different factors, such as the types of material that are going to be joined, the filler metals, the design of the workplace and the ability the welding equipment has to control the process. ESAB's contribution to a successful welding result is the new PEH Process Controller.

Figure 2. PEH control unit.

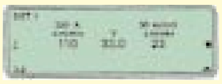
Main menu
Example of a display image if welding with a constant welding current (CA) is selected

A
35 — Selected welding current in amperes

Example of a display image if welding with a constant wire-feed speed (CW) is selected

cm/min
110 — Shows the selected wire-feed speed

Display image when welding with a constant wire-feed speed (CW) is in progress



35 A — The resulting welding current after the start of welding

For selections of (CA) or (CW), please consult the "ADVANCE SETTINGS WELDING" menu

SET 1	Shows that parameter set 1 of a possible 10 has been selected
30 kJ/cm	Specifies the heat input that is obtained with the selected values for welding current, arc voltage and pass speed
V 33.0	The selected arc voltage in volts
cm/min 23	The selected pass speed
	Specifies the type of start (selected in the advance welding settings)
	Specifies the direction of movement selected in the advance welding settings)
	Specifies whether the valve outlet is open or closed. In this case, it is open
3.0	Wire diameter (selected in the advance welding settings)

Figure 3.

The PEH unit is designed for use with ESAB's A2 and A6 automatic welding systems for SAW or MIG/MAG applications.The control unit is used in conjunction with the LAF (DC) and TAF (AC) power sources.

Integration of the control system in the power source guarantees precise process reliability, all functions required to control the welding process are included in the control panel.

Welding power sources – part of PEH

The welding power sources have been specially adapted to work together with the process controller. They are linked by a "two-wire bus", which makes it possible to regulate and control the welding process with far more precision than was previously feasible. The power source output can be adjusted directly from the control panel on the PEH.

ESAB's previous generation of welding power sources, such as the LAH, LAE and TAE, can be adapted for use with the new control unit using a conversion kit. New power sources are already prepared for the extremely straightforward connection to the PEH Process Controller, and provide the 42 V required for their operation.

User-friendly

The PEH is easy to use after a minimum of training. With a selection of 12 different languages, the system is monitored continuously and deviations from the set welding data are indicated on the display as error messages. When the power source is turned on, it is identified automatically by the control system and no manual re-adjustment is needed if it is changed. One of the main benefits of the control system is that the same PEH Process Controller can be used for different welding processes and different filler wire types. The characteristics of the power source are optimised for the selected process and wire type to be used. See Figure 2.

Manual or automatic operation

The PEH Process Controller can have welding parameters set manually or recalled from memory.
If manual operation is selected, wire feed and movements are controlled manually and the welding parameters and other welding settings that are needed for the weld in question are pre-set manually.

When welding in the automatic mode, a pre-set group of welding parameters can be selected and the relevant welding parameters can be precision adjusted. There are a total of ten different sets of parameters, for a given process and wire combination.

The control unit is ready for manual operation the moment the unit is switched on. When welding begins, automatic operation takes over. If the welding stops or an error occurs, the system returns to manual operation.

Menus

The PEH software has a number of menus, including the main, pre-setting display and error list menus and the system configuration.

Advance welding settings

	A	B	C
1	Direction	▲ triangle ■ square	
2	Start	Direct Scratch	
3	Welding stop	Crater filling (ms) Burnback time (ms)	10-3,000 10-3,000
4	Wire data	Wire type Wire diameter if "Solid" has been selected if "Flux-cored" has been selected if "Strip" has been selected Wire material Number of wires	Solid, Flux-cored, Strip 0.8 1.01.2 1.6 2.0 2.4 3.0 3.2 4.0 5.0 6.0 0.8 1.01.2 1.6 2.0 2.4 3.0 3.2 4.0 30 x 0.5 60 x 0.5 100 x 0.5 Fe, Al, SS 1, 2
5	Control	CA, CW	

Figure 4.

Main menu

In the main menu, the welding current, arc voltage and travel speed (if applicable) parameters are set. During the actual welding process, the operator can see the selected welding parameters and has the possibility to adjust them or select new and complete sets.

This menu also contains information about, and can display, heat input per cm, which of the ten possible pre-set parameter sets is in use and the parameter selected. If it has been decided under the pre-setting menu that the welding is to be performed at a constant wire-feed speed, both the value for the welding current and the wire-feed speed are shown during welding. See Figure 3.

Pre-setting menu

Under the pre-setting menu, it is possible to select the starting method, the welding direction, start and stop conditions, wire data such as the diameter, material and number of wires, as well as the type of control; constant current (CA) or constant wire-feed speed (CW). See Figure 4.

Different applications

The different setting menus which have restricted access are blocked using a password. These menus are used for example to set the desired user language, to decide whether the displayed value is to be metric or imperial and to select the configuration of the PEH for different types of welding equipment from ESAB.

The equipment suitable for use with the PEH control box includes A2/A6 welding tractors and welding heads, automatic system welders and columns and booms with the associated handling equipment such as roller beds and positioners. See Figures 1 and 5.

Figure 5. ESAB A2 welding tractor.

About the author

Billy Höög, European Welding Engineer, joined ESAB in 1976 and worked on the development of automation welding machines until 1982.

He then moved to the marketing department for Standard Automation where he was involved with mechanised TIG and submerged arc welding. Since 1999, he has been working at ESAB Welding Equipment AB, Automation & Engineering, as product manager for Standard Products.

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