Svetsaren

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Contents Vol. 57 No. 1 2002

Tank construction in Saudi Arabia

by Howard J. Hatt, Sen. M. Weld. I

Building tank farms with automated welding processes is certainly not new or innovative, but it was to the fabricator involved in the contract discussed in this article. The logistics of process change, productivity, fabrication techniques and distortion control are discussed, as well as the influence of the extreme climatic conditions.

Figure 1. A general view of the site during the early stages of construction which adequately shows the size of the tanks and the number of welded joints involved.

Background

The contractor, Al-Khadari Heavy Industries (KHI), based in Dammam, is active in a variety of multi-million-dollar activities which are fairly diverse and include highway construction and street cleaning, as well as steel fabrication. The company is owned and managed by the Al Khadari brothers and was founded during the early 1950s by their late father. It has grown progressively ever since and entered the steel fabrication industry in 1985 with the erection of the main fabrication complex, also in Dammam. This division is managed by Mr Ali Al-Khadari, an energetic US-educated engineer, who is dedicated to improving the scope and technical ability of the company. The company was recently audited by Aramco (Arabian American Oil Co), which demands very high standards from its suppliers and their employees, but ultimate accreditation will provide access to a massive new market.

Tank contract

KHI has built small tanks on site previously, although nothing on the scale of the current contract, which involves the construction of four tanks 90 metres in diameter and 20 metres in height. The contract was awarded by the Royal Commission and this organisation is responsible for the provision and construction of all the civil amenities within the eastern province of the kingdom. The steel construction projects are managed within the commission by the consultants Bechtel, who also act as the QA authority for the client at the site.

The tanks are for the drinking water authority and are being built to expand the capacity of an existing facility adjacent to the site, which is located in the industrial city of Jubail. Desalinated water from the Gulf is treated, stored and pumped by this facility to the capital Riyadh, which has minimal natural water resources.

Western or S-E Asian contractors are no longer able to compete with local companies for this type of work, so, in this case, TTN of Japan supplied the designs and all the steelwork. The roof supports, floor plates and shell plates arrive virtually in kit form, having been cut to size and, where appropriate, pre-rolled with machined weld preparations, all to a high standard of accuracy.

To date, KHI's experience of tank building has focused on MMA stick electrodes, a process which is still predominant in the Middle East. As with most contracts of this size, completion dates have to be complied with and the imposition of penal clauses adds to the incentive. There is insufficient labour with the required skills available locally, so personnel are recruited from agencies, usually in India, Pakistan and the Philippines. So the use of MMA on a contract of this kind would be extremely labour intensive with low

Figure 2. An A2 Circotech machine welding the horizontal joint between the second and third courses.

productivity and aggravated by a higher incidence of defects, especially in site conditions with welders of varying capability.

In this situation, KHI had to review the options for the introduction of higher productivity processes.

Procurement

Ultimately, it was decided that investment in fully automatic welding equipment to weld all the joints on each tank was not justified, especially if the machines were under- utilised after completion

ESAB was chosen as the manufacturer from whom to seek advice due to the vast product range and experience available. The local ESAB agent Medco carries large stocks of consumables and spare parts and has knowledgeable aftersales personnel and service engineers. In addition, this is backed up by ESAB Middle East in Dubai. No other welding house in the region could offer such comprehensive support.

The submerged arc process was selected for all the tank floors and circumferential joints on the shells and this was provided by the ESAB A2 Minitrac deck welders and the ESAB A2 Circotech single-sided girth welders with ESAB LAF1000 DC power sources.

The use of fully automatic MIG/MAG with gas-shielded, flux-cored wire was the preferred option for the vertical joints to be provided by the ESAB Railtrac FWR1000 machine, together with the ESAB LAW400 power sources and MEK4 wire feeders. This package was considered to be more cost effective than the more productive electrogas process, as the equipment is more versatile and infinitely portable, allowing it to be adapted for a wide range of alternative applications. The Railtrac FW1000 machine is driven by the 40V auxiliary power supply from a MIG power source and an electronic interface permits the remote control of welding parameters. The equipment is capable of welding in the vertical, horizontal and overhead positions and has a pre-programmable memory which simplifies on-site operation. It can also be used for cutting when fitted with a suitable burning torch. MMA would still be extensively employed on joints unsuited to automation and as a back-up where necessary to maintain the production schedule.

Welding consumables

The consumables for all the welding processes were selected from the ESAB range as follows:

Process	Consumable	AWS
MMA	OK 46.00	E6013
	OK 48.00	E7018
FCAW	OK Tubrod 15.14A	E71T1
SAW	OK 12.32 / OK Flux 10.71	EH12K

MMA

The use of an E7018 MMA electrode was specified for the shell because basic low-hydrogen types produce high purity weld metal with more dependable mechanical properties than rutile types. The only disadvantage is the higher degree of welder skills required and the storage of these electrodes in site conditions is more critical. In view of the latter and the high humidity, especially in July/August, all the OK 48.00 was supplied in Vacpacs.

FCAW

When high productivity is required for large volumes of vertical-up welding, the most cost-effective consumable is the rutile E71T1 flux-cored wire. It will only operate in the spray transfer mode, which ensures high deposition rates and produces a rapidly freezing slag to maintain good control of the molten weld metal and produce a flat profile. OK Tubrod 15.14A has exceptional running characteristics and produces minimal spatter with CO_2

Figure 3. Vertically welded joint showing the flat and smooth profile produced by the Railtrac machine and OK Tubrod 15.14A. The minimal spatter also simplifies preparation for painting.

shielding gas, which is commercially beneficial, as Ar-rich gases are very expensive in the region.

SAW

OK12.32 is a copper-coated solid wire which, when used in combination with OK Flux 10.71, produces a nominal all-weld metal UTS of 550 N/mm^2. The flux is a basic agglomerated slightly alloying silicon and manganese type with a basicity index of 1.6, which is lower than the fully basic OK Flux 10.62, which has a basicity index of 3.4. OK Flux 10.71 therefore allows for greater flexibility with regard to the scope of applications and combines excellent weldability, weld appearance and slag release.

Figure 4. Capping passes of horizontal joint welded by 2 Circotech with OK 12.32 and OK Flux 10.71. The excellent weld appearance and blending of the three passes is readily apparent.

Welding procedures

All the welding procedures had to be pre-qualified in accordance with ASME IX and the tank design code, which was API 650. The butt joint procedures were all carried out on 22 mm plate, which then qualified them for use on the minimum thickness of 10.5 mm up to the maximum of 32.5 mm. Other procedures involved fillet and lap joints.

Flexibility was required for the vertical joints, so procedures were submitted using both MMA and flux-cored wire. The root pass, however, was to be carried out with MMA in all cases, due to the joints being designed with open gaps to allow full penetration from one side.

None of the procedures required full mechanical testing. This was not considered necessary, as the tanks were to be built with ASTM A36 and ASTM A283 low to medium tensile steels and were for the storage of water at relatively high ambient temperatures.

The acceptance criteria were therefore based on visual and radiographic examination, which also applied to the welder qualification tests.

Productivity

All the shell plates are 14.5 metres long and 2.5 metres wide. With a tank circumference of 282 metres, 20 plates are required per course, which means that 50 metres of vertical welding have to be completed on each. These joints are subjected to the lowest productivity the welding position, so a productivity comparison will be made between MMA and FCAW on a 15 mm single V joint.

Productivity comparison

Deposition rates				
MMA	OK 48.00	2.5 mm@ 90 Amps	=	0.8 kg/hr
	OK 48.00	3.0 mm@ 120 Amps	=	1.3 kg/hr
FCAW	OK 15.14 A	1.2 mm@ 190 Amps	=	2.8 kg/hr
Theoretical joint volume		@ 180 cm/3	=	1.41 kg/m
Weight of root pass			=	0.20 kg/m
Weight of fill and cap			=	1.21 kg/m
(Note: Joint volume includes 3 mm reinforcement.)				
Arc times		MMA		FCAW
	Root pass	15 min/m		15 min/m (mma)
	Fill and cap	56 min/m		26 min/m
Total arc time		71 min/m		41 min/m
Actual time				
	@30% duty cycle	234 min/m@50% Duty Cycle		82 min/m
		or 3 hr 54 min		or 1hr 22mins
Actual time per joint @ 2.5 m = 9 hr 45 min			=	3 hr 24 min
Total saving by FCAW			=	6 hr 20 min/per joint

Tank construction

Figure 5. A view of the annular plate segments on wich the shell is erected. The fully welded floor can also be seen, but is not welded to the annular plate at this stage.

Annular ring

As with many similar construction projects, the initial activity involves putting in the concrete foundations. The depth is specified in API 650 and will depend on the dimensions and weight of the tank when full and on the type of ground, i.e rock, clay, soil or, in this case, sand.

Steelwork commences with the laying and welding of the steel segments that form the annular plate which runs around the outside circumference of the concrete base. It is on this plate that the tank shell is built, but it is not welded to it until the third course is erected and the shell has been dimensionally checked for the accuracy of the circumference. Should any distortion have occurred during the welding of the first two courses, the shell is still floating or free to move. In this way, any correction is more easily accomplished.

The annular plate is 14.2 mm thick and the section inside the shell ultimately becomes an integral part of the tank floor, which is only 9 mm.This ensures greater structural integrity where it is needed, as the bottom course of the shell is 32.5 mm thick. The tank floor itself, however, is only under a compressive load from the tank contents as well as the roof and its supports, hence the reduced plate thickness.

Floor area

This is where welding commences in large volumes and the tanks in question require a large quantity of plates measuring 9 metres by 2.5 metres to complete the floor area. In all, the weld lengths run into hundreds of metres, which is why SAW was selected as the most productive and cost-effective alternative to MMA.

As previously mentioned, the floor is only subjected to compressive loads and so through- thickness butt joints are not required. All the joints are of the lap type, which are more than adequate for the service conditions and require no expensive weld preparations. A method of this kind also simplifies production enormously as it allows greater tolerances with regard to fit-up. In fact, as is the case with the majority of tank construction, great reliance is placed on “dogs & wedges” for the positioning of plates, as they are inexpensive to produce and can be re-used.

It is essential that welding of the tank floor is completed in a strict sequence from the middle outwards and even then every third longitudinal seam is left unwelded until completion of the others. This is to avoid distortion, which can be exaggerated by the ambient temperatures that can exceed 45°C in July and 50°C in August. As an experiment, a check was made on the degree of expansion by placing a chalk mark at the junction of the annular plate and the tank floor, before the two had been welded. This was done at 1 pm when the ambient temperature was 45°C and the plate temperature was 80°C. At 6 pm, a second line was made at the same junction when the ambient temperature had gone down but only by 10°C. The result was a gap of 30 mm between the two marks, making a total of 60 mm on the diameter, so the effect of even greater temperature gradients can be readily appreciated. It is for this reason that the welding of the annular ring to the floor is carried out when the ambient temperature is at its highest and after the bottom shell plate has been welded to the annular plate.

Should a large repair or the replacement of a complete floor plate be necessary for any reason, the result would be catastrophic. The affected area would dome up and recovery might involve the renewal of the entire floor.

Shell fabrication

The tank wall sections are 2.5 m high, requiring eight courses to complete the overall design height of 20 m. Internal pressure from the tank contents is progressively reduced upwards as is the weight of the shell. The bottom course in this case is therefore thickest at 32.5

Figure 6. A two-pass lap joint as applied to all floor joints and welded with OK Autrod 12.32 and OK Flux 10.71.

mm and each successive course in made from thinner plate because it carries less weight than the previous one until the top, which is only 10 mm.

The control of distortion is also vital during shell fabrication. With this in mind, all the lower and thicker plate courses have a double"V" weld preparation, thereby reducing the amount of weld metal to fill the joint and permitting a balanced welding technique to control the distortion. All the courses with 15 mm plate and below have single "V" preparations, as it is impractical to use double "V". In all cases, the included preparation angle is 45 degrees, serving to reduce weld metal and the risk of distortion still further.

Erection commences with the first two courses being tacked in position on the circumference and the vertical seams were clamped with dogs and wedges so as not to disturb the open gap.

All the root passes were welded using 2.5 mm OK 48.00 and filling and capping were completed with either 3.0 mm OK 48.00 or with the Railtrac FWR1000 and OK Tubrod 15.14A 1.2 mm. It would have been most beneficial to use automated FCAW on all the vertical joints, but a plate shipment delay put the project behind schedule, necessitating the use of MMA in order to rectify the situation. In all cases, however, FCAW was used on the outside seams due to the vastly superior weld appearance achievable with automatic oscillation.

Initially, the capping passes were split weaved, because ASME rules dictate that maximum weaving should be three times the diameter of the electrode. This had also resulted in complaints from the client in respect to the valley between the capping passes or excessive reinforcement, especially with regard to the subsequent painting. These complaints were principally directed at the MMA – since OK48.00 is an E7018 type, the welders had difficulty keeping the split beads flat due to the restricted weave width.

At this point, KHI did not have a welding engineer to assist them with the inevitable teething troubles associated with such an abrupt change of welding processes or to interpret the codes of welding practice. It was at this point that the author came into the picture and the first change was to adopt full-width weaving of the caps, to the complete satisfaction of the client.

So often an ESAB client has rejected a recommendation because of a particular rule, but in the majority of cases a clause will eventually appear to the effect "unless agreed by the client", which enables such a change to be made.

The use of MMA on the inside and FCAW on the outside, however, was not without its problems, especially if a repair or two was required to the inside. The higher heat input from the MMA, plus any arc air gouging followed by more welding, could cause the joint to bow out, putting that section too far out of line with the course above, and this did actually occur on one occasion. A problem of this kind contravenes the design code dimensionally and causes considerable difficulty welding the circumferential seam above it, so remedial action was essential, but how? You learn something every day and the experience of the KHI personnel solved the problem by removing the outside weld and re-welding. The joint was pulled back into line and was a classic case of distortion being used to advantage for a change.

Figure 7. Guy ropes attached to the strong backs which serve to reduce distortion, especially where MMA welding.

The next stage was to weld all the vertical joints on the second course, still employing MMA on the inside and FCAW on the outside, but additional precautions were taken to avoid a repeat of the above problem. By attaching hand-winched steel guy ropes to the strong-backs welded to the inside joints during the MMA welding, excessive distortion was prevented. Defects with the automated OK Tubrod 15.14 A were extremely rare.

Welding of the first circumferential joint with the ESAB A2 Circotech machines could now proceed. The operators had received training in Dammam and the welding procedures were pre-qualified; no problem. Experience has demonstrated that this, however, is rarely the case, as welding in production brings difficulties that have not been foreseen. Since the tanks are 282 m in circumference, it would take one machine eight hours to complete one pass or four hours for two at average welding speed. Anything that could be done to reduce the number of passes would therefore be a bonus and management pressed to achieve this.

The outside preparation in the 32.5 mm plate was estimated at five passes but was completed in four by using the maximum amperage permitted by the PQR. Weld deposit dimensions were controlled by welding speed, welding head angle and to a lesser degree the voltage, which was kept as low as practicable. This is especially important on the root pass to maximise penetration into the 3 mm root face and reduce the depth of back gouging on the inside. On subsequent filling passes, voltage control is vital to maintain each pass in the desired position and prevent cold lapping and the attendant risk of fusion-related defects.

The design code permits a maximum of 5 mm misalignment in the straightness of the shell sides. A point is measured at one metre each side of the joint and a two-metre long straight edge placed between the two reference points. Any gap between the straight edge and the shell at the weld junction must be less than 5 mm. Following back gouging of the inside, more weld metal would be required to fill that side with the risk of distortion. With this in mind, the last capping pass was omitted from the outside until after the inside was completed. This was a precaution worth taking, as the small amount of distortion that did occur was rectified by the last capping pass on the outside.

The welding performance of a submerged are machine will only be as good as the preparation that is presented to it. Welding the root pass on the outside produced an excellent weld appearance and self-releasing slag, but the converse applied on the inside, following back gouging and grinding, due to the irregularities produced. This is aggravated by the fact that welding is in the HV position with no assistance from gravity, so gouging must be kept to the minimum required and must be as uniform as possible.

The incidence of defects with the SAW A2 Circotech machine is also extremely rare and, when they do occur, they are usually attributed to human error in the setting of welding parameters or a malfunction. With the judicial setting of all welding variables, including head angles, a truly excellent surface appearance and flat profile can be achieved, regardless of the number of overlapping passes. This is especially true when such a versatile flux as OK Flux 10.71 is employed.

Roof

Apart from the ancillary pipework and so on, the roof is the last major welded fabrication to be completed. This again involves the welding in situ of a considerable number of 4.5 mm thick plates, all with lap joints, but these are welded on both sides. The roof slopes up to the centre at an angle of 10 degrees and is supported by a systematic arrangement of RSJs, which are in turn bolted to the tubular columns.

The ambient temperature gradients on such a large area and the degree of thermal expansion that can be experienced dictate that the roof is not welded to the shell. An angle ring is welded to the outside edge of the roof and this fits over the tank shell like a lid on a tin, but with sufficient space to permit maximum contraction.

Considering the thickness of the plates at only 4.5 mm, a welding process which allows for rapid welding speed and a small weld cross-section is preferred. A seal against the weather and airborne sand is the main objective, as opposed to maximum structural strength. A small weld deposit produced at high speed would also serve to reduce distortion.

Figure 8. The roof support bases clearly showing the stainless rubbing plates. Corner fences will ultimately be welded to the tank floor to restrict movement to within restricted limits.

Realistically, only MMA and solid wire MIG/MAG using dip transfer could be considered using the semi-vertical-down technique. Ultimately, MMA was chosen for portability and ease of use, especially as welding on the inside of the tank is in the overhead position. The electrode selected was OK46.00 3.0 mm, which is an E6013 type and is capable of vertical-down and touch welding, combined with easy arc striking.

The bases of the tubular roof support columns are of interest as they are also free to move to a certain extent. A 316L stainless steel plate is welded to the bottom of each column and this rests on a slightly larger rubbing plate, which is welded to the tank floor. Stainless steel angle fences are welded to the rubbing plate to restrict movement to only that required to accommodate roof expansion and contraction. These components have to be made of stainless steel because, if they were painted, the rubbing would remove the paint and corrosion would set in.

Alternative equipment and processes

ESAB can supply welding equipment and processes that are capable of higher productivity, assuming the quantity of tanks to be built and the additional investment is justified.

SAW

The ESAB A2 Circotech machine can be supplied as a two-sided machine for single- or twin-wire operation, which allows the inside and outside circumferential seams to be welded simultaneously. The first welding head precedes the other by about 50 mm, so that the second operator can judge the penetration produced by the lead head by observing the heat spot, i.e. dull red would be insufficient while yellow would probably be enough. The preheating effect also aids penetration from the trailing head.

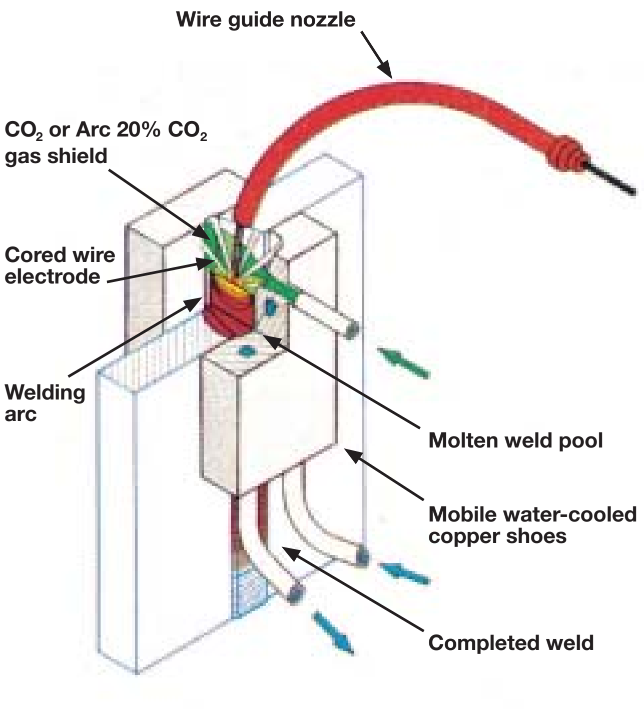

Figure 9. Schematic view of the electrogas process.

The offset between the two heads also allows any gas produced by the lead head from the welding process to escape easily. If the two heads were adjacent to each other, the gas could be trapped between the two weld pools, resulting in surface or underbead porosity.

The principal benefit, however, is in productivity, as labour-intensive and time-consuming back gouging is totally eliminated.

Electrogas welding

The ESAB Vertotech electrogas welding machine permits the welding of all vertical joints in one pass up to a plate thickness of 35 mm. The process is similar to continuous casting as the weld is produced between two water-cooled copper shoes, which progress up the joint with the molten weld pool to hold it in place until it has solidified. Oxidation of the weld pool is prevented by the Argon-rich or CO^2 shielding gas and the weld metal is provided by specially developed flux-cored wires.

When the plate thickness exceeds 20 mm, oscillation is required to ensure full side-wall fusion and the machine has a motorised slide for this purpose. Contol of weaving amplitude, speed and dwell times can all be pre-set before welding commences.

Deposition rates exceeding 12 kg/hr are possible, so that travel speeds can be measured in metres per hour. The 15 mm butt joint in the productivity example could be completed in 25 minutes, at only 450 amps.

Summary

Tank contracts of this size are not awarded frequently. Fabricating companies with the experience and equipment may therefore face long periods of inactivity, unless, like KHI, they are involved in other more general fabrication activities. The initial investment strategy of maximising productivity for the smallest capital expenditure while maintaining flexibility for the future was certainly vindicated. It is only the A2 Circotec machines that are restricted as far as alternative applications are concerned in comparison with the A2 Minitrac, Railtrac and the LAW 520 W semi-automatic MIG/MAG machines, which are completely flexible. In addition, there is the dramatic increase in productivity, together with the minimal incidence of defects and subsequent repairs. In combination with the reduced manpower and individual skills required, this has ensured a full return on the investment within the life of the contract.

Acknowledgements

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About the author

Howard J. Hatt, Senior M. Weld. I was in the welding industry for 40 years, initially with Murex, then BOC and ultimately the Esab Group in the UK.

Since 1973 he held sales and technical management positions both in the UK and export markets, but moved into marketing on joining The Esab Group in 1984. Until he took early retirement in 1999 Howard Hatt was involved in market development for cored wires and technical support to the group companies.

He now spends his free time gardening as well as building and flying radiocontrolled scale model aircraft, although is still available to ESAB when required.

South Korea is today's leading shipbuilding nation

The rise of South Korea's shipbuilding industry has been one of the most spectacular industrial phenomena of the past 30 years in global terms. This growth has taken South Korea to the top of the world's shipbuilding league. Its shipbuilders currently have 43% of new ship capacity on order.

Korean shipyards have primarily focused on building bulk carriers, tankers and containerships, but they have recently shown that they can also build complex vessels such as gas carriers, offshore rigs and FPSOs (Floating Production, Storage and Offloading).

By concentrating on qualified technological know-how and with their highly trained engineers, Korean shipyards are today able to comply with and built to almost any ship owner's design requirements.

DAEWOO shipyard with ESAB SeAH Corporation

Located in Okpo Bay on the island of Goje, off the south-eastern Korean peninsula, Daewoo Shipbuilding & Marine Engineering (DSME) had built 180 oil tankers by September 2001, including 70 VLCCs since 1988, which corresponds to about 13% of the world's VLCCs.

Since the company was established in 1978, it has delivered more than 400 commercial vessels, covering a wide variety of types and designs. Using state-ofñthe-art production facilities, DAEWOO is regarded as one of the most efficient and competitive producers of ultra large vessels such as VLCCs, ULCCs and a number of 320,000 dwt Very Large Ore Carriers (VLOC). DAEWOO also has the capability to construct high-tech vessels such as LNG and LPG carriers, FPSOs and deep-sea drilling rigs.

DAEWOO operates the world's largest dry dock measuring 530 x 131 x 14.5 m and equipped with a 900t lifting capacity gantry crane, which is registered in the Guinness Book of Records. This dock, together with a smaller 300,000 dwt dry dock measuring 350 x 81 x 14.5 m and three floating docks, enables the yard to build about 40 vessels a year, plus 10 warships, submarines and a number of onshore and offshore platforms and structures.

The current order book contains around 120 vessels, including 14 large LNG carriers. This will keep the yard fully occupied well into 2004.

ESAB SeAH Corporation (ESC) was set up in 1985 as a joint venture by The ESAB Group and SeAH Steel and it manufactures flux-cored wire, and stainless steel electrodes, in Changwon, where it is very close to the major shipbuilders such as DAEWOO, SAMSUNG and HYUNDAI.

DAEWOO has developed an automatic welding robot, Danny, which is more compact and easy to manoeuvre than conventional robots and provides greater accuracy of operation. Since 1996, when DAEWOO installed the first welding robot, some 14 units have been installed on the large block assembly line. ESAB (ESC) supplies Core Weld Ultra 1.6mm for the Danny. This new welding robot for shipbuilding is a promising substitute for workers who often have to endure harsh and dangerous working conditions.

Application information for Core Weld 111RB & 111 Ultra

Thanks to the higher productivity of cored wires in fillet joint welding, the consumption of flux-cored wire (FCW) is much larger compared to other welding consumables. The following table shows one example at SAMSUNG S/Y where the percentage of FCW welding is around 94%.

Consumable		Per cent (%)
FCAW	Welder	71.6
	mechanised	10.3
	robot	3.7
GMAW		0.1
SAW		11
SMAW		1.2
Gravity		1.8
EGW		0.3

Table 1. Record of welding consumables used at the Samsung Shipyard between July and September 2001.

As can be seen in Table 2, fillet welds, mostly in Zinc primed plate, account for around 90% of welding in shipbuilding. The shipyard has devoted great attention and effort towards mechanisation in order to save time and to reduce the risk of inhaling the fumes generated by welding over Zn primer-coated plate. Fig 1-3 show the

Ship grade	Weld length – km (%)		
	Fillet	Butt	Total
VLCC (single)	588 (88)	81 (12)	669
PAX. BC (73K)	220 (90)	24 (10)	244
97K COT	303 (88)	40 (12)	343
64K CONT'	396 (91)	42 (9)	438

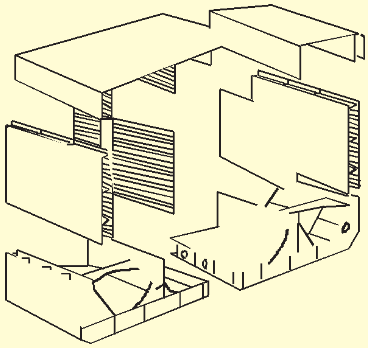


Table 2. Weld length of fillet and butt joints in shipbuilding.

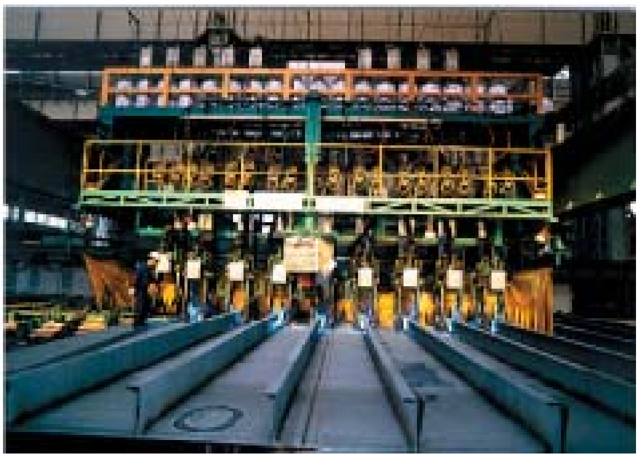


Figure 1. Mechanised system at shipyard (left: gantry type – single torch, right: TAMA type – twin tandem with 24 torches).

most famous mechanised system for fillet welding and ESAB (ESC) is supplying DAEWOO with CW111RB for the 2Y steel grade and CW111 Ultra for the 3Y steel grade

Supply is in 300 kg Marathon Pac bulk package, 1.4 mm and 1.6 mm diameter

Figure 2. Bead shape of C/W 111 Ultra.

Figure 3. Micro and penetration figure of C/W 111Ultra.

What's next?

The nation's yards are now focusing increasingly on complex vessels such as gas carriers, offshore rigs and FPSOs. The first domestically-produced LNG carrier was delivered in June 1994, while, more recently, a number of passenger ferries have been launched, so ship owners all over the world have come to regard Korea as being synonymous with high-quality ships at reasonable prices (see table 4).

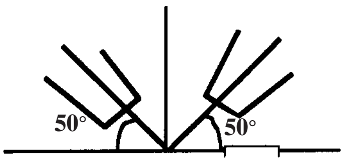
The growth potential of the Korean shipbuilding industry is largely due to much-improved productivity and efficiency, driven by increasing labour costs in Korea and by the growing presence of China in the shipbuilding market.

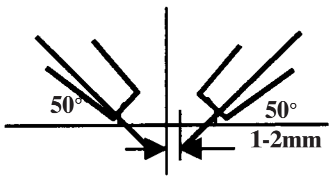
The work force currently has an average age of 39 years, much younger than its Japanese counterpart. While Japan is experiencing difficulties in recruiting skilled staff to the shipyards, Korea does not currently have these problems. Nevertheless, South Korean shipyards are currently increasing their R&D efforts to improve efficiency and productivity to avoid weakening of their competitive strength in the future.

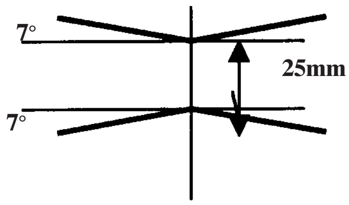
Unique welding equipment

1. Welding equipment: TAMA, company from Japan
2. Welding process: TOP (twin tandem one pool) method
3. Number of poles: Six poles (24 torches)
4. Welding condition See below
5. Welding materials FCW – Core Weld 111 Ultra

Leg length (mm)	Torch	Welding condition A	Welding condition V	Travel speed (Cm/min)	Stick-out (mm)	Angle (°)	Length between L & T (mm)	Angle adjustment
5 ~ 6	L	430	36	*5 mm leg length: 130	25	50	25	Forwards &
	T	350	34	*6 mm leg length: 110–120				backwards: 7°
8	L	420	35	80				
	T	340	34					







1. Project name: SHELL BRUTUS TLP
2. Applied welding consumable: D/S 81-K2
3. Wire consumption: 380 tonnes (Jan-Aug 2002)
4. Requirements: CTOD (ASTM E1290): min 0.25 ab 0° (H.I=1.4kJ/cm)

*TLP; Tension Leg Platform, *FPSO; Floating Production, Storage and Offloading, *CTOD; Crack Tip Opening Displacement

Table 3. Welding parameters

What does the future hold?

Since 1999, South Korea has held the top position in the world's shipbuilding league, ahead of Japan. How long will this situation continue? This will depend on a number of factors, such as the state of the world economy, the strength of the Korean won and the technological development within related industries. However, on its current form, Korea will prove hard to beat!

Korean shipbuilders are looking to transform quantitative growth into qualitative growth by focusing on securing a larger percentage of orders for high value-added ships, thereby acheiving higher profit margins.

Shipyards	Project	Amount ordered Vessel	Amount ordered G/T	Amount left Vessel	Amount left G/T	Amount dried Vessel	Amount dried G/T	Steel consumed MT/Y
HYUNDAI	LPG Rig LNG (Moss)	22	1.35M	113	8.47M	42	2.85M	1.05M
DAEWOO	VLCC F/C (big) LNG (membrane.)	38	3.34M	91	7.75M	35	2.86M	0.70M
SAMSUNG	FSO F/C (big) LNG (membrane.)	25	2.19M	89	7.08M	30	1.70M	0.65M
HYUNDAI MIPO	BULK F/C	32	0.84M	68	1.72M	14	0.30M	0.12M
SAMHO	BULK F/C LPG	16	0.95M	46	3.70M	22	1.07M	0.20M
TOTAL		165	9.68M	494	31.27M	169	956M	

Table 4. Market analysis of shipbuilding (as of September 2001).

Welding components for the petrochemical industry at Sirz Montaggi srl

by Bo Magnusson, ESAB AB, Sweden

The increasing use of products derived from the hydrocarbons referred to as oil and gas means that the industry working with these products is experiencing steady growth. Before final use as a consumer product, the raw materials are treated in a number of physical and chemical processes.

Firstly, the raw material is cleaned, which involves treatment to separate it from unwanted components such as sand, water, carbon dioxide and hydrosulphide. During this first step, the acidic sulphide environment already imposes heavy demands on the components that will come in contact with the raw material and this has led to the use of highly corrosion-resistant materials such as stainless steel of different grades, higher Ni-containing alloys and titanium. The next treatment can involve the fractionating of naphtha into groups of hydrocarbons of different chain lengths, which are more viable on the market. If the composition of the naphtha is dominated by the heavier hydrocarbons, it is possible to split the hydrocarbons into shorter chains. This is done in hydrocarbon crackers at high temperature and pressure.

For temperatures below 250°C, carbon steels are frequently used. For higher temperatures, chromium and molybdenum are added to improve creep and corrosion resistance. The pipe steel grades used for petrochemical components are normally those described in the ASTM material specifications for refinery service.

Grade	Alloy type
P1	C–0.5 Mo
P11	1.25Cr–0.5 Mo
P22	2.25Cr–1Mo
P5	5Cr–0.5Mo
P9	9Cr–1Mo
P91	9Cr–1MoNbNiV

If H_2S is present, it is necessary to use stainless steel grades 321 (18Cr8NiTi) or 347 (18Cr8NiNb) for cladding reactors or for piping in high-temperature service.

Since piping is a frequent structure in these constructions, the welding of pipes is an important activity. As mentioned earlier, the quality requirements are very high and the normal welding processes are TIG for welding the root and SMAW for filling layers.

Figure 1. TIG welding of Inconel pipes.

These are only some examples of components that are welded, where the requirements that are imposed on the consumables are very high. Some interesting components will now be examined in greater detail in terms of consumable selection and use. These components have been constructed at Sirz Montaggio

Figure 2. Mounting of the start-up heater.

srl in Porto Marghera outside Venice, Italy. Mr Gianni Pistore, the welding engineer at Sirz, was kind enough to show the components under construction. This company's production includes components for a methanol plant in Central Africa, an ammonia/urea plant in Egypt, petrochemical heaters for Pakistan and a fertiliser complex in Venezuela.

For the methanol plant, Sirz has built 40 module heaters for ethylene. Each heater has 21 catalyst pipes in Inconel 600. The pipes are produced by centrifugation and are welded to an Inconel 800HT manifold at one end and a P11 manifold at the other end. The Inconel pipes were welded with OK Tigrod 19.85 and the P11 pipes with OK Tigrod 13.12.

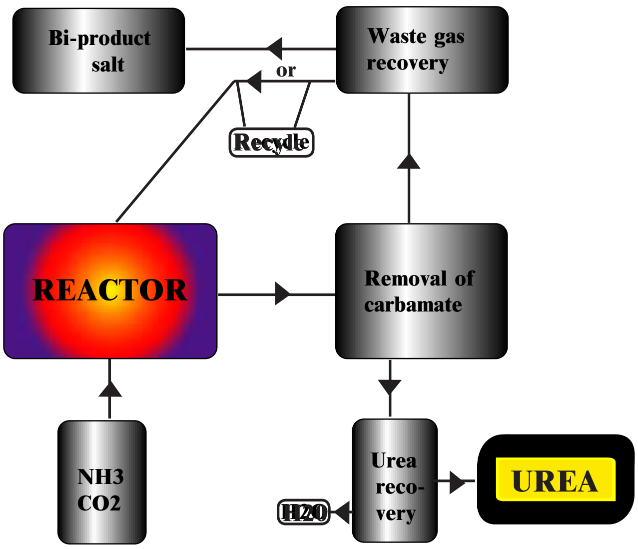


Figure 3. Simplified flow chart of the production of urea.

Figure 4. Mounting of waste train water heater.

Welding the manifolds

Another important product is urea, which is a nitrogen-containing fertiliser, that can be synthesised from ammonia. As mentioned above, temperature is important and once again one step in the process is to heat the reactants and Sirz has built a ”start-up heater” for a NH_3/urea plant. This is constructed from four pipes, each 200 m long, formed to produce a helicoil. The pipes have the following composition, ASTM TP 347H, and were welded with Siderofil TIG 347 in the root and SMAW Filarc BS 347 for the filling.

Another component for this plant is seven coil banks for waste heat trains. They are constructed from a number of different grades of heat-resistant materials, ranging from carbon steel to T1, T22 and T91.

The carbon steel was welded with Filarc 35S with Siderfil Argon in the root, T1 with Filarc KV2 and OK Tigrod 13.09 for the root, T22 with Filarc KV3L and OK Tigrod 13.22, T91 with OK 76.98 and OK Tigrod 13.38 in the root.

For another fertiliser project, twelve heaters weighing up to 260 tonnes were assembled by welding a large number of pipes of different qualities in bog ovens. The materials were of the types A106, P11, P22, 304H and 321H.

The amount of welding is measured by the length of the welds and, in the case of the pipes, 26,000 inches of welding were performed. Many of the welds were performed in difficult positions, which explains why the requirements imposed on the welding properties for the SMAW consumables are very high. The pictures show the welders in action.

The demand from a company like Sirz Montaggi srl on a wide range of consumables emphasises the need to have a complete supplier like ESAB. The full assortment and good deivery are important factors for Sirz Montaggi srl when a supplier is chosen and ESAB can fulfil those requirements.

Figure 6. Pipe welding in difficult positions.

Figure 5. Some of the welders in action.

About the author

Bo Magnusson is the Group Product Manager for mild steel and low-alloyed electrodes at ESAB Europe headquarters in Gothenburg.

He has studied at the Chalmers Technical University in Gothenburg and after a degree in Inorganic Chemistry he started in the development department at ESAB and has for the last ten years worked with product marketing.

Stub-ends & Spatter

From the demo of mechanised welding of an SMO pipe.

ESAB, a newly appointed IPLOCA member

On 13 June 2001, ESAB was granted membership of IPLOCA (International Pipe Line & Offshore Contractors Association), the service and communications network for pipeline and offshore construction which is operational in 125 countries.

ESAB's application was approved by IPLOCA for its extensive experience and reliability in the supply of welding equipment, consumables and technology to pipeline engineering and construction. Letters of reference from ESAB's pipeline customers also contributed positively to the decision.

All ESAB units will be included in the official IPLOCA directory and ESAB consumables will display the IPLOCA symbol, which is well known world wide.

For further information, please contact:

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Surfacing crossings on East-Siberian Railway

In the summer of 2000, at a new shop for a rail -welding train (RWT-32) at the Misovay Station, under the guidance of RPF "Plazmoprotek", work began on the automatic surfacing of worn crossings. The surfacing is done using equipment and materials from ESAB. The universal LUA 400 inverter power source, the MED 304 wire feeder, the PSF 400 welding torch and the mechanism for automatically moving the torch – RAILTRAC BV – are all applied. The surfacing tip and rail wings of worn crossings made of manganese steel are repaired using OK Tubrodur 15.65 self-cored wire. The surfacing of these crossings takes place on a special milling machine and they are then stowed on reception-despatch railway sidings. In 2000, the repair of about 100 crossings by surfacing and other forms of build-up was scheduled on the East–Siberian Railway.

Nordic Welding Days

Last year, on 6 and 7 November, the Nordic Welding Days were organised by the ESAB Segment Support Department. The seminars were held in Gothenburg at the Quality Hotel 11 and the ESAB Process Centre. Despite the fact that it took place shortly after the Schweissen & Schneiden Fair in Essen, Germany, this event attracted some 75 people. The seminars were full of interesting lectures with different applications. A new feature this year was the inclusion of practical welding demonstrations as well.

The lectures were as follows: Norms and standards, A modern pipe mill and welding methods, Complicated welding repairs at a nuclear power plant, Synergic cold wire in stainless steels, New steel types in the offshore industry, Robot stations now and in the future, Welding development at the Volvo Aero Corp and Wind tower production – simulation and control of welding processes.

The practical demos at the process centre were: Robot welding with MCW in thin plate, mechanised FCW welding overhead, mechanised welding in an SMO pipe, Synergic cold wire welding and multi-electrode SAW welding.

The participants were very interested and many questions were asked after each lecture. We hope that we will see the same and perhaps even more interest next year.

Friction Stir Welding in Denmark

Danish Stir Welding Technology, DanStir ApS, a company dedicated to offering services to industry in the field of R&D and the production development of FSW technology, was established in the summer of 2001.

During the autumn of 2001, an ESAB SuperStir™ welding installation from ESAB AB, Welding Automation in Laxå, Sweden, was commissioned at DanStir's building complex in Brøndby near Copenhagen.

The ESAB SuperStir™ machine will be used for R&D on tool and process technology, as well as for production trials and production for customers.

With a welding envelope of 3.5 (W) x 15 (L) x 1.5 (H) metres and a down-force capacity of more than 100 kN, it is able to weld large-scale components in a variety of aluminium alloys with a thickness of up to 25 mm.

DanStir ApS and ESAB AB, Welding Automation, are collaborators in the EUREKA EuroStir® project and are co-sponsors of Group Sponsored Projects on Friction Stir Welding at TWI in Cambridge, UK.

For more information,
please contact
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For more information on DanStir, please see: www.danstir.com

Installing a cross on a catholic cathedral

On Easter Day, 23 April 2000, a cross was installed on the Cathedral of the Immaculate Heart God's Mother in Irkutsk. The cathedral had been built as part of a project led by Polish architects and entitled "Irkutsk industry building". However, the production of the cross and its installation at a height of 27 metres had been entrusted to PRF "Plazmoprotek". The cross was connected so the PRF "Plazmoprotek" welders had had to weld tubes with a diameter of 63 mm and a wall thickness of 0.6 mm made from polished Chinese stainless steel to make the cross. The actual cross had a height of 6 metres and a width of 3.5 metres. The horizontal and vertical crossbars of the cross consisted of six tubes welded together to form an exact hexagon.

The cross was welded together by PRF "Plazmoprotek" using MIG (metal-arc argon-gas) welding equipment from ESAB – the Caddy 200 Professional and the LHN 200 with the Heliarc HW 24 torch. The filler was 18-8 wire and the welding included butt, fillet and overlap joints. Almost all of the more than 100 welds in the construction of the cross were annular.

After assembly and welding, the 100-kg cross was transported on a truck to the cathedral and lifted by crane to a height of 27 metres. The welders now had to fix it in place and weld it to two towers, between which it was going to be stand, in the shortest possible time. The welders from PRF "Plazmoprotek" managed to do the work in the allocated period and they did it using the Caddy Professional LHN 140 and OK 61.30 welding electrodes from ESAB. The reinforcement of the cross on the towers took the form of six beams made of stainless material. As a result, it looks as though the cross soars above a temple. Father Peter was delighted with the quality of the project and the time it took to complete. On 8 September 8 2000, the solemn consecration of the new Catholic Cathedral of the Immaculate Heart God's Mother in Irkutsk took place.

The ESAB Knowledge Centre on Internet

With the launch of the new ESAB Europe internet site (http://www.esab.net/) during Schweissen & Schneiden 2001, ESAB published a completely new technical section for students, welders and welding engineers, The ESAB Knowledge Centre.

Here you will find a wealth of detailed information on welding & cutting processes and case studies of industrial applications from practically any industrial branch. Also we included all recent issues of our technical magazine Svetsaren-The ESAB welding & cutting journal, and new issues will be published on the internet even before the paper copy is being distributed, so that you will have access to the latest technical information in the earliest possible stage.

In addition, you'll find an overview of the guiding software and sales literature available from ESAB, to be ordered or freely downloadable.

Dedicate some time to browse through this very interesting part of the ESAB site, and maybe you come across exactly that piece of information you were looking for.

For information on the ESAB knowledge centre contact:
ben. altemuhl@esab.nl

Simple mechanisation with new process package

ESAB After Sales, Equipment Operations, in Laxå, Sweden, has produced a range of particularly successful robot welding packages based on the Aristo 450 power source. They have now been supplemented with a MIG process package of universal type, suitable for use with robots and mechanisation processes of all kinds. More than twenty of these packages have already been sold.

The MIG process package is based entirely on standard components: the Aristo 450 power source (ESAB's most advanced inverter power source), together with the PUA1 control unit, an interface unit for connecting external equipment, and the Mech/MEK wire feed unit. These components are linked to each other using a CAN bus communication system.

Reliable communication

All communication with external units, such as the robot or mechanisation equipment, is channelled through the interface unit. This ensures that installation is fast and straightforward.

The PUA1 control unit can store 96 sets of welding data; 186 synergic lines are already preloaded and the user can create additional custom lines if required.

Danish interest

ESAB Denmark has installed the first MIG process packet at Hadi International, a company which manufactures agricultural machinery. The prospects are excellent and a second delivery from ESAB Laxå is due within the next two weeks. A further eight sets are due for delivery over the next two months.

Alstom increases production using ESAB's welding equipment

ESAB has received an order for fully automatic narrow gap welding equipment from ALSTOM Power AG Switzerland.

The order is divided into two parts; the first order involves a fully automatic narrow gap laboratory machine and the second comprises the replacement of the welding systems on ALSTOM's two existing welding gantries.

ALSTOM is involved in the production of generator and turbine axles. The equipment for welding consists of a TIG narrow gap welding station where the root passes are welded. At this welding station, the axle sections are welded in a vertical position on a turntable.

The narrow gap welds are performed by two welding gantries with roller beds and head and tail stocks.

The primary objective of the new purchase of welding equipment is to increase the level of production and automation. The main features that attracted attention to ESAB's narrow gap equipment were the:

- Pivoting torch, optimising the positioning of the wire when welding deep down in narrow gap joints
- Automated joint tracking and positioning of the wire
- Data recording of the compete welding procedure

Until now, the welding station has comprised old Hulftegger welding equipment with a local Swiss-manufactured gantry, roller beds, head & tail stock.

As the replacement time for the welding equipment had to be minimised and the reorganisation of ALSTOM's workshop was to be kept to a minimum, it was decided that only the welding equipment would be replaced.

Also included in the scope of supply is the equipment for positioning the welding system over the workpiece, including a 2.5 m long vertical boom that holds the wire and flux equipment. As ALSTOM uses two 300-kg wire drums and an 80-litre flux tank, the vertical boom for the welding equipment would have to be of the heavy-duty type.

The positioning of the welding equipment comprises the following:

- Carriage with linear slide support and rack & pinion drive
- Vertical boom with motor and screw gear
- S4/S5 slide cross

During the technical negotiations, it was found that the simplest way of changing the welding system would be to replace the whole upper part of the existing welding gantries. The reason for this was that extensive machining and fitting of an attachment plate to hold the welding equipment would be needed in order to fit the equipment on the upper part of the existing gantry.

The laboratory unit will be delivered during the autumn of 2001 and the second part of the order will take place during the second quarter of 2002.

AlcoTec Wire Corporation Receive ISO 9000 Registration

After many years of producing premium quality aluminum welding wire in accordance with a quality system modeled on ISO 9000, AlcoTec Wire Corporation was recently awarded registration by QUASAR, the quality system registration division of the Canadian Welding Bureau. This ISO 9000 quality system registration will complement AlcoTec's other international certifications including The American Bureau of Shipping, Canadian Welding Bureau, Korean Register of Shipping, Lloyd's Register of Shipping and Det Norske Veritas. AlcoTec Wire Corporation is located in Traverse City, Michigan USA.

ESAB/Capitol Steel Case Study

Capitol Steel finds mobile welding machine propels production – cuts labour costs by 25%.

Figure 1. Capitol Steel uses the A6 Tandem Mastertrac to make horizontal fillet welds up to 7/16" (11 mm).

Figure 2. A finished beam leaves Capitol Steel's shop.

Throughout its long history, Capitol Steel & Iron Company of Oklahoma City has relied on strategic moves – on and off the shop floor – to reach new markets and prosper. A key part of Capitol's philosophy has been the installation of new technology that increases production rates and helps to keep the company competitive through changing times.

Established in 1910, Capitol began as a fabricator of construction rebar and eventually evolved into a global fabricator of steel beams used in erecting cotton gins and military hangars. During the middle of the last century, the company found success working on structural steel buildings, with a concentration on fossil fuel power plants. It was during the last decade that the company focused on welding flange webs on plate girders for highway and railroad construction, which it performs in its 300,000 square foot facility.

Capitol Steel was purchased in 2000 by the Iowa-based Rasmussen Group, a prominent bridge construction firm. To supply the needs of this partner company and other prime contractors, Mark McCarty, operations manager at Capitol, is constantly looking for a means to speed his pre-fabrication process, meet tight construction schedules and provide consistent quality weldments.

Capitol now employs 120 workers who do all the pre-fabrication work in house, building plate girders that range in weight from 15,000 pounds up to 100 tonnes and extend from 50 to 130 feet in length.

Like all shop managers in his position, Mark McCarty is concerned with cutting labour time and costs. He decided to investigate the potential offered by an improved tractor-mounted submerged arc welding machine. "We were looking to replace some old equipment and do some upgrades in the shop," says McCarty. "We checked around with industry leaders and found that a mobile system was a reliable, fast technology."

To replace his outdated tandem sub-arc tractor, the unit he chose was a four-wheel drive A6 Tandem Mastertrac from ESAB. The power supplies selected to complete the system were an LAF 1250 DC and a TAF 1000 AC. The OPC flux recovery system was also added.

To permit horizontal fillet welding with two wires, the A6 Tandem Mastertrac was modified slightly. The standard A6 contact jaw assemblies were replaced with bent A2 contact tubes (part number 413511001) and the A6 guide bars were extended by bolting two guide bars together.

Capitol Steel uses this system to make 7/16" horizontal fillet welds. To make a fillet weld of this size with its previous system, the company had to position the beam to allow the weld to be made in the flat position.

Figure 3. Labor savings of 25% have been realized by the introduction of the A6 Tandem Mastertac.

"I was not familiar with this type of mobile system before," says McCarty. "What drew me to this technology was its capability to weld in a flat position with no turning. That saves considerably on material handling. We are now able to move the machine to the work and cut labour time."

"With this new tractor, we can do more welding and less re-positioning," says McCarty.

"I can set the beam down flat and that way I can weld down one side, turn around and weld down the other side without having to move the girder."

With his previous system, for each fillet weld the girder had to be rolled into position – for a total of four re-positions per girder. The new tractor enables welding of the entire girder with only one re-position, thereby eliminating three of the moves.

"This tractor welds flanges vertically and the web is horizontal, so both flanges are in an identical position," says McCarty. "Our old units ran in a trough position so that the corner where the two flanges met was located down at the very bottom. Each time you wanted to weld, you had to position the connection into that 45-degree position. This new system offers greater manoeuvrability with far less work." This is of particular benefit to a company such as Capitol Steel that works with such massive plate girders.

Another benefit of welding the girders in the horizontal position is that less tacking is required. "It saves on tacking the plates together, too," says McCarty. "I don't have to do as much of that. In the past, it took an entire shift or shift and a half to weld a girder together. Now I can complete two girders a day."

The company began to use the ESAB tractor when the Rasmussen Group assumed ownership over a year ago. Capitol purchased two of the units – one each in May and August of 2000. Since then, McCarty says his operation has realised savings of approximately 25% in labour costs.

Along with flexibility, the tractor offers PEH processor control for automated, high deposition rate welding. "This eliminates human error," says McCarty. The tractor can store ten presettable welding parameters and offers capacity for heavy production welding using up to 1/4 in. (6 mm) wire with 1,500 amps DC and/or AC power source.

According to McCarty, the implementation of mobile welding technology involves a learning curve on the part of his operators. However, this is compensated for reasonably quickly in terms of controlled, consistent quality welds and higher production. Reaction to the new system among his floor operators has been positive.

Capitol Steel and Iron processed approximately 4,000 tonnes of fabricating steel last year and already has close to 7,000 tonnes on the books for 2001. Prior to 2000, the company had fabricated a total of 5,000 tonnes in the previous four years combined. McCarty attributes this dramatic growth to a new management team and their willingness to explore new avenues of efficiency.

As he says, "Labour saving is the key to helping us get jobs and stay competitive."

A6 Mastertrac

The A6 Mastertrac is a strongly-dimensioned self-propelled, 4-wheel drive, automatic welding machine. The advancded electronic control equipment provides high precision and the digital display enables all the welding parameters to be preset accurately – either beforehand or during welding. The A6 Mastertrac is easly to use and can be supplied for submerged arc welding(SAW) in single, twin or tandem version. It is also available for gas metal arc welding (GMAW).

	Single SAW	**Single GMAW**	**Twin SAW**	**Tandem**
Max load at 100% duty cycly, Amp	1500	600	1500	2x1500
Wire diameter, mm	3.0-6.0	1.0-3.2	2x2.0-3.0	2x3.0-6.0
Wire feed, m/min	0.2-4.0	0.2-16.6	0.2-4.0	0.2-4.0
Travel speed m/min	0.1-2.0	0.1-2.0	0.1-2.0	0.1-2.0
Weight, kg	110	100	110	158

Modern cutting machines and techniques in the shipbuilding industry

by Klaus Decker, Managing Director, ESAB CUTTING SYSTEMS GmbH, Germany

Cutting machines should provide constant cut quality, giving the user the confidence to enable secondary processes to be started without correction processes such as the grinding of dross and so on.

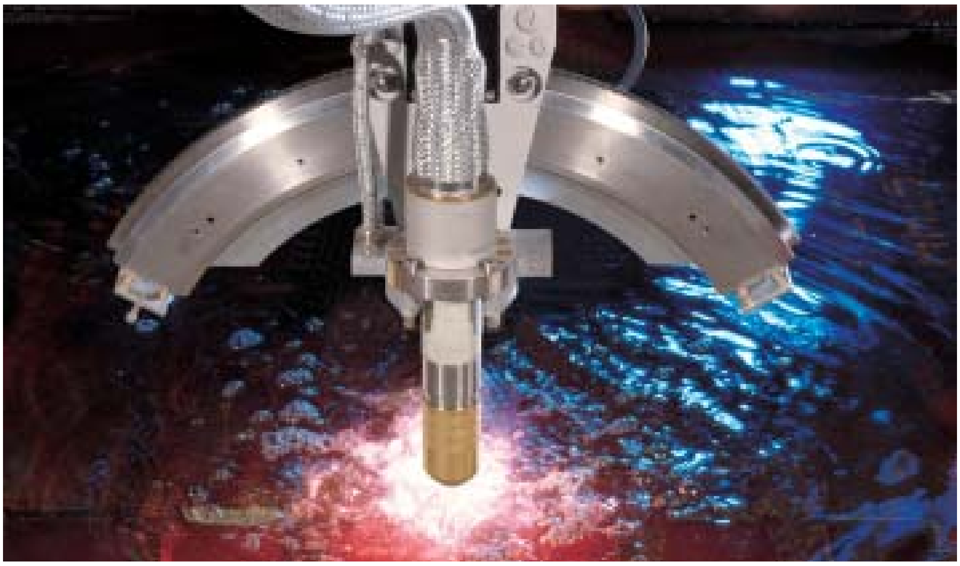

Figure 1. Water injection cutting

The cut parts should also be within the geometrical tolerances, together with the correct cut surface and cut angle. Breakdowns on cutting machines should be repaired quickly so that production losses are kept to a minimum. To realise these goals, you not only require a high-quality machine, CNC control also plays a very important role. To obtain constant cut quality, the cutting parameters must be set with very high accuracy; every parameter must quite simply be programmable. To minimise breakdowns, the controller must have its own checking system, which will report messages to the operator or to the work preparation department. For fast checking, the service department must have remote access to examine the controller and check cutting programs and follow up cutting sequences.

1. Introduction

This paper focuses on the cutting machines that are mainly designed for the shipbuilding industry. It will describe different methods for marking, as well as processes for the surface cleaning of primed material. New CNC Windows-based controllers are described; they do more than simply guide the machine. These new controllers are able to control the entire cutting process, automatically setting the correct parameters. Furthermore, via computer links and Internet connectivity, the CNC and the machine can be checked from the cutting machine supplier's service centre.

2. Cutting machine configurations

Modern cutting machines are typically equipped with one or two plasma bevel heads, which enable the customer to perform straight cuts or bevel cuts. At some yards, the bevel head is also used to compensate the normal bevel created from the actual plasma process. The torches are equipped with anti-collision devices, which protect them from crashes.

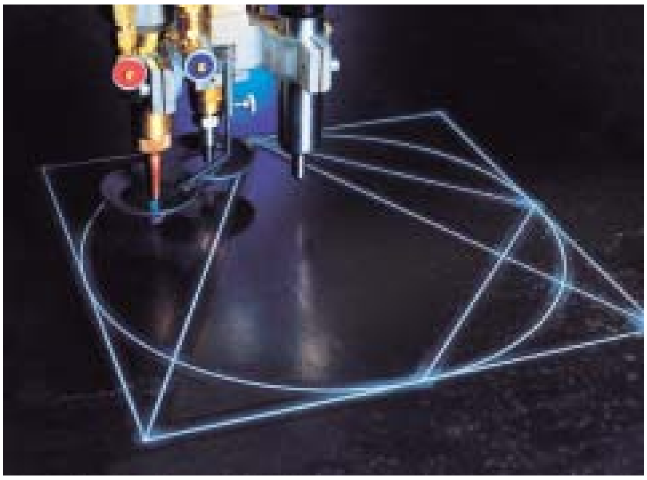

Figure 2. Powder marking

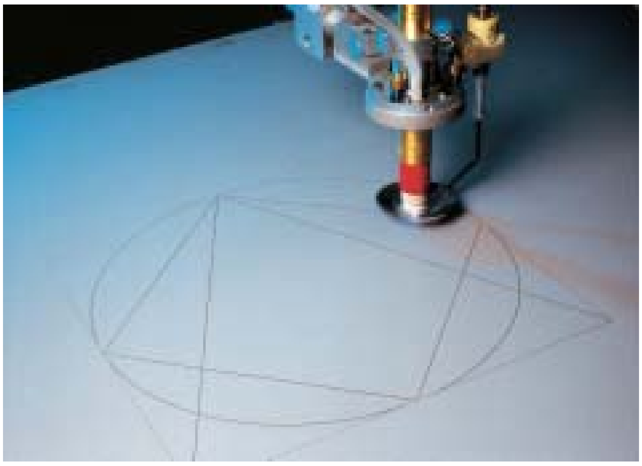

Figure 3. Arc marking

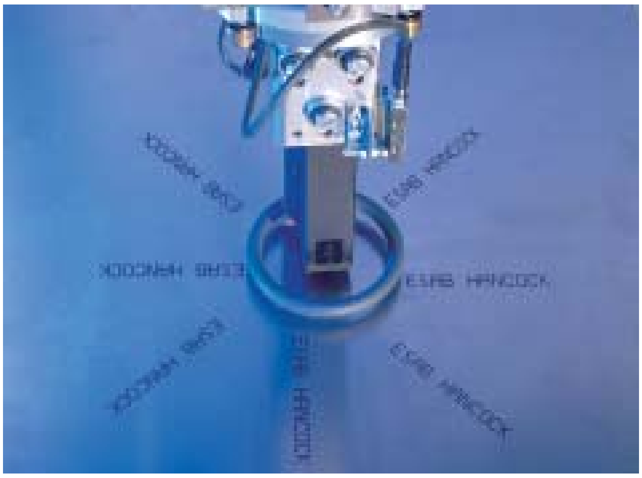

Figure 4. Ink-jet marking

These machines are operated all over the world for steel production at the yards. Oxy–fuel cutting can also be used, but mainly for weld edge preparation, thicker plates and strip cutting.

In addition to cutting, marking plays an important role at shipyards. For many cutting installations, it is a fact that the hours used for marking operations equal the hours used for cutting.

Users often express a wish to have a higher marking line speed, as marking, from an immediate technological viewpoint, is regarded as a process secondary to cutting.

While this is understandable, it can be disputed. When examining the comprehensive production layout, it could be argued that marking operations should be improved in terms of readability, logistics and production directions, in order to speed up operations in the following stages of production. Obviously, what we have is a case for development both quantitatively and qualitatively and thereby good reasons for looking at the systems available and new opportunities.

A system of long standing is powder marking, using a special powder through an oxy-fuel burner. Depending on the circumstances, it permits line speeds of up to 20 m/min.

Its drawback is that the powder is hygroscopic and that the system is demanding in terms of maintenance and upkeep. In spite of good upkeep, the line thickness tends to vary unintentionally

One recent development is the so-called plasma marking, referred to as Arc Marker.

This system produces what could be described as an etched line, but, as different to powder marking, it breaks the paint coating and penetrates slightly into the plate surface, a feature which is not always regarded as desirable. For both systems, it is characteristic that in principle they produce only lines and only in one line thickness. Other types of marking, such as systems which also create an opportunity for production directions by using different line characteristics or by marking with letters and signs, for logistical purposes, for example, were not available before the introduction of ink-jet marking.

Ink-jet marking permits marking speeds of up to 20 m/min, for both line drawing and lettering. The readability is very good and the potential ink-jet marking can add to an IPS (Integrated Planning System) in terms of improving logistics and the on-site availability of production directions is obviously a major step forward. The improved cutting installation provides immediate operational advantages, as well as major benefits in the production stages following cutting.

3. Surface cleaning

To cut welded plates (16–20 m) for further production of exact measurement, there are panel line machines which have a span of up to 25 m. These machines are not only used for cutting the edges for weld preparation. They also have to mark the positions at which the stiffeners should be placed.

For shipbuilders, the manufacture of vessels from shop primed material is a must. However, other steel fabricators also have to face certain production problems from today's protective paint systems. In particular, these problems are associated with the use of zinc-based paints and the like and the difficulties associated with

	Marking Arc-Marker line	Ink Jet line or letter	Surface Cleaning Grinding			Fine-beam shot blasting	
Speed mm/min	20	20	20	15	10	4	6
Residue %	n.a.	n.a.	8	5	2	15	40

Table 1: Test results for various machining processes involving marking and surface cleaning.

Figure 5. Grinding device for surface cleaning.

subsequent welding. If the paint is not removed, the Zn content will result in a reduction in the welding speed and, in some cases, it will produce unwanted porosity, necessitating a repair routine. In other cases, it can result in fillet welds with excessive throat sizes (or leg lengths), which results in costly consequences in the form of unwanted and unpredictable deformations and inaccuracies at subsequent erection stages.

There are various schools and viewpoints when it comes to the solutions to these problems. One way has been to integrate shot-blasting equipment in the cutting installation and thereby obtain more or less clean metal surfaces, where webs and stiffeners are to be welded at a later stage.

Figure 6. Grinding device installation on panel machine for a shipyard in France.

Figure 7. Windows-based CNC controller.

Using fine-beam shot blasting, it has been shown that a target for surface cleanliness of 15% (i.e. max. 15% foreign particles, such as paint inclusions) can be obtained with a feed speed limited to 4 m/min (Table 1).

In the general production layouts of today, this is a low moving speed and it does not fit in well with the marking speeds. This is important as it is common practice to run the surface cleaning operation in parallel with the marking operation and there is therefore an obvious need to match the processing speeds of the two.

Table 1 shows the figures that can be obtained with today's most advanced equipment for marking and surface cleaning and it will be noted that very high productivity, compared with previous techniques, is now possible when operating at marking and surface cleaning speeds of up to 20 m/min.

The latest development in this field has been the introduction of special grinding tools integrated in a cutting installation (Fig. 5).

The grinding tool permits a dramatic speed improvement and the surface cleanliness is also much improved (Fig. 6)

4. New controller generation for cutting machines

The Windows NT-based cutting machine controller is the only "Open CNC" available in the cutting machine market. This powerful control features a Pentium-based PS running Windows NT work station.

This means that nesting programs, post processors, productivity, production scheduling or remote monitoring software can be run straight on the control. Windows NT provides a stable, open architecture operating system that the customer can use to run any Windows or DOS programs. Some key figures of the Vision NT include a familiar Windows graphical user interface, network and Internet connectivity, kerf-on-the fly with kerf override, programmable cutting parameters, user-definable macro keys and enhanced shape library features.

5. Kerf on the fly

Traditionally, there have been two ways to calculate the kerf offset for a programmed path. Controls using pre-kerf take a long time to calculate the running path before executing the program. Controls using kerf on the fly calculate the running path during run time, but require faster, more expensive processors.

The Vision CNC calculates the entire kerf offset path, depending on modern microprocessor technology, before running a part, but enables the operator to adjust the offset during program execution. This means that the operator can adjust the kerf offset after cutting the first part of a nest in order to continue cutting without restarting the entire nest. The operator can scale the kerf offset between 50 and 150 per cent of the original value. This results in easier operation, less wasted time and material and more accurate parts.

6. Programmable cutting parameters

Programmable cutting parameters allow process times and parameters, along with feed rate and kerf values, to be recorded in a file that can be recalled later. A cutting parameter file can be created for each type of material a customer cuts, so that the repetitive, critical task of adjusting timers and parameters can be automated. The operator can manually select a parameter file or the files can be called from within a part program, thus automatically setting the same values every time. The operator can also correct these files himself and can store them.

The newly developed "Adaptive Process Control" provides a higher level of process automation and quality improvement. All the necessary process parameters can be programmed and are repeated during the cutting process with a very high level of accuracy.

- Cutting Speed
- Kerf Offset
- Pierce Time
- Preheat Time
- Arc Voltage
- Initial Height
- Gas Flow
- Master up Time

The machines must also be equipped with control functions such as proportional solenoid valves, pressure sensors, flow controls, speed measurements and so on.

7. Operator calling system

Cutting machines with the latest open CNC controllers can be run without or with very limited personnel. Connected telephone links to the controller permit status reports for the machine or the cutting process to be sent to the user of the machine. The transmission takes place using pre-selectable and prioritised telephone numbers.

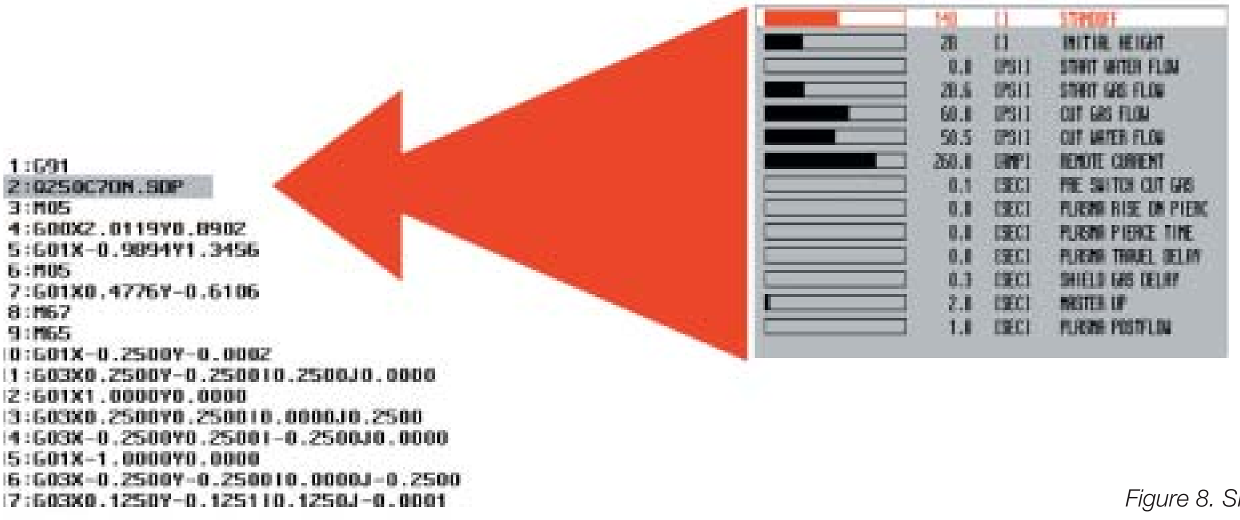

Figure 8. SPD files

A number of machines can be supervised by one operator without any problem.

8. Internet connectivity

This feature enables the operation of the entire machine (even over long distances) to be directly monitored from the cutting machine supplier's service centre.

Application

- direct access to the machine from the service centre
- in case of problems, the software department can trace all the functions of the specific machine on line
- scope function can be transferred to the service centre (drive problems)
- software updates can be directly installed from the service centre
- all machine parameters can be checked via specific software
- cutting programs can be downloaded from the cutting machine and checked at the factory
- there is also the chance to correct NC programs and send them back

In particular, intermittent errors, which occur at only one time of the day or week, can be detected with Internet connectivity. The service centre can write (store) all the activities of the selected machine, including push-button pressing, cutting program, drive system operation and so on. If an error occurs, the service department can check all the functions that were executed at that particular time to diagnose the cause of the error.

9. Outlook

At the present time, there are methods available, as described in the paper, which can set the process and control all the associated parameters. What is still missing and what we are working on is the control of plasma consumables. The cutting torches are fed with the right parameters to guarantee the best, repeatable quality. The operators can run more than one machine (ghost shifts are possible). The next step is to monitor the consumables because wear will affect the cutting quality and tolerances. The operator should also receive a message when the consumables have to be changed.

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Welding penstocks and coiled boxes for a hydropower plant using ESAB flux-cored wire

by Antônio J. S. França, quality manager of the consortium, José Roberto Domingues, consumable technical manager at ESAB Brazil, and Cleber J. F. O. Fortes, technical assistant at ESAB Brazil

ESAB is supplying the ODEBRECHT–INEPAR/FEM Consortium with OK Tubrod 71 Ultra rutile flux-cored wire for welding penstocks and coiled boxes for a hydropower plant.

Introduction

Due to the abundant water resources in Brazil, about 90% of the power generated in this country comes from hydropower plants. However, at the moment, Brazil is facing a significant deficit in power generation. For this reason, several investments are being made to increase the hydropower-generation capacity of existing plants and bring about the construction of new ones.

In this context, the ODEBRECHT–INEPAR/FEM Consortium as been assembling the second stage step of the hydropower plant of Tucuruí, which belongs to the Brazilian company Eletronorte, see Figure 1. This job will result in an increase in power-generation capacity from 4,000 MW to 8,370 MW in 2006. On this site, a new power-generation system is under construction; it comprises eleven new units with synchronic three-phase generators of 390 MVA, 13.8 kV, 81.8 rpm, operated by vertical Francis turbines. Each turbine has a penstock.

The hydropower plant of Tucuruí – the fourth largest in the world – is located on the River Tocantins, in the Amazon region (State of Pará, Brazil), a high-temperature (max. 40°C, average max. 33°C, average min. 23°C), high-humidity equatorial climate (average 85%).

One of the challenges of this job is the welding of penstocks and coiled boxes, as this has to be done in the very aggressive environment of the region. So the selection of the welding process was especially

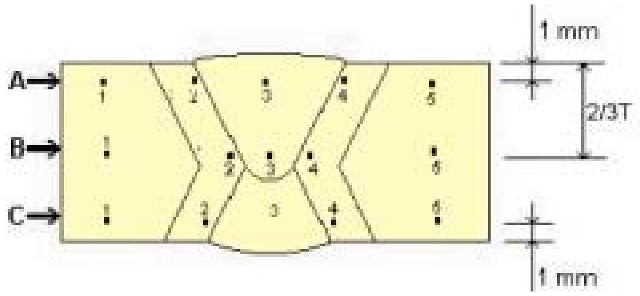


Figure 1. Type of Joint.

important in order to comply with not only the quality but also the productivity and cost requirements.

Traditionally, ASME SFA-5.1 E7018 and/or E7018-1 covered electrodes have been used in Brazil to weld the penstocks and coiled boxes. However, as previously mentioned, the aim of this job is to increase productivity by cutting costs. As a result, the feasibility of semi-automatic welding processes has been evaluated. The selected welding process was FCAW – flux cored arc welding – because of its high deposition rate, low cost and the high quality of the weld metal. For this process the most appropriate consumable was the OK Tubrod 71 Ultra (ASME SFA-5.20 E71T-1(M) / 9(M)) with 100% CO_2 as the shielding gas.

As all the welds were to be performed on site, in wind and excessive moisture, the selection of a welding process that requires a shielding gas could be discussed. In this case, a self-shielded cored wire could have been recommended, as a porosity-free weld metal

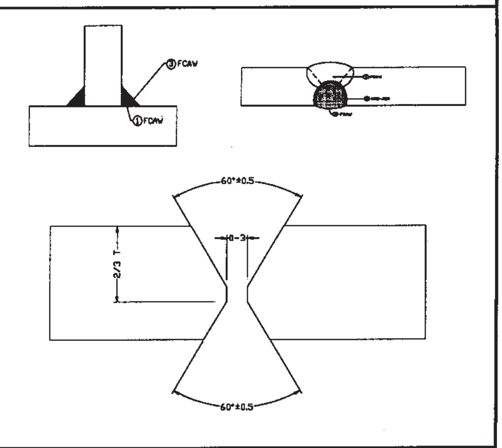
C	Si	Mn	P	S	Nb+ Si	C_{eq}.	Y.S. (MPa)	U.T.S. (MPa)	Elong. (%)	Impact 0°C (J)
Max. 0.20	0.10–0.55	Max. 1.50	Max. 0.030	Max. 0.030	Max. 0.12	Max. 0.44	Min.330	500–620	22	34

Table 1. Base Metal – USI SAR 50.

WELDING PROCEDURE

JOINTS		BASE METALS	
Bevel Type:	Butt/ fillet	*Material Specification:*	USI SAR 50
Backing:	N/A	*Type or Grade:*	A
Other:	N/A	*Thickness Range:*	19 — 41 mm

SKETCH



WELDING FILLER METALS		OTHER	
Dimension:	1.2 mm	Position:	All
ASME Specification:	SFA-5.20	Progression:	N/A
ASME Classification:	E71T-1(M)/9(M)	Shielding Gas:	100% CO_2
Manufacturer:	ESAB	Gas Flow:	18—20 L/min
Trade Mark:	OK Tubrod 71 Ultra	Polarity:	Positive

PRE HEATING					
Pre heating Temperature:	*Up to 25 mm = 18 °C min.* *25 < T ≤ 38 mm = 100 °C min.* *T > 38 mm = 150 °C min.*	*Interpass Temperature:*	300°C max		

WELDING PARAMETERS

Pass	*Process*	*Welding Filler Metal*		*Current (A)*		*Voltage (V)*	*Heat Input (kJ/cm)*
		Class	Diameter	Type & Polarity	Amperage		
1	FCAW	E71T-1	1,2 mm	CC+	150 — 250	23 — 27	Max. 23.9
2	Gouging and Grading						N/A
3	FCAW	E71T-1	1,2 mm	CC+	150 — 250	23 — 27	Max. 23.9

Figure 2. Welding procedure – pen stocks and coiled box.

Figure 3. Details of protection tent – pre-assembling.

was required. However, the practical application has demonstrated that, independent of the welding process, it is necessary to use a protection tent to obtain a sound weld metal in a windy, wet environment. This has made feasible the use of a gas-shielded, flux-cored wire, resulting in a sound weld metal, greater productivity and lower cost.

In this article, the selection of the welding process is discussed and the welding procedure qualification and its results are shown.

Selection of welding process and consumable

The selection of the welding process and consumable was based on an analysis of the cost and mechanical properties of the base metal, shown in Table 1, as well as the feasibility of use on site in Tucuruí. Table 2 shows

Welding process	% Cost – based on covered electrode	Deposition rate (kg/h)	Net deposition rate (kg/h)	Duty cycle (%)	Productivity (m/h)
Covered electrode	100%	1.40	0.35	25	0.10
Solid wire	95%	1.60	0.64	40	0.19
Gas shielded flux cored wire	74%	2.70	1.08	40	0.32
Self-shielded cored wire	140%	1.50	0.60	40	0.18

Table 2. Welding processes

C	Si	Mn	P	S	Y.S (MPa)	U.T.S (MPa)	Elong. (%)	Impact −29°C (J)
0.050	0.50	1.34	0.002	0.01	579	620	26	70

Table 3. Chemical Analysis and Mechanical Properties – OK Tubrod 71 Ultra 1,2 mm / 100% CO_2

Figure 4. Details of protection tent – assembling of a spiral.

the result of the cost analysis applied to covered electrodes, gas-shielded, flux-cored wire, self-shielded cored wire and solid wire. This analysis took account of the following areas: labour, overheads, consumables, gases and maintenance cost, deposition rate, efficiency and duty cycle. Taking the covered electrode as the reference level, the gas-shielded, flux-cored wire demonstrated the best result for cost/productivity/quality, with a cost that was about 26% lower and productivity that was 220% higher.

Based on the above analysis and the versatility in out-of-position welding, the gas-shielded, flux-cored wire was the selected welding process. The consumable selected was the OK Tubrod 71 Ultra 1,2 mm, a rutile, flux-cored wire of class E71T-1(M) / 9(M). The selected shielding gas was 100% CO_2.

Initially, the welding procedure qualification tests were carried out in accordance with ASME IX. Several test coupons have been produced to cover the complete requirements for all the welds, i.e. thickness from 19 mm up to 41 mm, welding positions vertical up, horizontal and overhead and geometry as shown in Figure 2.

Table 3 shows the chemical analysis and mechanical properties of the weld metal. The testing procedures followed ASME II Part C SFA-5.20 E71T-1(M) / 9(M), shielding gas 100% CO_2. The diffusible hydrogen content complied with the H8 class of ASME SFA-5.20, which means less than 8 mL/100 g of deposited weld metal.

Welding procedures

Figure 3 shows the approved welding procedure. Although preheating is not required for plates with a thickness of less than 25 mm, all the joints were preheated to guarantee welding on moisture-free weld joints.

Tables 4, 5 and 6 show the mechanical properties of the welded joint presented in Figure 1, vertical up.

Although one of the tensile tests shows a fracture of the weld metal, the tensile strength is greater than 580 MPa, the minimum required by the project.

It is important to mention that protection tents – made of an easy-to-move tubular structure covered by canvas – to prevent wind and rain have been strictly used, as shown in Figures 3 and 4. This protection has been used for tack welding, as well as for welding on site.

Quality of weld metal

Even in aggressive environmental conditions, the quality of the weld metal has shown good results. All the welds are inspected in accordance with an inspection plan, Table 7. Quality control issues a weekly welder's repair rate report. If the repair rate is above the maximum specified, the welder must be sent back to the Welders' Training Centre.

Table 8 shows that the repair rate is 1.05%, which is regarded as a low value. From this repair rate, 98% is accounted for by slag inclusion and 2% by porosity. Taking account of the fact that slag inclusions are not generally associated with shielding, it could be said that these figures show that the welding process has been effectively adapted to this job. It is important to note that these good results are also due to the welders' good qualifications and the fine training offered by the ODEBRECHT–INEPAR/FEM Consortium, which has been supported by ESAB Brazil. This is the first experience of FCAW for many of these welders, so it can be said that the process itself is versatile and easy to learn.

Final comment

The estimated consumption of cored wire for welding penstocks and coiled boxes in this job is about 100

CP No.	Dimensions a (mm)	b (mm)	Area mm²	Load (Kgf)	Stress (MPa)	Fracture region
T1	19.37	38.50	745.75	44,706	588	Weld metal
T2	19.16	38.53	738.23	43,447	577	Base metal

Table 4. Results of Tensile Tests on the Welded Joint – Vertical Up.

Hardness line	Result – HV 10				
	1	2	3	4	5
A	159	230	212	225	161
B	167	224	183	207	165
C	160	240	203	227	158

Table 5. Hardness Tests

CP	Result
DL 01	No cracks
DL 02	No cracks
DL 03	No cracks
DL 04	No cracks
DL 05	No cracks

Table 6. Guided Bend Tests

Part	Weld	Non-destructive examination (%)			
		Visual	US	LP (**)	RX
Turbine	Class 1 (*)	–	100	–	100
Coiled Box	Class 2 (*)	–	10	–	10
	Class 3	100	–	–	–
	Class 4	100	–	–	–
Forced water	Top (*)	100	100	20	100
flow tubes	Fillet	100	–	20	–

(*) The ultrasonic examination can be optional to radiographic examination.
(**) Liquid penetrant examination
Class 1, 2, 3 and 4 : Requirement class – welded joint

Table 7. Requirements for Non Destructive Examinations

Weld Length (mm)	Repair Length (mm)	Rejected Welds (%)
2,794,108	29,355	1.05

Table 8. Welding Inspection

Defect	%
Slag Inclusion	98
Porosity	2

Table 9. Defects

tonnes. By the end of 2001, 31 tonnes of welding consumables had been used.

About 30% of the welding of penstocks and coiled boxes has been finished. The job should be completed by the end of 2006.

Figures 5, 6 and 7 show the assembly of the coiled box to be leak tested. They also indicate the large size of this hydropower plant. Figure 7 shows the assembly of the penstocks, which will be concreted after welding.

As mentioned above, the gas-shielded, flux-cored wire OK Tubrod 71 Ultra has been shown to be suitable for this job, independent of the aggressive environmental conditions, with a reduction in cost and an increase in productivity. As this is a successful project, similar applications will be re-evaluated to define the potential for using this process in the future.

Figure 5. Positioning of a part for assembling of a spiral

Figure 6. Assembling of a spiral

Figure 7 – Upper part of a penstock

Acknowledgement

We would like to thank the ODEBRECHT–INEPAR/FEM Consortium for allowing us to visit the site and for providing us with the information on which this article is based.

About the authors

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ESAB Automation North America

by Richard Hadley, General Manager, ESAB Automation North America

In May 2001, at the AWS welding show in Cleveland, the green light was given to start ESAB Automation North America (NA). This business unit is a part of ESAB Canada and will use several experienced and knowledgeable specialists to sell and service automation equipment and products throughout the USA, Mexico and Canada. The product line consists predominantly of ESAB welding automation, built in Sweden, as well as PEMA material handling equipment, from Finland.

Figure 1. Live display of welding automation equipment.

It has been a very busy summer and autumn laying the foundations of this business. Our automation team has attended training in Sweden and, in turn, others have been trained in Canada. Training is the key to success: with the distance and time zone delay between Sweden and North America, we must have the knowledge and ability locally to support the projects.

Well-trained sales team

The main channel to the US market is through the American sales team. This group of approximately 80 welding experts possess a wealth of knowledge and, of course, they know most of the key customers. Each sales representative has been supplied with a complete sales manual of automation equipment. Each region has been given sales training, as a group, and formal technical training has been held at the Mississauga plant for the engineering services and key account people. These individuals are most enthusiastic about offering automation to their distributors and end users.

On 25 September, ESAB hosted a press conference and open house at the Canadian head office in Mississauga. In attendance were press from Canada and the USA, as well as many local clients and distributors. There were live displays of MKR 4x4, Mechtrac, the AHMA 7000 positioner and turning rolls, as well as smaller automation products such as Miggytrac and A2 tractors. The event was a resounding success, with plenty of encouraging feedback from visitors.

Now is the right time

Many people question the logic of starting a new venture in North America, when the economy is so bad. One key reason for why now is a good time is the exchange rate. The US dollar is still flying high against all other currencies, which makes European products very cost attractive. Next, the poor economy will drive some competition out of the market, as we have seen with the demise of Ransome (Texas) and Bode (UK). This will force customers to search out alternative suppliers, with ESAB as a prime contender. By starting our automation business now, we will be able to build our structure in a more controlled fashion and this will position ESAB to capture market share when the economy improves, which it most certainly will.

World class product line

The main reason for setting up the automation unit is simple – we see the market as needing a solution and we need the business. ESAB's automation product line is world class, well proven and affordable. There is no reason why the North-American market would not accept the line. More importantly, automation can be a key factor in growing all of ESAB's business segments, especially filler metals. ESAB has the unique advantage of supplying the customer with a finished weld, from

Figure 2. ESAB Mechtrac welding tractor.


Figure 3. PEMA AHMA7000 positioner.

filler metals to welding machines to positioners. Our goal is to provide the total solution, not just an equipment package. This lowers the customer's risk in a project. If ESAB supplies the filler metals, we will be highly motivated to service the customer, long after the initial capital goods sale has been made. The customer will value the long-term commitment and ESAB will be rewarded with both machinery and filler metals business. Of course, this approach is nothing new: ESAB Europe built its successful automation business by providing a total solution for the customer. It will work in North America, too!

ESAB is gradually building inventory in North America. We currently stock equipment such as manipulators, positioners and turning rolls. Demo machines will be set up in the Mississauga plant and in the new warehouse in Alberta – Canada's large oil patch region. Once customers recognise the quality and performance of the products, the orders will follow quickly. This inventory will allow for delivery in a reasonable length of time, which is essential to success.

Our challenges are not over. In the coming months, we have to continue to explore the US market and to follow up the many leads we have received. As we begin to book orders, we will stress our ability to handle the volume, both in Sweden production and in North America. The United States is a huge country, a huge market, which requires extensive air travel. The events of 11 September have made flying more time consuming and have reduced the number of options available. Although we may have the best product line in the industry, we need to be realistic in a recession economy.

Notable installations

ESAB Automation NA has already had some notable installations, which demonstrate the great strength and potential of the business. Formet Industries, Ontario, is a division of Magna, the largest automotive frame manufacturing plant worldwide. This company purchased a large quantity of ESAB Aristo MIG machines, based on the performance, features and reliability of the products.

Jasper Tank, a distinguished tank manufacturer operating out of Spruce Grove, Alberta, drastically improved its production rate with the purchase of an MKR column and boom, equipped with a PEH microprocessor weld controller. The new equipment reduced the welding time by 40% in one particular task: welding the baffle rings inside the tanks.

American Tank, Cleveland, Oh, manufactures extremely thick-wall pressure vessels. In September, ESAB delivered another large CaB 460 with tandem welding heads. The customer reports virtually defect-free welding performance with its ESAB installations.

ESAB is here to stay

We will survive this recession, we will emerge on the other side as a stronger company and ESAB Automation North America will succeed!

ESAB in the automotive industry

by Lars-Erik Stridh, EWE Segment Support Manager ESAB AB Göteborg

ESAB, the world's largest welding company, obviously has an important presence in the automotive industry. ESAB, the world's largest welding company, obviously has an important presence in the automotive industry. We invest substantial resources in developing welding processes, consumables, power sources, automation equipment and interfaces with robots.

ESAB does not supply robots to the automotive industry, but it is nonetheless a very active partner, together with robot suppliers, when it comes to finding the optimal solution in combination in every situation. This combination involves consumables, power sources, wire-feed units, shielding gas, welding procedures, interfaces and productivity. Different customer projects focusing on many different applications within the automotive industry are constantly in progress at the various ESAB process centres.

Consumables

The consumable that dominates the automotive industry is solid wire, made of different material grades, depending on the parent material. These consumables are the subject of ongoing development work designed to improve their welding characteristics. Some of this work focuses on optimising the chemical composition of the consumable in order to match the characteristics of the parent material as effectively as possible. Nowadays, a wide range of different grades of parent material is used in a car body. There are other requirements that are also important and they include feed reliability, low spatter levels, low or non-existent levels of surface impurity on the weld joints and problem-free welding on zinc-coated or aluminised sheet metal. The introduction of metal-cored wires in special applications in the automotive segment is currently taking place and they will be described at a later stage in this article.

When it comes to the welding of the exhaust system and the catalytic converter system, extensive research is being conducted to develop the most durable systems possible, together with materials that withstand increasingly high temperatures, in order to control emissions as effectively as possible. This naturally imposes the same demands on the consumables, which have to provide high-temperature characteristics, corrosion resistance and good fatigue strength properties. Here, too, metal-cored wires are making an entrance.

Change of process

The following example shows how a change of consumable/process resulted in enhanced quality and, in this case, also in improved productivity.

The object of this example is a catalytic converter and its outlet pipe connection to a flange. The catalytic converter outlet pipe is made of a ferritic stainless material and it is welded to a flange made of normal C/Mn steel. Initially, the customer welded this joint using a solid wire (1.0 mm) of an Nb-stabiliserad 409 grade. A number of problems occurred, including welding spatter, sharp transitions to the parent material à which resulted in poor fatigue strength and far too much hardness in the HAZ. One of the problems associated with using this "matching" consumable is that the parameter range that is needed to produce a satisfactory result is very small. In this case, where a "mixed joint" is involved, the tolerance range requirements are extremely rigorous.

As the work of finding a process that improved the quality and was also more "forgiving", in order to guarantee more stable quality, progressed, a metal-cored wire was tested. It was also of the E 409 grade. The result of this test was a significant reduction in spatter and more uniform transitions between the weld and the parent material, thereby substantially improving the fatigue strength. The problem of the hardness in the HAZ still remained; it was still a little too high and it was difficult to control it using the welding parameters.

In an attempt to control the hardness and retain the temperature resistance and corrosion resistance at the same time, another metal-cored wire, E 307(18/8/6), was tested. This wire has a diameter of 1.2 mm. The hardness now declined, no individual hardness value exceeded 225 HV10 and the transition between the ferritic stainless steel and the C/Mn steel contained no undesirable microstructures.

There was also an extra bonus. In addition to solving the aforementioned problems, the introduction of this metal-cored wire increased the welding speed from 12 mm/sec to 20 mm/sec. This then meant that the cycle time for the welding operation was reduced, thereby cutting the cost of each part that was welded by 22%.

Figure 1. The results using the metal-cored wire, PZ 6470 1.2 mm. Note the smooth transitions between the welds and the parent material, the clean weld surface and the absence of spatter.

New approach to welding thin sheet metal

ESAB's enormous process know-how and collaboration with suppliers to the automotive industry and with the automotive industry directly has resulted in a new concept when it comes to welding thinner plate thicknesses. This concept is being used successfully by a number of companies which supply welded parts to the automotive industry.

When it comes to welding thin materials, the "normal" approach is that, when the plate thickness is reduced, the diameter of the solid wire that is used should also be reduced. There are very few companies if any that have adopted the opposite approach and instead increased the diameter and also changed to a metal-cored wire. This is, however, the direction developments have taken – namely, a robotic wire of the metal-cored type with a diameter of 1.4 mm.

The product is called OK Tubrod 14.11. It is a flux-cored wire that has been developed as the ideal match for robotic welding. It therefore has excellent feed properties, as feed stoppages are unacceptable. The arc is extremely stable and therefore produces a minimum of spatter. One very important characteristic is that this wire can be welded with high current in combination with low arc voltage, without any deterioration in arc stability. All this has been made possible by highly target-oriented development work.

Figure 2. A typcial thin-plate application from a supplier to the automotive industry. Welded with the new metal-cored wire.

The above photograph shows a brake pedal from a supplier to the automotive industry. In this specific case, the solid wire that had been used for welding was replaced with OK Tubrod 14.11.

The result of this change was that the cycle time in the robot was reduced by 31%. As most people know, a kilogram of flux-cored wire costs about four times as much as a kilogram of solid wire, but, as the productivity increases, the production cost of each brake pedal is reduced by 11%. Using the more expensive consumable leads to a significant reduction in the production cost. As a "side-effect" of this change of consumable, the quality improves and the spatter levels are also reduced considerably.

The potential for trimming the cycle times for robotic welding in thin plate is enormous. This is something that is especially applicable to the automotive industry and its suppliers who demand high productivity with reproducible quality. It is, however, very important that, when a new and more efficient consumable is introduced, the whole production chain is taken into account so that no bottlenecks are created elsewhere in the production flow, as the benefit of the increase in productivity is then lost. By planning the welding operation carefully and adapting the rest of the production chain, significant sums of money can be saved.

Measures designed to make savings should be implemented where they are most effective.

As can be seen in Figure 1, it is not that difficult to see where action should be taken to reduce the cost of production in a robot cell. It goes without saying that the cost of the robot and operator is part of the 94% sector. When the above figure is studied, the following question is justified. How cost effective is it to spend many hours negotiating the price of consumables in order perhaps to obtain a reduction of 5%? Not especially smart when it comes to cutting production costs.

The reason why using the relatively expensive metal-cored wire, OK Tubrod 14.11, has been given such a good reception is naturally due to the fact that it enables a reduction in the production cost and an increase in productivity. In addition, the quality levels are enhanced. The bead geometry produces extremely uniform transitions to the parent material. The penetration profile is wider and more stable, making the welding more tolerant of variations in gap. This reduces the risk of welding defects and the number of rejects is significantly reduced. These are savings that have a direct, positive impact on the margin. What is more, the

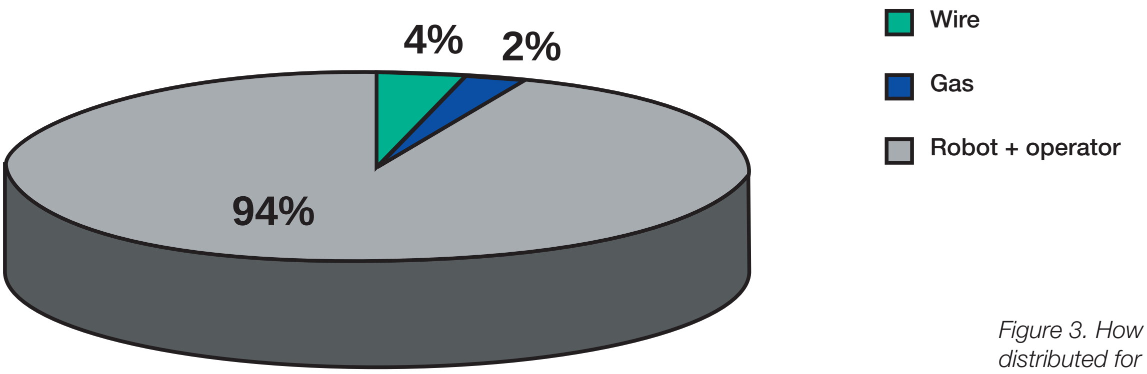

Figure 3. How the costs can be distributed for a robot cell.

spatter levels are substantially reduced and the number of stoppages for cleaning the fixtures also decreases. Another advantage, which is associated with spatter, is that the number of stoppages to allow the robot to visit the cleaning station to have the gas hood cleaned can be reduced by at least 50%. Yet another factor with an effect on cycle times.

It is also important to choose the most optimal wire packaging. When it comes to solid wire, Marathon Pac is the most logical choice. Jumbo Pac has also been introduced. It contains 475 kg of wire. It is also interesting to consider Endless Marathon for solid wire, as it makes it possible continuously to join a new drum and eliminate stoppages completely.

About the authors

Lars-Erik Stridh, EWE, graduated from Bergsskolan in 1982. He worked three years as a welding engineer at a repair and maintenance company in Göteborg and after that 13 years as product manager for flux cored wires at a competitive company. Lars-Erik Stridh joined ESAB in 1999, is based in Göteborg but works on ESAB's total market.

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