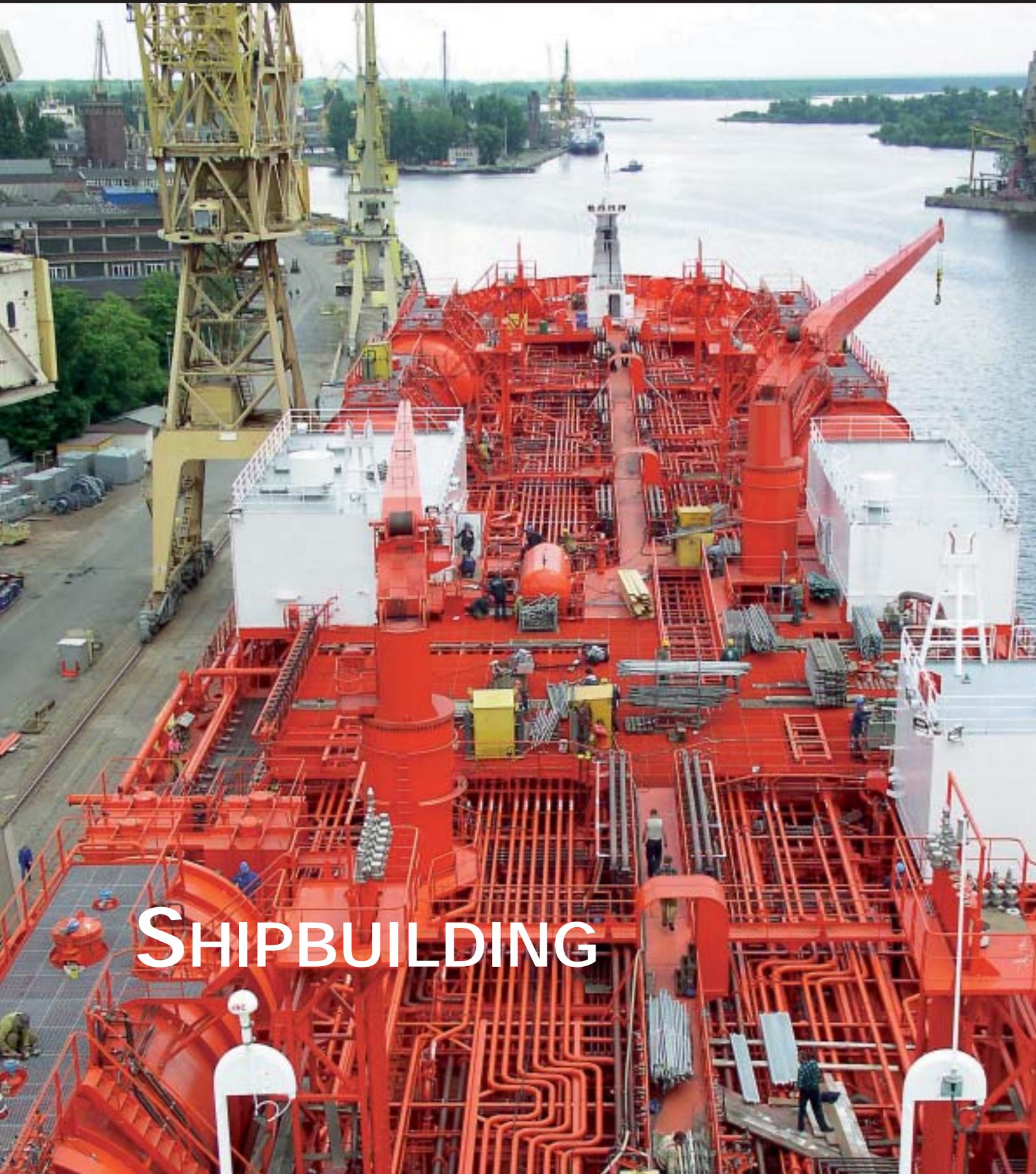


Svetsaren



THE ESAB WELDING AND CUTTING JOURNAL VOL. 58 NO.1 2003



SHIPBUILDING

Svetsaren

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Publisher
Bertil Pekkari

Editor
Ben Altemühl

Editorial committee
Björn Torstensson, Johnny Sundin, Johan Elvander, Lars-Erik Stridh, Lars-Göran Eriksson,
Dave Meyer, Tony Anderson, Peter Budai, Arnaud Paque, Klaus Blome

Address
SVETSAREN, ESAB AB, Marketing Communication
c/o P.O. Box 8086, 3503 RB Utrecht, The Netherlands

Internet address
<http://www.esab.com>
E-mail: info@esab.se

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Photo courtesy Stocznia Szczecinska Nowa, Poland. The Bow Sun, the world's largest duplex chemical tanker. The FCAW of a series of these tankers will be covered in the next issue of Svetsaren.

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New developments within the Aluminium Shipbuilding Industry

By Tony Anderson - Technical Services Manager - AlcoTec Wire Corporation

The article describes recent developments in the construction of fast patrol and transportation vessels for the US military by Bollinger/Incat Inc., applying the latest higher strength varieties of the 5083 aluminium marine alloy. The section on weldability addresses the open-end questions that surround these very new alloys.



Figure 1. The Spearhead - new generation of 98-metre wavepiercers

The creation of this article was promoted by current activities within the United States military, the extraordinary developments in aluminium shipbuilding that have been taking place in Australia, and the creation of new high strength aluminium alloys, primarily in Europe, for the shipbuilding industry.

I was fortunate enough recently to visit Incat Tasmania Pty Ltd. (Shipbuilding) off the southeast coast of Australia. This manufacturer has over the years taken aluminium shipbuilding to exciting new levels. In 1977 they launched their first high-speed catamaran, and today they are manufacturing the new generation of 98-metre (100 plus yards) wavepiercers that are being evaluated by the United States military (see figure 1).

Incat has constructed more than 50 vessels of varying lengths. The company's first passenger/vehicle ferry was delivered in 1990, a 74-metre Wave Piercing Catamaran with a maximum deadweight capacity of 200 tonnes.

The more recent 98m Evolution 10B range has a deadweight four times that amount. While Incat-built ferries initially revolutionized transport links around the United Kingdom, today its ships operate in North and South America, Australasia, the Mediterranean, and throughout greater Europe. Incat's extensive shipbuilding activity is conducted from a modern facility with over 32,000 m² under cover, located at Hobart's Prince of Wales Bay Tasmania.

Aluminium Welded Ships Within The United States Military.

In response to great interest from the US military in high-speed craft, a strategic alliance has been formed between Incat, the premier builder of the world's fastest vehicle/passenger ferries, and Bollinger, a proven builder of a variety of high speed, reliable and efficient patrol boats for the US Navy and Coast Guard.



Figure 2. GMAW being used on high strength large aluminium structural components at Incat's Shipyard in Australia

The US government has awarded Bollinger/Incat USA the charter for a High Speed Craft (HSC) for a multi-service program operated by various arms of the US military. The HSC Vessel, now known as Joint Venture HSV-X1, is being used for evaluation and demonstration trials in order to assess the usefulness of such technology in US military and Coast Guard applications.

Another charter, the USAV TSV-1X Spearhead is the US Army's first Theater Support Vessel (TSV) and is part of the Advanced Concept Technology Demonstrator (ACTD) program by the Office of the Secretary of Defense and the US Army. TSVs promise to change the way the US Army gets to the fight by allowing personnel to quickly deliver intact packages of combat-ready soldiers and leaders with their equipment and supplies.

Another order, from Military Sealift Command, Washington, D.C., calls for the lease of a 98m craft from Bollinger/Incat USA, LLC, Lockport, La., to support US Navy Mine Warfare Command. The ship will be capable of maintaining an average speed of 35 knots or greater, loaded with 500 short tons, consisting of 350 personnel and military equipment, have a minimum operating range of 1100 nautical miles at 35 knots, and a minimum transit range of 4000 nautical miles at an average speed of 20 knots. The craft will be capable of 24-hour operations at slow speeds (3-10 knots) for small boat and helicopter operations.

New Developments in High Strength Aluminium Alloys for Marine Applications

Until fairly recently, the most popular base material used for aluminium shipbuilding, 5083, has had very little rivalry from other alloys. The 5083 base alloy was first registered with the Aluminium Association in 1954, and while often referred to as a marine aluminium alloy, has been used for many applications other than shipbuilding. The popularity of the 5083 alloy within the shipbuilding industry has been largely based on its availability and also its ability to provide an aluminium alloy with excellent strength, corrosion resistance, formability and weldability characteristics. Other lower strength alloys, such as 5052 and 5086, have been used for the manufacture of usually smaller, lower stressed and typically inland lake boats, but 5083 has been predominant in the manufacture of ocean-going vessels.

In recent years, progress has been achieved by aluminium producers in the development of improved aluminium alloys specifically targeted at the shipbuilding industry. In 1995 the aluminium manufacturer, Pechiney of France, registered the aluminium alloy 5383 and promoted this material to the shipbuilding industry as having improvements over the 5083 alloy. These improvements provided potential for significant weight savings in the design of aluminium vessels and included a minimum of 15% increase in the post-weld

yield strength, improvements in corrosion properties and a 10% increase in fatigue strength. These developments, coupled with formability, bending, cutting, and weldability characteristics, at least equal to that of 5083, made the 5383 alloy very attractive to designers and manufacturers who were pushing the limits to produce bigger and faster aluminium ships.

More recently in 1999, the aluminium manufacturer, Corus Aluminium Walzprodukte GmbH in Koblenz (Germany), registered the aluminium base alloy 5059 (Alustar) with the American Aluminium Association. This alloy was also developed as an advanced material for the shipbuilding industry providing significant improvements in strength over the traditional 5083 alloy. The 5059 alloy is promoted by Corus as providing improvements in minimum mechanical properties over alloy 5083. These improvements are referenced as being a 26% increase in yield strength before welding and a 28% increase in yield strength (with respect to alloy 5083) after welding of H321/H116 temper plates of the AA5059 (Alustar alloy).

Welding the New Aluminium Alloys

The welding procedures used for these high strength alloys are very similar to the procedures used when welding the more traditional 5083 base alloys. The 5183 filler alloy and the 5556 filler alloy are both suitable for welding 5383 and 5059 base alloys. These alloys are predominantly welded with the GMAW process using both pure argon and a mixture of argon/helium shielding gas. The addition of helium of up to 75% is not uncommon and is useful when welding thicker sections. The helium content provides higher heat during the welding operations, which assists in combating the excessive heat sink when welding thick plate. The extra heat associated with the helium shielding gas also helps to reduce porosity levels. This is very useful when welding the more critical joints such as hull plates that are often subjected to radiographic inspection.

The design strength of these alloys are available from the material manufacturer, however, there would appear to be little as-welded strength values incorporated in current welding specifications. Certainly these relatively new base alloys are not listed materials within the AWS D1.2 Structural Welding Code – Aluminium, and consequently no minimum tensile strength requirements are included in this code. If this material continues to be used for welded structures, there will be a need to address this situation by establishing appropriate tensile strength values and to include them in the appropriate welding codes.

Early testing on the 5059 (Alustar) base alloy indicated that problems could be encountered relating to the weld metal being capable of obtaining the minimum tensile strength of the base material heat affected zone. One method used to improve the weld tensile strength was to increase the amount of alloying elements drawn from the plate material into the weld. This was assisted by the use of helium additions to the shielding gas, which produces a broader penetration profile that incorporates more of the base material. The use of 5556 filler alloy rather than the 5183 filler can also help to increase the strength of the deposited weld material.

Obviously these high performance vessels require high quality welding. The training of welders, development of appropriate welding procedures, and implementation of suitable testing techniques are essential in producing such a high performance product.

The future

With the increasing demand to create larger and faster ships, particularly for military service, and the development of new improved, high-performance aluminium base materials, it is apparent that aluminium welding has acquired an interesting and important place within the shipbuilding industry. Also, with the pending introduction of this unique technology into the United States, it is important that designers, manufacturers, and particularly welders and welding engineers are adequately trained and familiar with this new technology.

About The Author:

Tony Anderson is Technical Services Manager of AlcoTec Wire Corporation, MI, USA, Chairman of the Aluminium Association Technical Advisory Committee on Welding and Joining, Chairman of the American Welding Society (AWS) Committee for D10.7 Gas Shielded Arc Welding of Aluminium Pipe, Chairman of the AWS D8.14 Committee for Automotive and Light Truck Components Weld Quality - Aluminium Arc Welding and Vice Chairman of the AWS Committee for D1.2 Structural Welding Code - Aluminium.

FSW – possibilities in Shipbuilding

By: Kari Lahti, ESAB AB Automation, Gothenburg, Sweden

Aluminium is increasingly being recognised as an alternative, weight-saving construction material in shipbuilding. Friction Stir Welding expands the scope of application of this material by providing accurate welded components that require minimal fit-up work, and by allowing the use of high strength aluminium grades that were formerly regarded as un-weldable. ESAB LEGIO™ modular friction stir welding machines bring this new welding process within reach at moderate investment costs. Here we discuss the main benefits of friction stir welded aluminium components in ship structures.



Figure 1. Friction stir welded, straight panels under inspection at ESAB FSW Center of Excellence in Sweden.

Assembly work has never been easier

Imagine if a large catamaran could be constructed from building blocks, just like a toy boat. All pieces would fit perfectly to each other and dimensional accuracy and changes could be mastered to full degree. Friction Stir Welding takes the first step towards such assembly work in shipbuilding. Due to the low heat-input during joining and resulting very low residual stresses, the welded components are accurate and minimal fit-up work is needed. The resulting savings in both time and money are obvious. Since this creates competitive advantage to the users of FSW pre-fabricates, documented information of actual savings is not very often reported. However, Midling et. al. 2000, gives an idea of the possibilities gained by friction stir welded pre-fabricated panels from a panel producers point of view:

- Industrial production with a high degree of completion.
- Extended level of repeatability ensuring uniform level of performance, quality and narrow tolerances.
- The flexible production equipment and capacity allows customer built solutions with reliability of delivery.

- The completed panel units are inspected and approved at present by classification authorities such as DNV, RINA and Germanischer Lloyds.
- The high level of straightness of the panels ensure easy assembly at yard, which means less manual welding.
- Supplementary work for the customer, such as less need for floor levelling and preparation for floor coverings also is a major cost saving with FSW panels.

What is gained after the welding?

One of the most attractive features of friction stir welded products is that they are ready-to-use. No time consuming post-weld treatment such as grinding, polishing or straightening is needed. With proper design the elements are ready-to-use directly after welding. However, it is important to keep in mind that designs which are made for MIG or TIG welding, are not necessarily suitable for friction stir welding. The limiting factor often being the relatively high down-force needed when friction stir welding. A proper support in a form of backing bar or design change are often needed (Figure 2). Once done, repeatability reaches levels previously not experienced in welding.

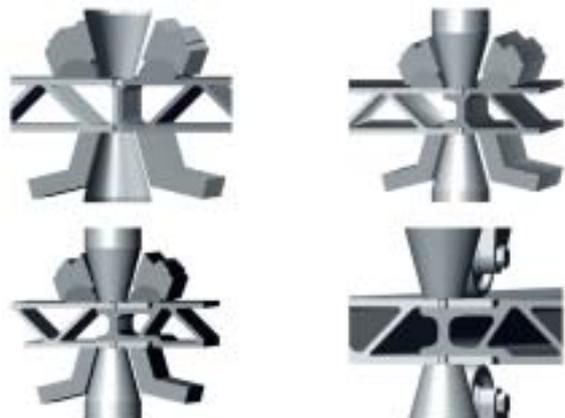


Figure 2. Designs suitable for friction stir welding of 2-skin profiles in aluminium. Illustration: ESAB

When producing large surfaces like walls or floors, besides the straightness of the panels, also the resulting reflections are an important and expensive issue to consider. A lot of time is spent polishing and "making-up" surfaces which are architecturally visible. In FSW prefabricated panels, the reflections are merely caused by the surface appearance of the aluminium plates and profiles in the as-delivered state, not by the reflections caused by welding heat input.

Why use aluminium instead of steel?

One excuse of not using aluminium has always been "that it is not as strong as steel." True – and not true. It, of course, depends also on the alloy to be used, and surprisingly enough, there are aluminium alloys which are as strong or even stronger than steels. For example the so called "ALUSTAR" has yield and tensile strengths comparable to low-alloyed steel S235. AlCu4SiMg (AA2014) – an alloy typically used in aerospace applications – has significantly higher strength than alloys in 5xxx- and 6xxx series which are typically used in shipbuilding. Some of these alloys just have not been used in shipbuilding before, due to their poor weldability!

With friction stir welding, some of these barriers can be overcome – just imagine, for example, using strong alloy AA7021 for making aluminium floor panels even thinner, and gain weight savings by "thinking differently". In Figure 3 the weldability of various aluminium alloys is shown as a reminder. The typical alloys used in shipbuilding are from 5xxx –series due to their good corrosion resistance, or from 6xxx –series due to the strength. A dissimilar combination between these two alloys is of course also possible (Larsson et. al. 2000).

An easy way to make small-scale pre-fabricated panels or components

Figure 4 gives an idea of relatively easy implementation of FSW in shipbuilding. ESAB's new LEGIO™ concept is ideal for fabrication of small batches of friction stir welded panels. The equipment is placed on the workshop right next to the assembly of the shiphull. The picture is from Estaleiros Navais do Mondego S.A. Shipyard in Portugal. Even small batches can effectively be welded on-site.

The LEGIO™ concept represents a modular, modern design available for friction stir welding. A series of standardised welding machines puts FSW at everyone's reach. Welds with highest quality are produced even in small batches. Table 1 summarises the range of machines available in the LEGIO™ system. A size "3" should cover the needs of most shipyards.

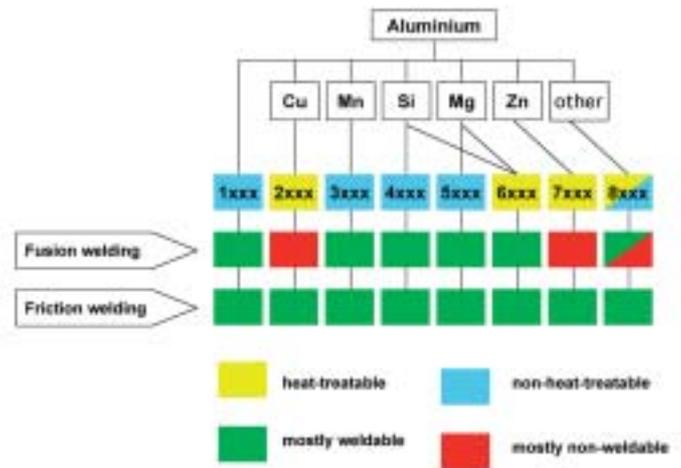


Figure 3. Weldability of different aluminium alloys. " TWI.



Figure 4. FSW LEGIO™ 3UT installed next to shiphull production line at Estaleiros Navais do Mondego S.A. Shipyard in Portugal.

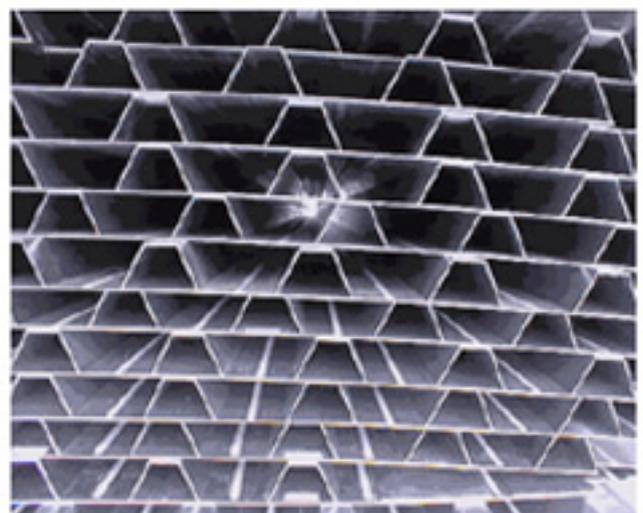


Figure 5. Hat profiles stacked for shipping. Definitely no straightening needed after the welding process. Photo: Hydro Aluminium.

Table 1. The family picture of the new modular LEGIO™ family for easy implementation of friction stir welding.

Size	Vertical downforce	Spindle effect	AA 6000	AA 5000	AA 2000 AA 7000	CU (oxygen free)
FSW 1	6 kN	3 kW	3 mm	2 mm	1.5 mm	0.8 mm
FSW 2	12.5 kN	5.5 kW	5 mm	3.5 mm	2.5 mm	1.5 mm
FSW 3	25 kN	11 kW	10 mm	7 mm	5 mm	3 mm
FSW 4	60 kN	18 kW	18 mm	10 mm	9 mm	7 mm
FSW 5	100 kN	22 kW	35 mm	20 mm	18 mm	12 mm
FSW 6	150 kN	45 kW	60 mm	40 mm	35 mm	25 mm
FSW 7	200 kN	90 kW	100 mm	75 mm	70 mm	40 mm

How to proceed?

Friction Stir Welding is much easier to implement than most other welding processes. The welding operator does not need any special skills, since the parameters are repeatable and high quality is easily achieved time after time. You don't need to be big and powerful to invest in Friction Stir Welding – the modular way. It may, however, make You big and powerful by shortening cycle times and improving the quality of Your products. Just dare to do it!

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About The Author:

Mr. Kari Erik Lahti graduated from Helsinki University of Technology, Finland, 1994 with a M.Sc. degree in welding technology. After working as a research scientist in the field of welding metallurgy, he joined Oy ESAB in Finland 1997 and started as product manager for welding automation. In 1998 Kari Lahti finalised his Ph.D. in "nominal stress range fatigue of stainless steel fillet welds" Since 2002 he has been working at ESAB AB Göteborg, Sweden, currently as marketing manager for advanced engineering products.

Efficient production of Stiffeners for Shipbuilding

By Herbert Kaufmann, ESAB AB, Welding Automation

ESAB's new IT-100 automatic T-beam welding machine offers highly productive, automated welding in an unmanned production environment to shipbuilders and other fabricators with a need to produce beams. Optimum welding speed, beyond 1m/min., is provided by double-sided tandem submerged arc heads. Web and flange are automatically longitudinally centered in the in-feed conveyor, whereas on-line straightening of the beams is provided by inductive heating, avoiding time-consuming post-weld straightening procedures.

1. Introduction

ESAB has marketed and distributed robust, manual T-beam welding equipment for many years, equipment design generally following market demand. Although, a typical T-beam welder was partly mechanized, all settings of the welding machine had to be carried out manually by an operator due to its prescribed welding procedures. Therefore, the design and control technology of such machines is fairly simple, relying heavily on highly skilled operators to produce parts of consistently high quality.

Many companies, especially shipyards, are experiencing increasing competition from many other worldwide operating enterprises. To survive, in an often tough and continuously shrinking market, shipyards must now find new ways to increase their internal productivity. One way to increase productivity is to increase factory automation. Production equipment whose design provides the factory with a higher degree of automation also increases efficiency and quality levels.

For example, modern control technology makes it also possible to schedule "tighter" production runs by pre-setting the production equipment with instruction sets important for unmanned operation. The control system can also be connected to an internal MRP system for even more efficient production efficiency.

As suppliers of state-of-the-art welding equipment, ESAB has seen an increasing demand for more sophisticated production systems equipped with the latest control technology. To meet this demand, ESAB has developed an automated T-beam welding system, which can be used in an unmanned production environment.

2. Equipment for T-beam Production

Situated upstream and downstream of the T-beam welding machine there are a number of material handling equipment cells, including:

- In-feed conveyor usually situated after a cutting machine.
- Grinding and shot-blasting equipment.
- Web raising station.
- Web alignment station upstream to the T-beam welder.
- T-beam welder with peripheral equipment.
- Out-feed conveyor with raising/lowering capability.
- Cooling bed.
- Straightening equipment.
- Shot-blasting equipment.
- Priming booth.
- Cutting equipment for notches and holes.
- Centralized control system.

Modern production equipment needs to be flexible to work efficiently in an automated environment. It is therefore of great importance to be able to integrate these work cells into a centralized computer system, which is then able to communicate with modern information systems (e.g. MRP).

2.1 In-feed conveyor

The beam welding system becomes more productive if the beam is supported and conveyed through the machine in a very precise manner. In other words, the precision of the in-feed conveyor will directly affect the precision of the finished beam (Figure 1).

A raising station situated upstream of the in-feed conveyor will place the web in the middle of the flange and

then feed it into the in-feed conveyor. The beam then stops after it passes through the first set of the vertical feed rollers. The flange width will be measured and its dimension will be transferred to the controller of the beam welder.

Even if the measured flange width differs along the beam length, centering the web exactly on the center of the flange now becomes easier. If the measured dimension of the flange is out of tolerance an alarm will sound and then the operator can decide if the target beam should be welded or not.

Before reaching the T-beam welder, longitudinal centering adjustment of the web and flange has been completed after the beam has passed through all three pairs of rollers. T-beams with a positive or negative value can be produced even though the offset defaults to "zero".

The traverse speed of the in-feed conveyor is synchronized with the beam welding speed, which is controlled by the T-beam welder.

2.2 T-beam welder

The newly developed IT-100 Automatic T-beam welding machine has been optimized for the production of symmetrical T-beams. With small modifications, the machine will weld other types of profiles and beams (Figure 2).

All pre-set values for the T-beam welder, for example, of the beam sizes and associated weld parameters can be made by the operator or obtained from a customer's production planning system. It is therefore possible to run the T-beam line with mixed production schedules of varying sizes of T-beams, without interrupting the ongoing production.

Several features of the new IT-100 Automatic are worth mentioning. With the IT-100 Automatic, beams can now be welded without having to tack weld the web and flanges. Another important improvement is the automatic centering feature which always positions the web into the center of the flange even if the flange width varies. Also, welding 5 mm from the start and the end of the T-beam guarantees efficient utilization of T-beam material for the finished beam.

The system's main controller is an Allan Bradley PLC type Control Logic 5550. Internal communication is via a DeviceNet bus. All external devices are linked to the controller by an Ethernet bus system. The controller also uses a modem for remote supervision, to make programme alterations, and to become assessable for service diagnostics from the outside. Installation and specific production parameters (welding parameters and work piece dimensions) can be entered from the operators panel (Panel View 600). The operator can protect all settings with passwords.



Figure 1. Infeed conveyor, front view.

Technical data:

Length of infeed conveyor	6000 mm
Height of conveyor	720 mm
Weight	6 tons
No of flange/web rollers totally	6 (3 pairs of rollers)
Rapid speed max.	16 m/min

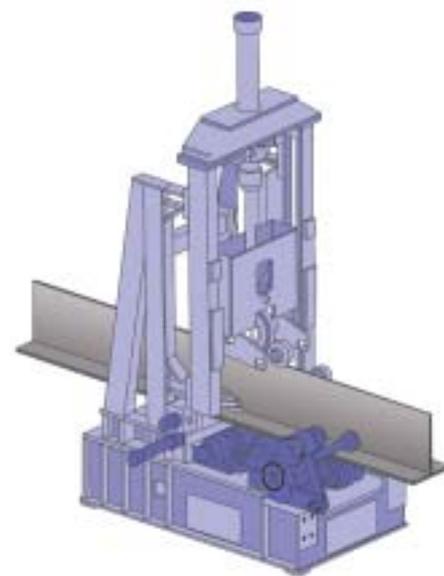


Figure 2. ESAB's T-beam welder IT-100 Automatic.

Technical Data

Width of Flange	102 – 600mm
Thickness of flange	10 – 41mm
Height of Web	150 – 915mm
Thickness of Web plate	6 – 25mm

The controller is also equipped with a built-in quality monitoring system. Parameters such as axis position, weld speed, voltage and current deviations are continuously monitored. Alarms will sound if parameters are outside predetermined limits.

By tracking the consumption of consumables (wire and flux) the IT-100 Automatic will generate an alarm in good time before new wire or flux needs to be loaded.



Figure 3. Platform for storage of peripheral equipment.

2.3 Platform

To save space all essential components have been placed on a platform located over the T-beam welders and parts of the in-feed conveyors. The corresponding span is approximately two parallel T-beam lines (10 x 8 Meters) (Figure 3).

Essential components include control cabinets, a flux feeding system, and the hydraulic power unit and cooling units. Additional space is also available on this platform for storing flux and wire. All cables including main power connections are installed in cable trays underneath the platform. Fences surround and guard the platform area which is accessible only through two sets of stairs.

3 Beam straightening methods

Another important feature in ESAB's new T-beam welding line is the ability to produce straight T-beams with a high degree of precision and repeatability without utilizing a "post-weld" straightening procedure. Any necessary straightening process is done during the welding phase and, therefore, subsequent manual straightening procedures are unnecessary.

Due to the heat input from the welding process, the finished beam will have a certain positive camber (bow). Without ESAB's straightening process a typical camber for a 16m long beam would be between 60 and 100mm, depending on the amount of heat input during the welding process. Corrective straightening operations afterwards will most likely adversely affect the beam's accuracy and straightness and possibly introduce other residual stresses in the beam.

Cutting notches or holes into the beam after the straightening process will affect the straightness of the beam, again because of the release of some of the remaining stress in the beam section.

There are different production methods used to produce straight beams. In the following section there are four different straightening methods discussed.

3.1 Mechanical Flange straightening

- Manual operation requiring a special machine.
- Must be done by skilled operators.
- Time consuming process.
- Cannot be done during welding.
- Risk of buckling distortion in the web.
- Many types of distortion phenomena can be corrected.

3.2 Manual Flame straightening

- Difficult to achieve high accuracy.
- Time consuming process.
- Use of water after welding causes corrosion problems in subsequent operations.
- Must be done by skilled operators.
- Many types of distortion phenomena can be corrected.

3.3 Flame straightening with Propane burners mounted to the T-beam welder (Figure 4)

- Heated simultaneously during welding.
- Difficulty predicting heat input.
- Manual setting of heat input.
- Poor repeatability.
- Distortion in only one dimension can be corrected (Camber).



Figure 4. ESAB's T-beam welder IT258 with Propane torch heating/straightening.

3.4 Induction line heating straightening

Both mechanical and thermal straightening techniques are used to straighten beams subjected to plate shrinkage. Mechanical straightening requires large, expensive machines, which produce process "wrinkles". As with thermal straightening, this technique adds another step to the beam production line.

Thermal straightening requires that the opposite (upper) side of the beam is heated – which later induces a compensating shrinkage. This is supposed to compensate for the initial shrinkage induced during the welding process mentioned above and can be done with Propane burner heating (see 3.3). The use of

induction heating equipment (Figure 5 + 6) offers several advantages:

- The concentrated heating produces a higher straightening effect.
- Less risk of overheating the surface.
- No noise.
- Direct heating of the beam produces less heating of the environment.
- No toxic fumes.
- Heat input is controlled.
- Good temperature control.
- Excellent repeatability.
- Heat input can be set automatically (programmable).

Induction heating is easy to adapt to an existing line. The required power for an induction heating system for larger T-beam production is approximately 60 to 100 kW (EFD:s Minac 60 or 100 Dual system). The use of a Dual system (with two coils) is recommended where one heating coil is used simultaneously on each side of the Web.

By balancing the power input at Curie temperature, this system can be, “self-regulating”. The rapid heating allows the thermal straightening to be done at the same time as the welding providing a one-step production procedure. This is very cost effective due to substantial reduction in manpower and energy consumption.

When an alternating current flows through a coil, eddy currents are induced in a metal object placed inside the coil. Heat is developed where these eddy current flows.

On the other side of the T-beam an identical induction coil with guide rollers heats the hub.

4. Welding Process

The IT-100 submerged-arc welding (SAW) configuration uses two single wires (DC+ AC) on each side of the web (Figure 7). The torch arrangement uses a leading DC wire and a trailing AC wire. Offset between the wires is 12 mm. Power sources include the LAF 1250 and TAF 1250. The welding controller is an Allan Bradley PLC type Control Logic 5550

4.1 Welding Equipment

The power sources proposed for this application are the LAF 1250 DC power source and the TAF 1250 AC (square wave) power source.

The welding system includes ESAB's well-proven and reliable A6 components. Each of the welding torches can be adjusted in three dimensions using slides and scales for accurate set-up. Wire drums (365 kg) are placed on the platform above the beam welding machine. All wire feeders and wire straightening settings are also equipped with scales for easy adjustment after changing wire.

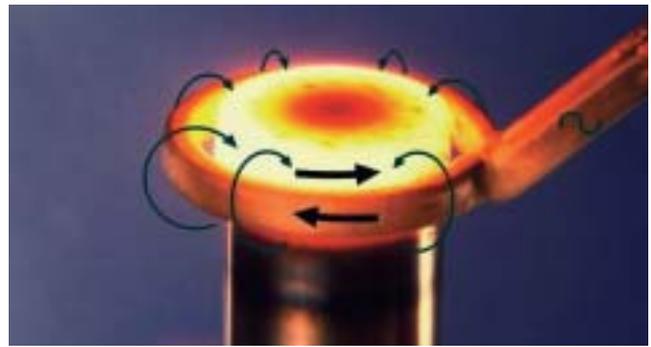


Figure 5. Induction heating principle.

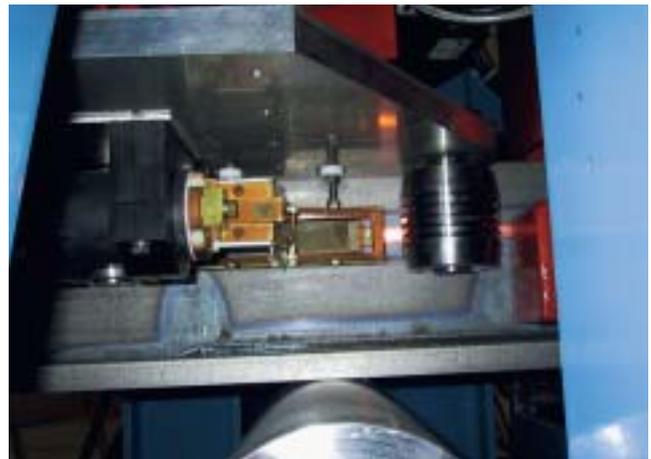


Figure 6. Induction coil with guide rollers during heating for straightening of T-beams.



Figure 7. DC-AC Torch arrangement in ESAB's T-beam welder.

4.2 High speed SAW welding

Weld undercuts and arc blow due to welding at higher currents are often the limiting factor for welding speed. In most situations multiple wires allow elongation of the arc heat source to enable faster welding without undercuts. To avoid or reduce arc blow, the best solution is a tandem welding arrangement using a leading DC and a trailing AC torch.

Weld speeds above 1 m/min can be easily achieved. For high speed quality welding, it is also important to weld on clean plates free of mill scale and rust. Shot blasting or grinding of all original parts is essential (Figure 8).



Figure 8. Cross section of welded T-beam.

5. Theoretical analysis of the distortion after welding a symmetrical T-beam

The intense heat input from the welding process and the molten steel, which is deposited into the joint, contribute to thermal expansion and contraction of the heated parts. Also residual stresses released in the rolled and raw-cut material will have some influence on the final shape of the beam.

If the welding is done on only one side of the web the plate will bend upwards and sideways (sweep and camber). If two welds are done simultaneously, one on each side of the web, the beam tends only to exhibit beam-camber due to the shrinkage produced after welding.

Distortion can be minimized in symmetrical designs by applying the heat into the material in a symmetrical manner. The remaining distortion on the final part can rarely be tolerated in subsequent assemblies and must be eliminated with thermal or mechanical methods (see part 3 above).

5.1 Type of distortion in symmetrical T-beams:

Camber:

Bending distortion produced by longitudinal shrinkage upwards. Can be neutralized by applying similar heat input as during the welding process into the upper part (above the neutral axis) of the T-beam.

There are different methods to calculate the size of the camber. With modern CAD systems, mathematical and thermal problems can be modeled easily. The biggest challenge is to determine the heat transfer and the associated distribution in the beam that is needed as input for the calculation. Traditional methods of determining the size of the camber use established beam bending theory (within the elastic range of distortion) where the beam is exposed to compressive forces and torque on each end of the beam:

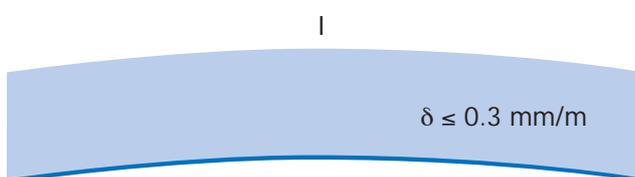


Figure 9. Camber. δ

$$(1) \delta = M \times L^2 / 8 \times E \times I = P_w \times b \times l^2 / 8 \times E \times I$$

Where

δ = Camber in mm.

P_w = Shrinking force in N.

L = length of beam in mm.

E = modulus of elasticity in N/mm².

I = moment of inertia in N/mm⁴.

b = distance from flange to neutral axis.

Shrinking force “ P_m ” per mm² for different welding methods has been determined by Malisius (see references below). Typical shrinking forces for fillet welds are 6300 N/mm²

With this formula, an approximate camber value can be easily calculated. For a beam web size, flange size, and total length of 475 x 13mm, 125 x 25mm, and 16m, respectively, a resultant camber of 53mm is calculated assuming a fillet weld on each side (leg length = 8mm).

The result in this case seems to be too small compared with empirical data found in the field. The difference can perhaps be explained by considering additional forces associated with the shrinking effect of the flange. One effect could be attributed to the temperature difference between the web and the flange measured at the welding site. The temperature difference seems to be the reason why the flange (but not the web) length increases by δl during welding. The heat will enter into the flange much faster than the Web because the cross sectional area of the flange is much smaller than the web's.



Figure 10. Elongation of flange during welding

$$(2) \delta l = \delta T \times \alpha \times l$$

if $\delta T = 30$ degrees, $\alpha = 11,7 \times 10E-7$ and $l=16m$ then is $\delta l = 5.3mm$

Shrinking force P_{ax} which will reduce the beam length by δl

$$(3) P_{ax} = A \times \delta l / l \times E \text{ (Hookes law)}$$

If $A =$ area of flange $125 \times 25mm = 3125mm^2$ and $E = 210 \text{ MN/m}^2$. With the known figures the shrinking force $P_{ax} = 220000 \text{ N}$

However, it is difficult to determine the temperature difference δT . An average temperature must be used as the temperature distribution in the flange depends on the mass ratio between the web and the flange.

The total shrinking force becomes:

$$P = P_w + P_{ax} = 403200 + 220000 = 623 \text{ kN}$$

By using formula (1) again the total camber Δ now becomes 82 mm. This is more in line with the empirical results.

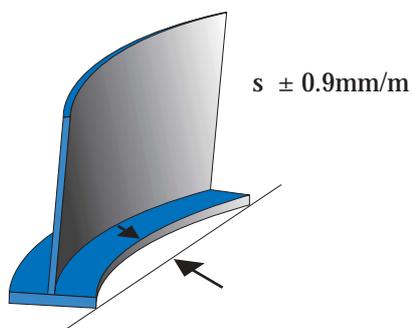


Figure 11. Sweep.

Sweep:

Bending distortion due to longitudinal sideways shrinkage caused by unsymmetrical welding heat input (e.g. different weld parameters in fillet welds or big longitudinal offset between torches).

The sideways sweep phenomenon can be calculated in a similar way, but its associated shrinking force must be determined experimentally. It is important to limit unsymmetrical heat input to the beam and also to make sure that the web is centered and perpendicular to the flange (Figure 11).

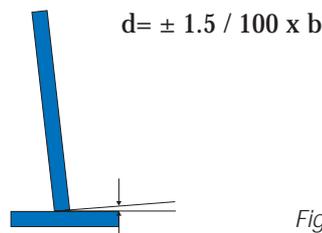


Figure 12. Perpendicularity.

Perpendicularity between web and Flange:

Perpendicularity deviations are usually caused by using different weld parameters for fillet welds or from big longitudinal offset between torches (Figure 12).

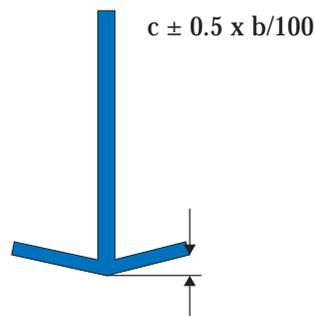


Figure 13. Angular Change.

Angular Change (of flange) in fillet weld:

Caused by different temperatures between top and bottom of flange. Bending distortion caused by transversal shrinkage sideways and upwards (Figure 13).

Release of Residual stresses from previous heat treatment and rolling operations:

Residual stresses contained in the raw sheet material due to milling and cutting operations will have an unpredictable impact on the straightness of the finished part. It will particularly influence the repeatability of the straightening process.

Summary of all types of beam distortions

Type of distortion	Reason	Measure
Camber	Bending distortion by longitudinal shrinkage upwards.	Can be neutralized by applying heat on top of the T-beam (see point 3 above).
Sweep	Bending distortion by longitudinal shrinkage upwards. Unsymmetrical heat input from the welding process (different weld parameters in fillet welds. Big longitudinal offset between torches).	Perpendicularity (see below) needs to be corrected. Change setting of weld parameters and reduce offset of torches.
Perpendicularity (between Web and Flange)	Different weld parameters in fillet welds, big longitudinal offset between torches.	Change weld parameters and reduce torch offset.
Angular change (of flange)	Caused by different temperatures between top and bottom of flange. Bending distortion by transversal shrinkage sideways and upwards.	Use mechanical "pull down" straightening feature of T-beam welder.
Release of residual stresses	Releasing of residual stresses from earlier heat treatment and rolling operations of raw material.	Use heat treated material, use cutting process with lower heat input.

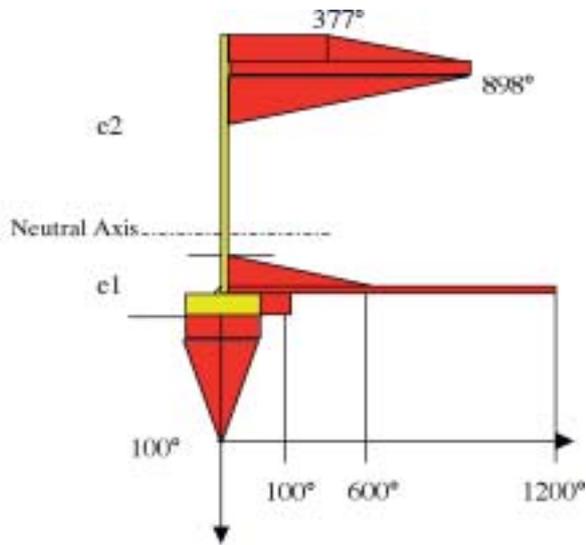


Figure 14. Heat distribution in a T-beam during the welding operation.

5.2 Straightening by line-heating

By applying heat to the top of the beam during the welding process it is possible to produce straight beams (see point 3.4). The theory behind this is to achieve a balance between the heat applied by the welding process (below the neutral axis of the T-beam) and by the heat applied by the proposed straightening process (above the neutral axis of the T-beam).

The best way to predict the required heat input of the straightening process is to create an empirical table with data derived from full-scale experiments. The final condition of the beam is usually obtained after approximately 1 hour after welding was finished. Theoretical calculations require a lot more data. Heat distribution in a beam can be measured and then be used as part of these calculations. The heat distribution in a T-beam (same size as used in above calculations) is shown in figure 14.

A beam is free from distortion (camber) when the heat input from the welding process can exactly be balanced by the heat input from the induction heater:

$$\sum \text{heat input above Neutral Axis} = \sum \text{heat input below Neutral Axis}$$

or expressed by formula:

$$(4) \int_w X_b \times f(x_{\text{weldtemp}}) dx = \int_H X_a \times f(x_{\text{heating}}) dx$$

(Temperature x length to neutral axis)

Where

X_b = distance to neutral axis (welding).

$f(x_{\text{weldtemp}})$ = heat distribution in the T-beam from welding process.

X_a = distance to neutral axis (heating).

$f(x_{\text{heating}})$ = heat distribution in the T-beam from heating process.

By solving the integrals in formula and by using the heat distribution as shown in the figure the heat input on both sides of the neutral axis must be equal.

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About The Author:

Herbert Kaufmann, M. El. Sc. and M. Mech. Sc., joined ESAB in 1988 as Technical Director at ESAB Automation Inc., USA. He is currently working as Project Manager within the Engineering Department of ESAB Welding Equipment in Laxå Sweden.

ESAB Railtrack FW 1000 aids fabrication efficiency of the world's largest aluminium yacht

Translation of an article first published in Laswijzer, the customer magazine of ESAB The Netherlands.

By: Guus Schornagel, ESAB, The Netherlands.

Improved welding efficiency has been a major consideration for Dutch boatbuilder, Royal Huisman, in the planning, design and construction of The Athena – the world's largest aluminium yacht. This has been achieved by implementing mechanised MIG welding with Railtrack FW 1000 for horizontal and vertical butt welds on the yacht's hull.



If you can dream it, we can build it. The making of a sailing yacht is an intense synergy between art and science, between heart and hand: It is a striking harmony between rough sketches on foolscap and crisp printouts on mylar; a translation of vague mental conception into hard-edged lofting; a focusing of diffuse artistry into plasma-sharp cutting; the landing of euphoric flights of imagination by a micro chip's swift calculation. (Excerpted from "Juliet: The Creation of a Masterpiece" text by Jack A. Somer and photographs by Peter Neumann).

Royal Huisman

The history of this Dutch yard dates back to 1884 when the Huisman family started to build many different types of wooden boat. From 1954, all boats were fabricated in steel and, in 1964, the yard was among the first in Europe to construct boats in aluminium. In the following years, Huisman expanded this specialisation to the point where, today, all their products are made from aluminium. The company's in-house motto is "if you can dream it, we can build it."

The yard employs some 325 personnel, including those of Rondal, a supplier of masts, deck fittings and winches. Huisman personnel work directly for the customer which results in a high degree of flexibility and efficiency during the build process. The yard has its own advanced composites department, painting halls, and

an advanced furniture workshop that produces internal designs to satisfy the wishes of individual clients. Huisman is renowned for its global customer base. The legendary Flyer I and Flyer II, winners of the Whitbread Race around The World, with captain Connie van Rietschoten, are perhaps the most famous examples of Huisman's performance.

The Athena

On November 22 in 1999, after a year of intensive preparation and design, the contract was signed for the construction of the world's largest three-master schooner - The Athena. With a total length of almost 90 meters, she is the largest yacht ever to be constructed in aluminium. The Athena project came to life on the drawing board of designers Pieter Beeldsnijder and Gerard Dijkstra and will be completed in September 2004.

Significant features of the vessel are:

- total length: 90m
- width: 12.20m
- depth: 5.5m
- three 60m masts
- two 2000 HP Caterpillar engines
- weight: 982 ton
- total sails surface: 2474 m²
- crew: 21 persons

The hull, produced in Huisman's indoor hall, took one year to construct. Hulls are usually constructed up-side down. However, the unusual dimensions of The Athena made it necessary to build in the upright position.

The welding

The construction of a ship hull requires an enormous amount of welding. Traditionally, manual MIG welding was applied for horizontal and vertical butt joints in the hull. However, the scale of this project made higher welding efficiencies and economies very important.

In close cooperation with ESAB's product specialist, Piet Lankhuyzen, the possibilities of using ESAB Railtrac equipment were investigated.

Demonstrations and tests were carried out at the yard and further production advice was offered by another yard, Barkmeyer in Stroobos, that had several years of satisfactory experience with Railtrack equipment. Royal Huisman finally opted for ESAB's Railtrac FW 1000 Flexi Weaver with a 30 meter long rail and vacuum suction brackets. The thickness of the hull plates varies between 10 and 15mm and the equipment is used for both horizontal as well as vertical joints. The welds are primarily built-up in three layers, one root pass and two cap beads.

Production experience

Huisman's production manager, Henk Petter, is very satisfied with the results so far. He cites "reduced arc time, the consistent weld quality, the absence of lack of fusion defects, and, very importantly, the fact that the work has become less strenuous for the welders" as the most appealing improvements.

"The welders have been involved right from the start", says Henk, "which facilitated the implementation and acceptance of the new technology. The close co-operation between the yard and ESAB has played a crucial role in this process."

Railtrac FW 1000

- Suited for welding magnetic and non-magnetic materials in all positions.
- Quick fit-up and user friendly.
- 5 programmable settings.
- Calibrated settings in cm, mm and seconds.
- Programmable function for crater fill-up.

- Instructive handbook for programming.
- Flexible rail without rack made of standard aluminium profile.
- Rail can be lengthened or shortened as required.
- Optional unit for torch angle adjustment.
- Tilting weaving unit for fillet welds (optional).
- Rotatable weaving unit for horizontal movements on vertical slanting joints (optional).
- Hovering head for mechanical height adjustment (optional).
- Remote control for parameter setting.



About the author

Guus Schornagel joined ESAB in 1966, and until his retirement in 2001 he had various technical-commercial positions, among others as PR manager for ESAB The Netherlands. Currently, he works as a freelance technical writer for Laswijzer, the customer magazine of ESAB The Netherlands.

How much heat can various steels and filler metals withstand?

By Juha Lukkari, ESAB Oy, Helsinki, Finland and Olli Vähäkainu, Rautaruukki Steel, Raahе, Finland

The mechanical properties of welded joints and, in particular their quality in production welds, is amongst the most important considerations when developing welding procedures. High heat input (welding energy), in particular, weakens the toughness properties of welded joints.

The cooling rate determines the properties. The mechanical properties of a welded joint significantly depend on the cooling rate of the joint, and this in turn is influenced by the heat input (welding energy), plate thickness and working temperature (inter-pass temperature). The most significant microstructure changes from the viewpoint of the properties of the weld metal and the heat-affected zone take place during the cooling of the joint within the temperature range of 800-500°C. It is usually the cooling time $t_{8/5}$, i.e. the time required for this temperature range to be passed, which is used to describe the cooling rate.

It is recognized that high heat input (kJ/cm, kJ/mm), i.e. a long cooling time $t_{8/5}$ (s) weakens the mechanical properties of the joint - both its tensile strength and impact toughness. Toughness is generally more sensitive than tensile strength to high heat inputs. For example, heat input is high when the welding speed (travel speed) is low, as shown in the equation:

$$\text{Welding energy} = \frac{\text{Welding current} \times \text{Arc voltage}}{\text{Welding speed}} \quad (\text{arc energy})$$

$$E = \frac{6 \times I \text{ (A)} \times U \text{ (V)}}{1000 \times v \text{ (mm/min)}} \quad (\text{kJ/mm})$$

$$\text{Heat input} = \text{thermal efficiency factor} \times \text{welding energy (arc energy)}.$$

$$Q = k \times E \text{ (kJ/mm)}$$

Thermal efficiency factor (EN 1011-1):

- Submerged arc welding: 1
- MIG/MAG and MMA welding: 0.8

Figure 1 shows schematically the effect of cooling time on the hardness and impact toughness of the heat-affected zone. Optimal properties will be obtained for the joint when the cooling time is within range II.

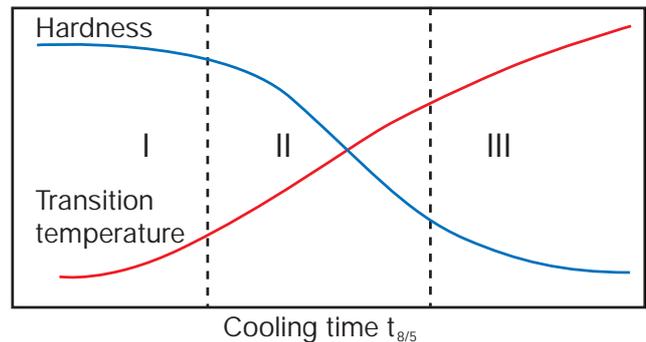


Figure 1. Effect of cooling time on the hardness and the impact toughness of the heat-affected zone of the welded joint.

When cooling time is short, i.e. when the weld cools quickly (e.g. low heat input or considerable plate thickness), the hardness within the heat-affected zone increases greatly as does the tendency to hydrogen cracking because of hardening. On the other hand, the impact toughness properties are good, i.e. the transition temperature is low. Likewise, if the cooling time is very long, hardness will remain low but the impact toughness properties will be impaired, i.e. the transition temperature rises to higher temperatures and tensile strength may decrease.

Heat input to be restricted

To ensure sufficient impact toughness in the welded joint, it is necessary to restrict the maximum heat input. This need to restrict maximum heat input is so much the greater, the more demanding is the particular steel's impact toughness (i.e. the lower the guarantee temperature of the impact toughness is), the higher its strength class and the smaller its plate thickness.

When the issue is that of impact toughness requirements at -40°C or lower, for example when applying thick welds in submerged arc welding applications, then the upper limit for heat input is of the order of 3-4 kJ/mm.

High heat inputs cause powerful grain size growth within the overheated heat-affected zone, immediately adjacent to the fusion line. Moreover, this causes the formation of microstructures, within the heat-affected zone, that are disadvantageous from the viewpoint of ductility; for example, grain-boundary ferrite, polygonal ferrite and side plate ferrite. Furthermore, impurities (sulphur and phosphorus) segregate to the grain boundaries, which also impairs ductility. Similar characteristics also apply to the weld metal.

Rautaruukki is, possibly, the first, steel mill in the world to have drawn up heat input graphs for its production steels. The graphs were based on the results of extensive tests in which fine-grained steels were subjected to different heat inputs for welding. Impact toughness was tested by studying different zones in the welded joints.

The lower the heat input, the more passes have to be made, and the lower, generally, is the deposition rate. This has the effect of diminishing the productivity of welding. The general aim is to use high heat inputs, which is restricted by the heat-input limits issued by the steel mill on a particular steel grade. Rautaruukki has published heat input restrictions on its steels in the form of welding energy or heat input graphs, e.g. in the booklet *Hitsaajan opas (Welding guide)*, Figure 2.

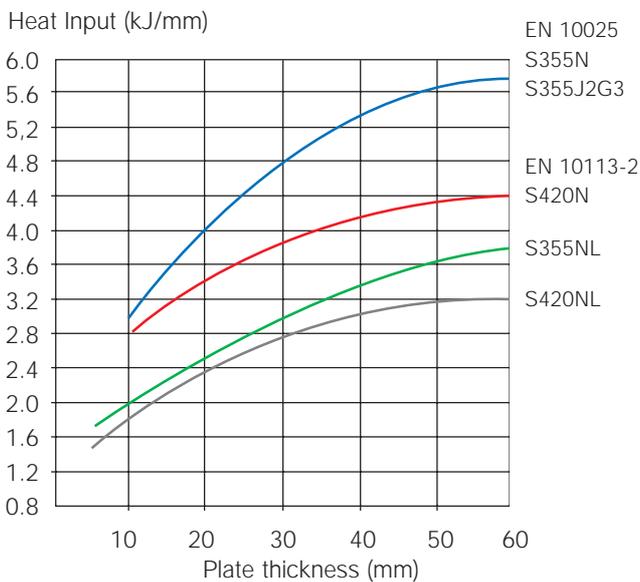


Figure 2. Heat input limits for Rautaruukki steels when welding butt joints.

Restricting heat input can also be indicated by means of cooling time $t_{8/5}$. Rautaruukki presents the maximum allowable cooling times for various steel grades in the booklet, Table 1. The booklet also sets out the instructions for determining cooling times, which can be done by calculation, or graphically by means of a nomogram.

Steel grade EN	$t_{8/5}$ 1) (s)	T 2) (°C)
S355J2G3 (= Fe52D)	30	-20
S355N	30	-20
S355NL	20	-40
S420N	25	-20
S420NL	15	-40
S355M	40	-20
S355ML	30	-50
S420M	35	-20
S420ML	25	-50
S460M	35	-20
S460ML	25	-50
S500M	35	-20
S500ML	25	-50

- 1) Cooling time $t_{8/5}$.
- 2) Testing temperature for impact toughness.

Table 1. Maximum values for cooling time $t_{8/5}$ as issued for Rautaruukki steels.

Rautaruukki repeats research

Since the publication of the first heat input graphs, in 1972, Rautaruukki has conducted many studies into the effects of heat input - most recently in 2001-2002. On the basis of these tests, the heat input recommendations for the foremost Rautaruukki hot-rolled steels will be reviewed and where necessary the instructions will be reformulated. By applying the heat input recommendations it will be possible to ensure maximum productivity of welding joints along with the impact toughness and tensile strength firmness requirements imposed on joints.

The plate thicknesses used were 12mm (two-run welds, not reported in this shortened article), 20mm and 40mm. Submerged arc welding, which readily enables high heat inputs, was the process applied. The heat input in the tests varied between 20 and 80 kJ/cm.

The first group comprises conventional and commonly used steels, fine-grained steel RAEX Multisteel (corresponds to EN 10025: S355J2G3 and S355K2G3) and the general structural steel S355J2G3 (EN 10025):

- Strength properties: $R_{eH} = \min 355 \text{ N/mm}^2$ ($\leq 16\text{mm}$) and $\min 345 \text{ N/mm}^2$ ($s \geq 16 \leq 40\text{mm}$), $R_m = 490\text{-}630 \text{ N/mm}^2$.
- Impact toughness (RAEX Multisteel): $\min 40 \text{ J}/-20^\circ\text{C}$.
- Impact toughness (S355J2G3): $\min 27 \text{ J}/-20^\circ\text{C}$.

The second group comprised thermo-mechanically rolled (TM) steels, whose ability to withstand high heat inputs is, as is well known, good:

- RAEX 420 M/ML (EN 10113-3: S420M/ML):
 - Strength properties:
 $R_{eH} = \min 420 \text{ N/mm}^2$ ($s \leq 16 \text{ mm}$) and $\min 400 \text{ N/mm}^2$ ($s > 16 \leq 40 \text{ mm}$), $R_m = 500-660 \text{ N/mm}^2$.
 - Impact resistance (M): $\min 40 \text{ J/-20}^\circ\text{C}$.
 - Impact resistance (ML): $\min 27 \text{ J/-50}^\circ\text{C}$.
- RAEX 460 M/ML (EN 10113-3: S460 M/ML):
 - Strength properties: $R_{eH} = \min 460 \text{ N/mm}^2$ ($s \leq 16 \text{ mm}$) and $\min 440 \text{ N/mm}^2$ ($s > 16 \leq 40 \text{ mm}$), $R_m = 530-720 \text{ N/mm}^2$.
 - Impact toughness (M): $\min 40 \text{ J/-20}^\circ\text{C}$.
 - Impact toughness (ML): $\min 27 \text{ J/-50}^\circ\text{C}$.
- New markings: RAEX 420 ML = RAEX 420 ML OPTIM (EN 10113-3: S420 ML).
- New markings: RAEX 460 ML = RAEX 460 ML OPTIM (EN 10113-3: S460 ML).

The filler metals were the ESAB wire-flux combinations typically used with these steels, Table 2.

The wire-flux combination used with fine-grained steel RAEX Multisteel and the general structural steel S355J2G3 was the non-alloyed OK Autrod 12.22 + OK Flux 10.71 and for TM steels it was the nickel-alloyed OK Autrod 13.27 with flux OK Flux 10.62. This combination produces good impact toughness in multi-run welding down to -60°C .

Test plates were tested to determine their tensile strength by means of a transverse tensile test and their impact toughness was examined along different zones in the joint (weld metal, fusion line and heat-affected zone: fusion line + 1 mm and fusion line + 5 mm).

The impact test results are presented in Tables 3-6, and these results are dealt with in the following.

The results were good, some even surprisingly excellent. What else can one say when the entire joint withstands a heat input of 80 kJ/cm and when the impact energy persists at 100-200 J at test temperature of -50°C !

Impact toughness of 40mm joint

The results for 40 mm TM steel plates were extremely good and they easily met the requirements of Tables 3 and 4. The applied heat inputs were extremely high, 70 kJ/cm and 80 kJ/cm. S420 M/ML and S460 M/ML were able to easily withstand heat inputs as high as these and the impact energy of the heat-affected zone exceeds 100 J at the test temperature of -50°C . Even the weld metal would appear to be able to withstand this. In the case of steel S460 the value of the impact energy of the weld metal also exceeded 100 J at -50°C .

Wire, flux and weld metal	EN 756	EN 760
OK Autrod 12.22	S2Si	-
OK Flux 10.71	-	S A AB 1 67 AC H5
Wm: 12.22+10.71	S 38 4 AB S2Si	-
OK Autrod 13.27	S2Ni2	-
OK Flux 10.62	-	S A FB 1 55 AC H5
Wm: 13.27+10.62	S 46 6 FB S2Ni2	-
OK Autrod 12.34	S3Mo	-
OK Flux 10.62	-	S A FB 1 55 AC H5
Wm: 12.34+10.62	S 50 5 FB S3Mo	-

Table 2. The filler metals used in submerged arc welding and their EN classifications.

Also, steels RAEX Multisteel and S355J2G3 and their weld metals were surprisingly able to withstand heat inputs as high as 70 kJ/cm when impact resistance was tested at -20°C , Tables 5 and 6. However, the safe limit is most probably much lower than this.

It should be borne in mind that the impact toughness of the weld metal is also significantly affected by the weld structure (run sequence) and the reheating of following runs, which may be manifested in the tables for welds involving 45°, half-V, and 60°-V grooves. In the case of a weld having a different run sequence, the impact energy value could be different, e.g. it could be lower, even if the heat input were the same.

Impact toughness of a 20 mm joint

The heat input in welding TM steels was 55 kJ/cm. Steels and weld metals withstood such high heat inputs extremely well. Impact toughness was tested, at the required test temperatures, down to -50°C , Table 3 and 4.

When welding the steels RAEX Multisteel and S355J2G3 the heat input varied between 30 kJ/cm and 55 kJ/cm. The cooling times become considerably longer than when welding 40 mm plates even though the heat input is considerably lower. The maximum heat inputs appear to be excessive from the point of view of the weld metal, and the upper limit is perhaps around 45 kJ/cm with the impact test temperature being -20°C , Tables 5 and 6.

The same remarks concerning the run sequence apply in this case for impact properties of the weld metal as are mentioned for 40 mm plate.

Heat input and plate thickness

Heat input, alone, may be misleading. Heat input should always be considered together with plate thickness. These, together with the interpass temperature, specify the cooling rate of the weld.

The tables reveal, for example, that a heat input of 80 kJ/cm with plate thickness of 40 mm gives a cooling time $t_{8/5}$ of 59 s. With plate thickness of 12mm, the cool-

Plate thickness (mm)	Joint preparation	Heat input Q (kJ/cm)	Cooling time $t_{8/5}$ (s)	Number of passes	Impact test: location	Impact energy -20°C (J)	Impact energy -40°C (J)	Impact energy -50°C (J)
20	45°-1/2-V	55	98	5	Wm	177	162	155
					Fl	179	225	198
					Fl+1	240	205	162
					Fl+5	283	274	270
					Parent material	299	299	270
					Requirement: M	min 40	-	-
40	60°/90°-X	80	59	3+3	Requirement: ML	-	-	27
					Wm	136	73	44
					Fl	207	199	185
					Fl+1	243	233	242
					Fl+5	299	229	119
					Parent material	-	-	230
Requirement: M	min 40	-	-					
Requirement: ML	-	-	min 27					

Table 3. The impact toughness of welded joints in S420 M/ML steel.

- Submerged arc welding.
- Filler metals: OK Autrod 13.27+OK Flux 10.62.
- Preheating: No.
- Interpass temperature: 50-80 °C.
- Wm = weld metal, Fl = fusion line, Fl+1 = fusion line + 1 mm etc.
- Impact energy: mean of three tests.

Plate thickness (mm)	Joint preparation	Heat input Q (kJ/cm)	Cooling time $t_{8/5}$ (s)	Number of passes	Impact test: location	Impact energy -20°C (J)	Impact energy -40°C (J)	Impact energy -50°C (J)
20	45°-1/2-V	55	98	5	Wm	156	112	79
					Fl	127	71	63
					Fl+1	123	149	127
					Fl+5	228	188	181
					Parent material	214	191	173
					Requirement: M	min 40	-	-
40	60°/90°-X	80	59	3+3	Requirement: ML	-	-	min 27
					Wm	203	157	102
					Fl	210	164	156
					Fl+1	241	207	195
					Fl+5	261	258	168
					Parent material	-	-	326
Requirement: M	min 40	-	-					
Requirement: ML	-	-	min 27					

Table 4. The impact toughness of welded joints in S460 M/ML steel.

- Submerged arc welding.
- Filler metals: OK Autrod 13.27+OK Flux 10.62.
- Preheating: No.
- Interpass temperature: 50-80°C.
- Wm = weld metal, Fl = fusion line, Fl+1 = fusion line + 1 mm etc.
- Impact energy: mean of three tests.

Plate thickness (mm)	Joint preparation	Heat input Q (kJ/cm)	Cooling time $t_{8/5}$ (s)	Number of passes	Impact test: location	Impact energy 0°C (J)	Impact energy -20°C (J)	Impact energy -40°C (J)
20	45°-1/2-V	31	35	6	Wm	-	110	62
					Fl	-	101	31
					Fl+1	-	225	196
					Fl+5	-	104	45
"		37	45	5	Wm	-	129	55
					Fl	-	136	88
					Fl+1	-	207	160
					Fl+5	-	108	66
"		43	60	5	Wm	-	84	61
					Fl	-	109	56
					Fl+1	-	167	144
					Fl+5	-	91	91
"		55	98	4	Wm	-	100	57
					Fl	-	111	39
					Fl+1	-	179	136
					Fl+5	-	79	70
"	60°-V	50	81	2+1	Wm	42	25	17
					Fl	101	66	35
					Fl+1	115	78	37
					Fl+5	183	134	52
					Parent material:	-	114	64
					Requirement:	-	min 40	-
40	60°/90°-X	70	40	3+3	Wm	72	69	35
					Fl	111	63	35
					Fl+1	80	53	27
					Fl+5	105	51	27
"	45°-K	71	43	3+4	Wm	-	40	38
					Fl	-	109	70
					Fl+1	-	90	79
					Fl+5	-	175	174
					Parent material:	-	186	165
					Requirement:	-	min 40	-

Table 5. The impact toughness of welded joints in RAEX Multisteel.

- Submerged arc welding.
- Filler metals: OK Autrod 12.22+OK Flux 10.71.
- Preheating: No.
- Interpass temperature: 50-75 °C.
- Wm = weld metal, Fl = fusion line, Fl+1 = fusion line + 1 mm etc.
- Impact energy: mean of three tests.

ing time for the weld is the same (60 s) even though the heat input is only one-third of the above, i.e. 25 kJ/cm. Thick plates withstand considerably higher heat inputs than thin plates.

This research, leads to the conclusion that, when dealing with multi-run welding of thick plates, surprisingly high heat inputs can be used in submerged arc welding applications without impact toughness properties being excessively impaired.

Strength not a problem

When transverse tensile tests were performed on welded joints, the majority of the test specimens broke on the parent material side - all the results fulfilled the

requirements set on the parent material (not reported in this shortened article). Even the highest heat inputs of 70-80 kJ/cm did not soften joints to such an extent that this would have been essentially manifested in the tensile test results.

Summary

As a means of reducing labour costs and of improving productivity, maximum heat input must be applied when welding. However, in order that sufficient impact toughness properties might be obtained in the welded joint, it is at times necessary to restrict the maximum heat input. The need for restriction is so much the greater, the lower the temperatures at which good impact toughness properties are required, the greater

Plate thickness (mm)	Joint preparation	Heat input Q (kJ/cm)	Cooling time $t_{8/5}$ (s)	Number of passes	Impact test: location	Impact energy 0°C (J)	Impact energy -20°C (J)	Impact energy -40°C (J)
20	45°-1/2-V	31	35	6	Wm	-	95	61
					Fl	-	112	79
					Fl+1	-	178	125
"	"	37	45	5	Fl+5	-	43	19
					Wm	-	103	58
					Fl	-	120	60
"	"	43	60	5	Fl+1	-	132	52
					Fl+5	-	51	20
					Wm	-	113	52
"	"	55	98	4	Fl	-	80	44
					Fl+1	-	90	58
					Fl+5	-	74	45
"	60°-V	50	81	2+1	Wm	-	73	31
					Fl	-	57	32
					Fl+1	-	112	56
					Fl+5	-	50	29
					Wm	48	21	13
					Fl	47	31	20
40	60°/90°-X	70	40	3+3	Fl+1	55	35	25
					Fl+5	76	71	23
					Parent material:	-	43	28
					Requirement:	-	min 27	-
					Wm	70	56	27
					Fl	94	62	34
40	60°/90°-X	70	40	3+3	Fl+1	73	45	27
					Fl+5	104	46	33
					Parent material:	-	83	-
					Requirement:	-	min 27	-
					Wm	70	56	27
					Fl	94	62	34

Table 6. The impact toughness of welded joints in S355J2G3 steel.

- Submerged arc welding.
- Filler metals: OK Autrod 12.22+OK Flux 10.71.
- Preheating: No.
- Interpass temperature: 50-75 °C.
- Wm = weld metal, Fl = fusion line, Fl+1 = fusion line + 1 mm etc.
- Impact energy: mean of three tests.

are the tensile strength requirements, and the thinner the plate being welded.

The research showed that modern-day steels and welding filler metals can withstand surprisingly high heat inputs when welding thick plates and using multi-run arc welding.

In a light-hearted sense, one could say that the results for the heat-affected zones and weld metals were such that the "traditional impact toughness competition" between steel manufacturer Rautaruukki and filler manufacturer ESAB ended in a draw!

About The Authors:

JUHA LUKKARI
Is Head of Technical Service Department at ESAB Oy, Helsinki, Finland

OLLI VÄHÄKAINU
Is Product Manager at Rautaruukki Steel, Raahе, Finland

ESAB Brazil provides BrasFELS shipyard with extra FCAW productivity for offshore vessels

By: José Roberto Domingues, Technical Manager Consumables and Cleber J.F.O Fortes, Technical Assistant, ESAB Brazil.

The BrasFELS shipyard, in Angra dos Reis, Brazil is involved in the conversion of petroleum tankers to FPSO (Flotation-Production-Storage-Operation) vessels. OK Tubrod 75 all-position basic cored wire, a Brazilian development with European, US and Korean equivalents, passed the yard's extensive qualification tests to provide extra FCAW productivity.

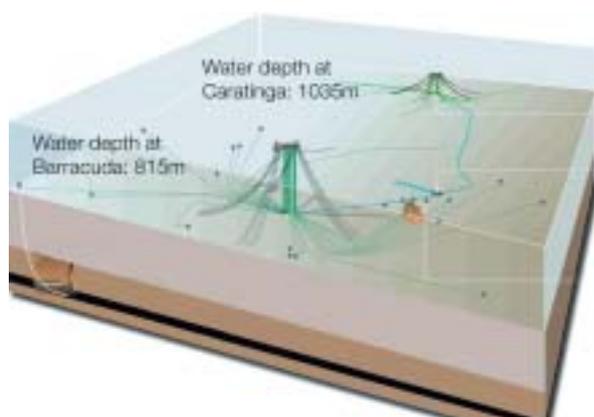


Figure 1. Barracuda & Caratinga Project.

Acknowledgement

We thank BrasFELS production management for their support in producing this article.

In Brazil, offshore fields supply 80% of the country's oil requirements, some 60% coming from very deep waters, underlining the importance of offshore operations for the Brazilian economy. As a consequence, there is a very high level of offshore activity.

BrasFELS has recently built two FPSO vessels for the Caratinga and Barracuda oil fields (Figure 1), and has another two FPSO vessels in its order book.

OK Tubrod 75

The Caratinga FPSO was completed earlier this year. Two consumables were widely applied, OK Tubrod 71 Ultra (E71T-1) for FCAW of components for a service temperature down to -30°C and the basic OK 55.00 (E7018-1) stick electrode for the welding of EH36 with a CVN impact requirement down to -40°C .

For the construction of the Baracuda FPSO, a higher welding productivity was required and the yard evaluated

other consumables and processes. Replacement of MMA with OK 55.00 by FCAW was considered a viable option for increased productivity, provided that the new consumable yielded at least the same mechanical properties. OK Tubrod 75, a development of ESAB's Brazilian cored wire factory, was evaluated by BrasFELS and was judged to be the best available.

OK Tubrod 75 is an all-position basic cored wire (E71T-5/E71T-5M) for use in both CO_2 and Ar/CO_2 shielding gas. For reasons of availability and optimum outdoor gas shielding, the BrasFELS yard prefers the use of CO_2 . Table 1 surveys the chemical composition and mechanical properties of OK Tubrod 75 in the as-welded condition. Table 2 gives an overview of the satisfactory results of tensile, bend, impact and hardness tests derived from the Welding Procedure Specifications in EH36. ESAB Brazil assisted the BrasFELS yard in the establishment of these procedures and obtained the necessary ABS approval (4SA, 4YSA H10).

Table 3 and 4 give the Welding Procedure Specifications in 2G and 3G positions for a 60° V-joint with a nominal root opening of 8mm and a land of 1mm, in 25mm plate thickness. Root passes are welded on ceramic backing strips.



Figure 2. Conversion to FPSO vessel.

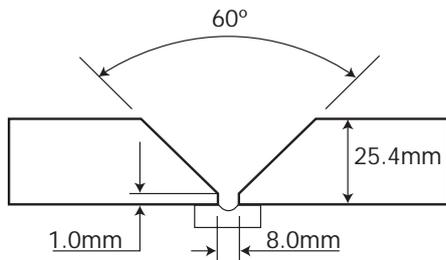


Figure 3. Bevel configuration.

Productivity

The conversion from MMA to FCAW yielded similar benefits in productivity as those previously achieved by BrasFELS when they introduced OK Tubrod 71 Ultra. The comparative performance of table 5 is based on a standard cost calculation applied by the yard. The resulting improvement in relative welding costs is nearly 35% which is a welcome reduction for any shipyard.

Note: OK Tubrod 75 is a local product for the Brazilian market. Basic ESAB types for offshore fabrication with a comparable performance are:

OK Tubrod 15.24 and FILARC PZ6125 for Europe. Dual Shield T5 for the US and Asia Pacific.

OK TUBROD 75

Typical chemical composition of the weld metal (%)

	C	Si	Mn
CO ₂	0.040	0.50	1.50
Ar+CO ₂	0.055	0.53	1.68

Typical mechanical properties of the weld metal

	Strength (MPa)	Yield (MPa)	Elong. (%)	Impact (J) at -40°C
CO ₂ (DC-)	480	400	22	90
Ar+CO ₂ (DC+)	480	400	22	40

Table 1. Typical properties of OK Tubrod 75.

DESTRUCTIVE TESTS

Tensile tests

2G	550 MPa, ductile fracture in base metal
	580 MPa, ductile fracture in base metal
3G	530 MPa, ductile fracture in base metal
	540 MPa, ductile fracture in base metal

Side bend tests: no cracks

Impact tests (J) at -40°C

	Weld centre	Fusion line	Fusion line +2 mm	Fusion line +5 mm
2G	36 / 44 / 48 av. 42.7	126 / 44 / 44 av. 71.3	30 / 40 / 30 av. 33.3	70 / 72 / 34 av. 58.7
3G	36 / 28 / 28 av. 30.7	22 / 58 / 76 av. 52.0	40 / 32 / 66 av. 46.0	90 / 56 / 52 av. 66.0

Hardness tests (HV5)

	Base metal	Weld metal	Heat affected zone
2G	157 - 185	201 - 236	185 - 286
3G	160 - 177	189 - 244	191 - 248

Table 2. Destructive tests.

WELDING PROCEDURE, 2G POSITION

Welding Process:	FCAW	Position:	2G
Base Material:	EH 36	Thickness:	25.4 mm
Filler Metal:	OK Tubrod™ 75 Ø 1.2 mm		
Classification:	AWS A 5.20 E71T-5 (M)		
Shielding Gas:	CO ₂ / 18 L/min		
Preheat:	21°C min.	Interpass:	250°C max.
Technique:	Maximum weave 25.0 mm		
Electrode extension:	10 - 15 mm		
Current / Polarity:	DC-		

Weld Layer	Current (A)	Voltage (V)	Travel Speed (mm/s)	Heat Input (kJ/mm)
Root	140	24	1.1	3.1
2nd Pass	130	24	3.5	0.9
Fill	160	25	4.7	0.9
Cap	175	25	4.7	0.9

Table 3. Welding procedure data, 2G position.

WELDING PROCEDURE, 3G POSITION

Welding Process:	FCAW	Position:	3G
Base Material:	EH 36	Thickness:	25.4 mm
Filler Metal:	OK Tubrod™ 75 Ø 1.2 mm		
Classification:	AWS A 5.20 E71T-5 (M)		
Shielding Gas:	CO ₂ / 18 L/min		
Preheat:	21°C min.	Interpass:	250°C max.
Technique:	Maximum weave 25.0 mm		
Electrode extension:	10 - 15 mm		
Current / Polarity:	DC-		

Weld Layer	Current (A)	Voltage (V)	Travel Speed (mm/s)	Heat Input (kJ/mm)
Root	150	23	0.6	5.8
2nd Pass	130	22	1.3	2.2
Fill	130	22	3.0	1.0
Cap	130	22	3.3	0.9

Table 4. Welding procedure data, 3G position.

COMPARATIVE PERFORMANCE

	Ø (mm)	Dep. rate (kg/h)	Net dep. rate (kg/h)	Relative cost (%)
OK 55.00	4.0	1.75	0.52	100
OK Tubrod 75	1.2	2.78	1.11	65.5

Table 5. Welding costs.

About the authors

José Roberto Domingues is Technical Manager Consumables for ESAB Brazil. He is responsible for the R&D and quality control of welding consumables and their applications. He joined ESAB in 1988.

Cleber J.F.O. Fortes is Technical Assistant in the field of arc welding consumables. He has been involved in welding for over 20 years, and joined ESAB in 2001.



Secure downhill MAG welding of butt- and fillet welds with ESAB OK Tubrod 14.12

Translation of an article first published in Fenster, the ESAB Germany customer magazine.

By: Dipl. Ing. Frank Tessin, ESAB GmbH, Solingen, Germany.

The downhill welding of fillet welds by the MAG process is regarded as an insecure method by many in the welding industry, and is, therefore, rarely used. Some German shipyards, however, have successfully developed and applied downhill welding procedures for thin-walled applications using OK Tubrod 14.12 metal-cored wire.

Root defects

Welding defects in the root of the weld, associated with downhill MAG welding, have made shipbuilders reluctant to apply this method, in spite of the productivity benefits offered by the process. Typical root defects are:

- Lack of penetration.
- The occurrence of slag or slag particles in the back of the root when using flux-cored wires.
- Lack of fusion when using solid wire.

Secure fillet weld penetration with downhill MAG welding

Ongoing development of the OK Tubrod 14.12 metal-cored wire has resulted in a consumable with a very secure penetration that avoids the above mentioned welding defects associated with downhill MAG welding. The weld penetration depth has been recorded between 1.3 and 2.0mm when using CO₂ shielding gas and between 1.0 and 1.5mm for M21 mixed gas. These depths are comparable to the very secure penetration



Figure 2a. Penetration, vertical down welding with solid wire.

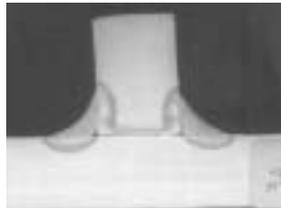


Figure 2b. Penetration, vertical down welding with metal powder wire XX (pos. pole).



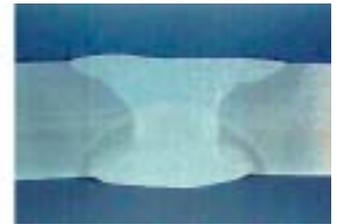
Figure 3. safe penetration in vertical down welding with OK Tubrod 14.12.



Root



Root with 1st final run



Root with final run on either side

Figures 4 to 6. building-up of runs, square butt weld, $t = 7$ mm; vertical down welding.

observed in uphill welding with rutile flux-cored wires. OK Tubrod 14.12 is normally welded with – polarity and welding parameters are carefully adjusted to obtain optimum weld penetration. With a single bead, fillet welds with a thickness of $a=2.5$ to 3.5 mm are perfectly feasible. Thicker fillet welds must be uphill welded with rutile flux-cored wire or downhill depositing multi-beads with OK Tubrod 14.12.

It is essential to avoid pushing-up the arc, in order to obtain a large fillet weld thickness. In this case, the arc will burn onto a large weld pool which will go at the expense of the good weld penetration.

Additional benefits

Additional benefits of the downhill MAG welding of fillet welds with OK Tubrod 14.12 are:

- A concave weld cross section without undercut.
- A smooth fine-rippled weld surface.
- A low heat input (4-5 KJ/cm).
- Minimal distortion.
- A high welding speed (50-70 cm/min.).

A new fabrication method for butt welds

Exploring the possibilities of this high penetration welding consumable, german shipyard HDW Kiel, tested the vertical down welding of butt welds. The results were remarkably positive and led to a completely new production technique by which I-joints, in plate thickness 3 to 7 mm, and V-joints, in plate thickness >8 mm, are welded extremely fast and without



Figure 7. Weld pool of the root layer.



2mm gap



3mm gap



4mm gap



5mm gap

Figure 8. I-butt, $t = 6$ mm. Gap bridging possibility of the OK Tubrod 14.12 at gap variation.

ceramic backing material. The I-joints are given a larger than normal root gap, and during welding a phenomenon occurs that has not been observed before in welding. Under the influence of the arc and the very hot weld pool, the plate edges are securely melted without any fusion faults, while the root is contracted along the centerline of the joint.

The root is exactly located in the neutral zone of the plates, resulting in a total absence of angular distortion due to shrinkage – a problem that is almost always present when welding thin plates and requires cumbersome straightening work.

A further benefit of this type of root is that it has a very smooth tie-in, avoiding fusion faults when welding subsequent layers.

This technique is applicable for plate thicknesses from 5-7mm. For thinner plates, the common two layer technique is being used, with a smaller root gap. With plate thickness above 8mm, there is a risk of fusion defects. Because of the high welding speed, the heat input is no longer sufficiently high to melt the weld edges thoroughly. This can be solved easily, however, by changing the joint to a V-design where the plate edges require less energy to be melted. From the yard's research it was concluded that the downhill welding of V-joints is possible up to plate thickness of 12-15mm. For the welding of I-joints up to 7mm thick, a few millimeters root gap tolerance is acceptable without leading to any problems (figure 8).

Metallurgically perfect

The welded joints are easily tested by X-Ray. Fusion faults introduced by lack of skill give clear indications. The excellent mechanical properties have been confirmed by various tensile, bend and CVN impact tests. Weld metal and HAZ hardness increase has not been observed.

A higher productivity and increased flexibility
Productivity calculations yield a welding time that is reduced by 80% for 4mm thick plate, compared with solid wire MAG welding. The savings on straightening work are even substantially higher. Even for 8mm plate, compared with rutile flux-cored wire, savings are achieved, apart from reduced straightening work.

Another aspect to be considered in relation to V-joints is the flexibility. Should fit-up work result in too large a root gap, one can always revert to uphill welding with rutile wire and ceramic backing. Root gaps that are too small can be covered downhill with OK Tubrod 14.12 metal-cored wire. Corrective work during fit-up of the joints is, therefore, never needed.

Conclusions and outlook

HDW has obtained approval from Germanischen Lloyd, Lloyds Register, and BWB for the welding of fillet welds and butt joints for shipbuilding steel grades A up to D36. The process has been used now for a couple of years and has resulted in clear savings and increasing weld quality. The fillet welds are slightly concave without undercut, and the weld surface is smooth with a fine ripple. The butt welds are narrow and show only a small over-thickness.

The vertical down welding of fillet welds with OK Tubrod 14.12 is relatively easy to learn and investment in new welding equipment is not needed. Welders will soon produce good quality welds, while applying the fast travel speeds involved. This is not equally valid for the vertical down welding of butt welds, however. It takes time for welders to develop the skill and to produce consistently high quality welds.

Vertical down welding with OK Tubrod 14.12 is nowadays the most economic solution for joining thin-walled plates. At the yards involved, it has become common practice to place constructions in the vertical position to benefit as much as possible from the economic advantages.

The new method will undoubtedly change the future of thin plate welding, in general. Further progress may be expected from consumable development and dedicated use of industrial shielding gas mixtures.

About the author

Frank Tessin, M.Sc, is Product Manager Cored Wires at ESAB in Germany.

He studied mechanical engineering and started working for ESAB in 1992.

Since two years, he is also Key Account Manager for ESAB's automotive business in Germany.

Thermal Beveling Techniques

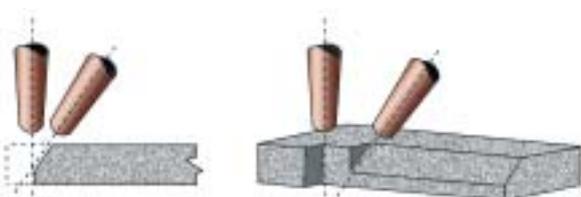
By: Arnaud Paque, ESAB Cutting Systems, Karben, Germany.

The article discusses the thermal beveling techniques available from ESAB highlighting several cutting processes and a variety of plate edge preparation applications.

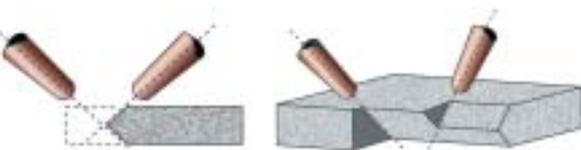
At first glance, the beveling of plate edges may look easy, but it requires considerable knowledge and expertise to build an installation that cuts accurately and fast and that is, at the same time, user-friendly. Over more than 70 years, ESAB Cutting Systems has used its global experience in cutting installations to further improve each generation of control units. The result is continuing improvements and simplification in programming and the use of cutting installations. This constant innovation, results in lower beveling costs, higher productivity, and increased customer competitiveness.

Bevel shapes

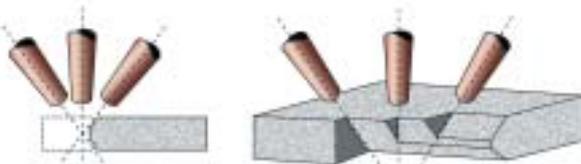
The welding of medium and large thickness plates requires a weld joint preparation which can be either a V-, Y-, K- or X- bevel, depending on the welding process, application and plate thickness.



V- and Y- bevels with an angle of 20 to 45° are normally used for plate thicknesses from 10mm to 75mm.



X-bevels with an angle of 20 to 45° are applied from 15mm to 75mm plate thickness.



K-bevels with an angle of 20 to 45° are used from 20mm to 75mm plate thickness.

Figure 1a, 1b, 1c. V-, Y-, X- and K- bevels

When welding, the accuracy of the angle and the cut quality are very important, but the straightness of the cut is critical. If it is not perfectly straight, the root gap will vary and unacceptable weld defects are more likely to occur; this apart from the fact that the joint volume increases and more filler material is needed.

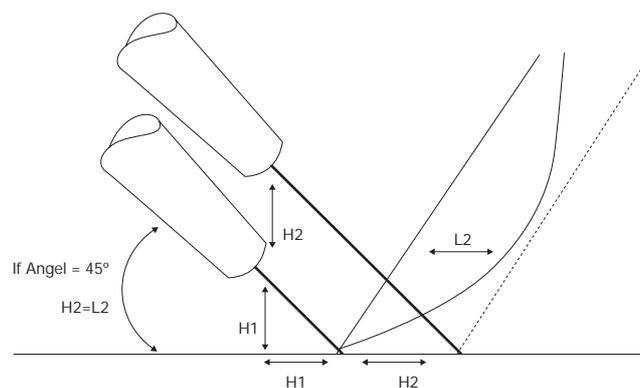


Figure 2. Cutting angle.

This is precisely the reason why ESAB has carefully designed high accuracy height control devices and incorporated them into all its beveling tools. These devices are independent from the cutting process itself, which varies with the cutting needs of fabricators.

Another important aspect for consideration is the cutting length. It is larger than the plate thickness and corresponds to the plate thickness/COS angle.

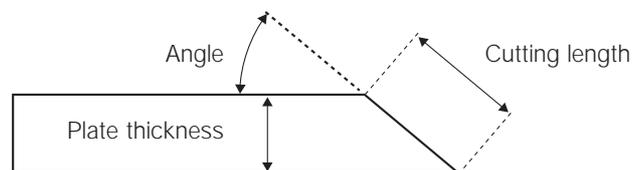


Figure 3. Cutting length.

Cutting processes

Different thermal cutting processes can be used for bevelling and all have their specific advantages:

Oxy-fuel cutting.

The earliest technology to be incorporated in gantry cutting machines, and still one of the most cost-effective cutting processes. Oxy-fuel cutting is, however, limited to the use of carbon steel and is not suited for aluminium, stainless steel, brass or copper. When used for bevelling, it is limited to a plate thickness of 75mm and a 45° angle.

Plasma cutting.

Can cut all electrically conductive materials, including stainless steel, aluminium, and copper alloys. Plasma cutting is the best choice for thinner materials, especially for non-carbon steels. The cutting speed is up to 6 times higher than with oxy-fuel cutting. The cutting thickness depends on the plasma source, but the process is commonly used for plate material up to 30mm thick.

Laser cutting.

The laser cutting process itself allows cutting carbon steel up to 30 mm, but the bevelling capacity does not exceed a plate thickness of 12mm. It provides an extremely accurate cut with a very small kerf width and an excellent edge quality, making any secondary machining process obsolete.



Figure 4. Manual bevelling head.

Weld edge preparation of a rectangular plate

When a plate just needs to be cut to the right size, in transverse and longitudinal directions, a manual bevelling head can be used (+/-90°). The angle setting from 15° to 45° is made manually, and the head can make a straight cut without contour.

The height of the head is adjusted via a wheel castor which guarantees a constant height control.

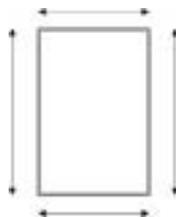


Figure 5. Manually rotatable head.

Main features:

- Floating device with castor wheel for cutting V-, Y-, K-, and X-bevels from ~10 to 75mm material thickness and capacitive height control for vertical cutting up to 120 mm.
- Up to 45° manual angle setting adjustment of the lateral torches.
- 200 mm motorised height adjustment.
- Manually rotatable head (+/- 90°) which can be installed on the SUPRAREX type of machines.

This solution provides a very good investment/performance ratio.

Weld edge preparation of a contour

This involves most of the applications requiring bevel shapes. In this typical case, the bevelling head follows the contour and must always be perpendicular to the contour. The ESAB numerical controller controls, in real time, the tangential position of the head relative to the contour, in order to guarantee optimal accuracy. The programming is easily achieved by the use of Auxiliary Functions (AF), enabling a full control by the NCE. The endless rotating head allows bevelling to any shape, even a spiral.



Figure 6. The endless rotating head allows bevelling to any shape.



Figure 7. The tangential position of the head relative to the contour.

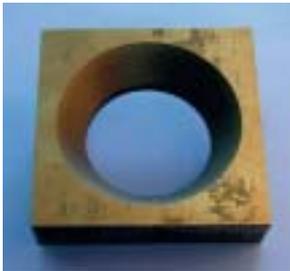


Figure 8. Up to 45° manual angle setting of the lateral torches.



Figure 9. The endless rotating head allows any kind of bevel shape.

Main features:

- Endless rotating head which allows any kind of bevel shape.
- Linear potentiometer height control with air cooled sensor foot, for bevel cutting of V-, Y-, K- and X-joints, offering:
 - Highly accurate bevel height control of +/- 0.3° for absolute cutting straightness, due to the external sensor foot.
 - The sensor air cooled foot has a long life cycle.
 - An air stream blown through the sensor foot ensures the removal of small slag particles and keeps the head at a constant height, resulting in less straightness variation.
- The sensor foot can be pneumatically lifted for position rotation and is equipped with a drop-off safety device for plate ends or holes.
- Up to 45° manual angle setting of the lateral torches and 70 to 185mm lateral torch adjustment.
- Vertical height setting via capacitive ring.
- 200mm motorised height control.
- The head is automatic (CNC) and infinitely rotated for contour. It can be installed on SUPRAREX machines, type P2 and P3.

Weld edge preparation of a contour and automatic bevel adjustment

This bevelling head has the same functions as the previous head, but all torch settings, such as lateral torch adjustment and bevel angle per torch, are fully CNC controlled.

In the fabrication of, for example, wind mill towers, it is quite common to connect plates of different thicknesses, requiring separate weld edge preparations. In addition, and also occurring in the shipbuilding industry, the joint angle varies from one side to another, or even varies continuously. In these cases, the numerical controller has to control and adjust the angle and the lateral torch adjustment, automatically.

The use of such a fully automated bevelling head guarantees:

- a high productivity, because the machine is not stopped at each change of bevel setting.
- a high accuracy due to the CNC controlled setting of the bevel angle.

All programming is easily achieved by using Auxiliary Functions, making this sophisticated head very easy to use.

Main features:

- Endless rotating (CNC) which allows any kind of bevel shape.
- CNC controlled lateral torches and angle setting.
- Linear potentiometer height control with air cooled sensor foot, for bevel cutting of V-, Y-, K- and X-joints, offering:
 - absolute high accurate bevel height control of +/- 0.3° for absolute cutting straightness, due to the external sensor foot.
 - The sensor air cooled foot has a long life cycle.
 - An air stream blown through the sensor foot ensures the removal of small slag particles and keeps the head at a constant height, resulting in less straightness variation.
- The sensor foot can be pneumatically lifted for position rotation and is equipped with a drop-off safety device for plate ends or holes.
- CNC angle setting of the side torches from 20° to 49° with lateral torch adjustment.
- Vertical height setting via capacitive ring.
- 200mm motorised height control
- This head can be installed on the NUMOREX and TELEREX machines.



Figure 10. Any kind of bevel shape is allowed by the endless rotating CNC controlled head.

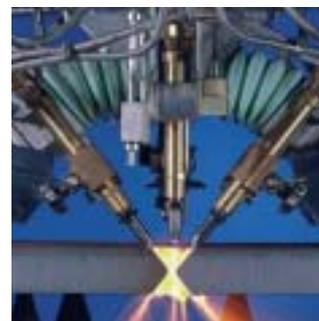


Figure 11. CNC angle setting of the side torches from 20° to 49° with lateral torch adjustment.

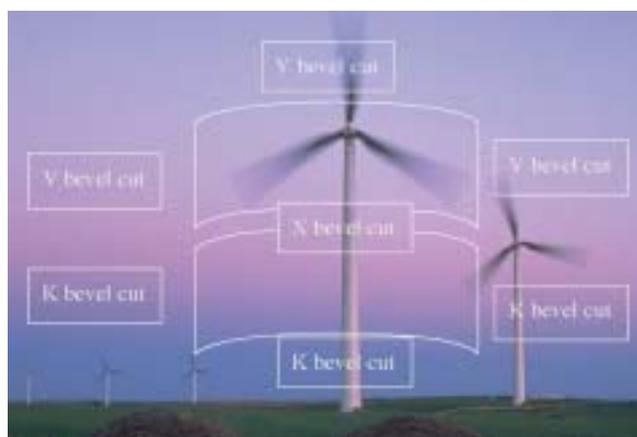


Figure 12. In the fabrication of windmill towers, plates of different thicknesses are often connected.

Weld edge preparation of a contour and automatic plasma bevel

This unit is the most robust and precise plasma beveling head. All electrically conductive material can be bevel cut from -45° to $+45^\circ$ with a fixed bevel angle, or continuously. The endless rotating head allows cutting of any shape. The plasma process cuts bevels up to 6 times faster than the oxy-fuel process, particularly on thin material. It is mostly used for cutting V-bevels or to compensate its own natural degree bevel angle on the cut face.

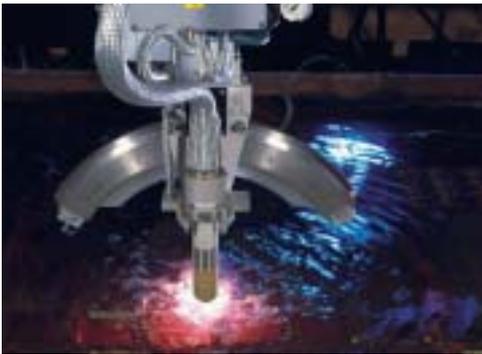


Figure 13. The precision plasma beveling head.

To reach optimal bevel straightness and cut part accuracy, ESAB has equipped their controller with automatic compensation software for all natural deviations of the plasma process:

- The plasma naturally generates a few degree of bevel angle.
- The bevel angle naturally varies somewhat with the material thickness.

In order to automatically compensate for these deviations, ESAB has created and integrated an organisation programme - which is a customer updatable database that compensates and guarantees the bevel degree accuracy to 1° . As many databases as necessary can be created depending on the material range.

As previously stated, height control is one of the most important factors to be considered. With the plasma process, the cutting arc length changes with the bevel angle and is, therefore, not accurate enough to be used



Figure 14. Bevel degree accuracy of 1° .

as a reference for the height control. Moreover, the condition of the consumables changes during their life-cycle. This is the main reason why ESAB very precisely controls the height with an external height foot sensor that guarantees extreme cut accuracy.

Industries, such as shipbuilding require specific beveling applications where the architecture of NCE programming brings out its full power. In fact, it's quite common in shipbuilding to create a panel with different plate thicknesses, which must also be bevel cut. In other words, all the power is inside the NCE, programming being easy and user-friendly. By also using the cutting parameters databases which can set all cutting parameters (amperage, gas pressure etc.), the machine can work automatically. In this typical application, straightness must be guaranteed, meaning that the NCE has to interpolate the plate thickness, in real time. With the organisation programme module and the cutting parameters database, this can be very efficiently achieved with the straightness being absolutely perfect for the welding application.



Figure 15. Panels with different plate thicknesses are common in shipbuilding.

Main features:

The bevel angle rotating point (angle-lateral calculation) can be automatically shifted from the upper to the lower side of the plate (depending on kerf and cutting direction).

- Bevel height control accuracy less than ± 0.3 mm.
- The bevel angle can be continuously (interpolated) changed within one linear contour block or within numerous following blocks.
- The programmed cutting speed will be continuously adjusted for the change of bevel angle.
- Bevel angle setting accuracy: $\pm 0.2^\circ$
- Straightness of the cutting edge: $\pm 0.5^\circ$ within 1000mm.
- The organisation programme module.
- Can compensate the angle variation up to $\pm 1^\circ$.
- Can consider the upper melting radius.
- Can reduce the repeatable dimension tolerances to ± 2 mm & bevel $\leq 30^\circ$ at 15mm thickness.
- Installation on NUMOREX and TELEREX type machines.

Weld edge preparation of a contour and automatic laser bevel

The laser head also facilitates automatic, low power cutting and marking sequences. Due to the narrow kerf and low heat distortion, the laser process enables, under certain circumstances, complex bevels such as Y, K, and X, to be performed in 2 or 3 paths.

The laser head can carry out a bevel cut from -45° to $+45^\circ$, fixed or tapered-off. The resonator is directly installed on top of the gantry enabling cutting and bevelling operations of up to 4.5 - 5m width with almost no limitation in terms of length. This is really convenient for the laser bevel cutting of long parts. The multi-axis bevel cutting head works with the highest level of precision. This ensures a smooth cutting process and results in a high quality laser cut.

Main features :

- Endless rotating head (CNC) which allows any kind of bevelling shape. To be installed only on the ALPHAREX range of machines.
- Bevelling capacity up to 45° on 10mm carbon steel and 30° on 12 mm carbon steel.
- CNC controlled lateral torches and angle setting.
- High accurate bevel height control via the capacitive nozzle.
- Less heat distortion.
- Y-, K- and X -bevels possible under certain circumstances.
- Marking and cutting possibilities.

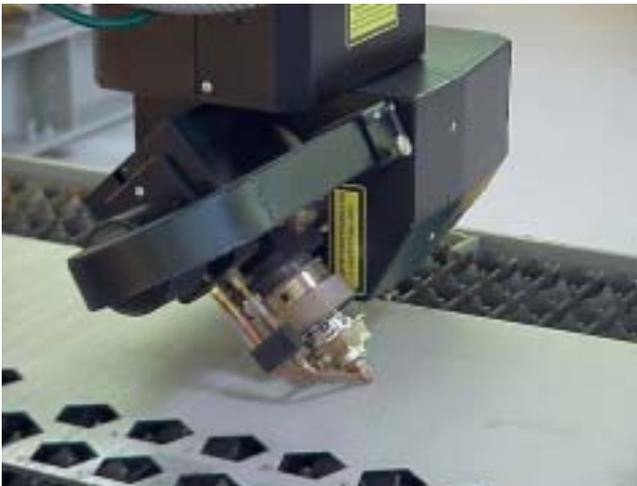


Figure 16. The laser head can carry out a bevel cut from -45° to $+45^\circ$.



Figure 17. The smooth cutting process results in a high quality laser cut.



Figure 18. Bevelling capacity up to 45° on 10mm carbon steel and 30° on 12mm carbon steel.

About the author

Arnaud Paque MSc. has been in the cutting industry since 1989. He is Global Cutting Marketing Director and Sales Manager Cutting for Western Europe.

Stub-ends & Spatter

NEW EAGLE PLASMA CUTTING MACHINE COMBINES HIGH SPEED PRECISION OUTPUT WITH EFFICIENT MATERIAL UTILIZATION



A latest range of plasma cutting machines from ESAB uses new production technologies to improve material utilization and increase plate handling efficiencies.

The **Eagle series** of plasma cutting machines combines advanced precision mechanical engineering with recently developed Super Rapid Initial Height Setting System (SRHISS) technology to increase both the speed and quality of cutting across a wide range of materials and plate sizes. The combination of additional speed and better material utilization results in a new cutting solution that delivers the lowest possible unit cost for component production. A number of new developments come as standard that includes the ESAB anti-collision system.

With the Eagle, both the marking and the cutting operations share the same torch and only one electrode is needed on the plasma for

the full thickness range. The cutting settings are adjusted automatically from an on board database which is controlled and monitored by a Vision PC Controller.

The introduction of these latest Eagle machines reinforces ESAB Cutting Systems' strength in offering complete and totally integrated turnkey solutions. These packages combine cutting machine, process expertise, numerical controller, programming, cutting table and filters to deliver simple to use, highly mechanized solutions. With a cutting width of up to three metres and incorporating automatic adjustment of cutting parameters according to plate thickness, the Eagle can operate at speeds of up to 35 metres per minute with high point to point acceleration.

ESAB Eagle machines are designed to give a compact and uncomplicated appearance, but

beneath this outward design-simplicity exists an advanced mechanical design solution that incorporates a transverse linear guiding system for increased stability and accuracy. The rails are positioned lower than the cutting table with a minimum space of 250mm between the table and the track to ensure an easy up/download of the work plate and cut parts.

The VisionPC controller is free-standing to minimize space and the cutting torch is installed with an anti-collision system that allows complete removal of the head. This feature avoids the risk of impact damage and provides for the easy interchange of service parts by being able to remove the torch from its support.

Different plate materials such as carbon steel, aluminium and stainless steel and of differing thickness can be cut in sequence whilst on the same table, thanks to ESAB's numerical controller (with automatic database) and precision plasma source. For example, one press of the start button immediately initiates marking of the first plate, then switches to cutting mode before automatically moving to mark up the second plate and to repeating the cycle through to the third plate. Travel time is 35 metres per minute and, despite the varying thickness of the work plates, the height re-setting cycle time is less than two seconds for each plate.

ESAB'S UNIVERSAL WELDING MACHINES ARE ULTRA-VERSATILE



ESAB's new AristoMig Universal welding machines are suitable for welding virtually all weldable metals, ranging from mild steel to the most advanced nickel-based stainless steels and aluminium. As well as MIG/MAG and pulsed MIG, the units can also be used for DC-TIG, pulsed TIG and MMA welding, or for Carbon Arc gouging.

Notwithstanding this remarkable versatility, the AristoMig Universal machines produce high-quality welds and allow the user to work extremely efficiently.

Customers can choose models with a 320, 400, 450 or 500 Amp power supply and there is an optional water-cooling unit that is suitable for both MIG welding guns and TIG torches. Two compatible wire feeders are also available, namely the AristoFeed 30-4 and AristoFeed 48-4.

For controlling the welding system, customers can specify either the new U6 control panel or the AristoPendant U8 control pendant. Both are highly advanced units on which up to 99 sets of welding parameters can be stored, and the

controllers are delivered with a number of pre-programmed synergic lines that enable users to start welding as quickly as possible. If a customer has a number of AristoMig Universal machines carrying out similar tasks, the AristoPendant U8 can be used to transfer welding parameters very quickly via a memory card.

Furthermore, ESAB has also developed a PC programme to handle the synergic lines created on an AristoPendant U8. These synergic lines can then be downloaded to AristoMig Universal machines equipped with either the U6 control panel or the AristoPendant U8. Thanks to the use of stored synergic lines and the versatility of the welding machine itself, the AristoMig Universal is simple enough to be used by inexperienced welders, but sophisticated enough that skilled users can achieve exceptional results in a very wide variety of applications. More information about the AristoMig Universal and associated accessories is available in a new ESAB brochure.

ESAB AND PERMANOVA JOIN FORCES IN LASER-HYBRID WELDING

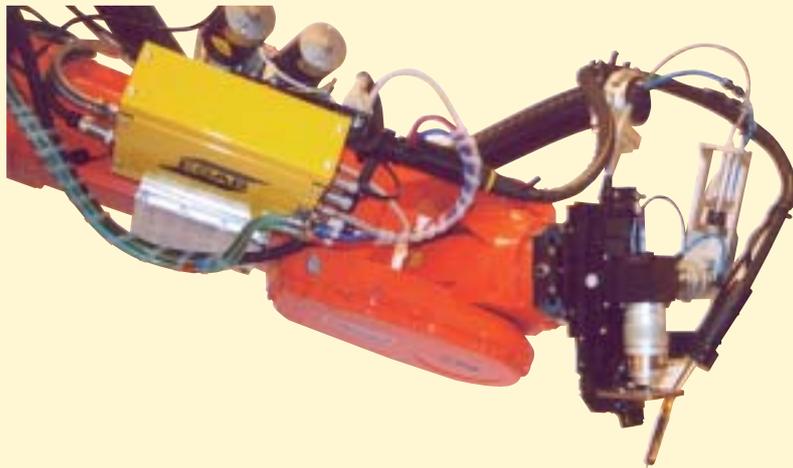
ESAB and PERMANOVA of Mölndal, Sweden, have announced an agreement under which the two companies will co-operate closely in the development of laser-hybrid welding systems.

Bringing together ESAB's vast knowledge of welding & cutting and PERMANOVA's expertise in laser processing, the new combination is ideally situated to serve the world market with the very latest in laser welding and cutting technology. Both companies are already market leaders in their sectors, and this pre-eminence will be reinforced with the new agreement.

PERMANOVA, as a producer of laser systems, is renowned worldwide for its expertise in laser process

tools and high power fiber optics. It holds a strong position in the automotive industry with robotised laser solutions for welding, cutting, brazing, hybrid welding, hardening and marking.

The main focus of the new combination will be on laser-aided MIG/MAG welding, a very productive and high quality welding process with a wide range of applications in welded fabrication.





NEW ESABMIG FOR HEAVY DUTY SOLUTIONS

ESAB is launching the ESABMig range of versatile, heavy-duty welding machines that is packed with advanced features based on proven ESAB technology. The powerful and economical semi-automatic range gives both outstanding welding performance and exceptional reliability.

Designed for heavy industrial use, the high-power ESABMig delivers up to 500A at a 60% duty cycle, and is suitable for welding mild and stainless steel from 1.0mm thick and aluminium from 1.5mm thick. High productivity is assured thanks to the ESABMig's stable arc that gives excellent welding properties when used with welding wire up to 2.4mm in diameter.

Three induction outlets allow the settings to be easily optimised to give superb welding performance and characteristics with mixed gases and CO₂. Further control is provided by means of an adjustable crater fill function that ensures a smooth finish and eliminates cracks.

The sturdy and robust equipment is available in a choice of two variants: the ESABMig 400t and the ESABMig 500t. Both machines are housed in a sturdy galvanised steel casing with an optional built-in air filter for use in harsh industrial environments. Integral ergonomic handles are provided to make the units easily portable.

Two new wire feeders, the ESABFeed 30-4 and ESABFeed 48-4 complement the ESABMig welding machines. Both feeders benefit from four-wheel drive and optimised feed roller profiles to ensure excellent feeding qualities; electronic control of the drive wheels helps to achieve an accurate and stable arc. The two feeders are available either with an enclosed spool holder or equipped to use ESAB's Marathon Pac' bulk wire spools.

A synergic control function on the feeders allows simple, accurate setting of the welding parameters, and there are 14 pre-programmed synergic lines for easy single-knob control. Furthermore, another two synergic lines can be created to optimise the settings for customer-specific applications. Significant savings in time, as well as a wide working radius, are possible by virtue of the fact that all settings can be made on the wire feeder.

For increased productivity, the ESABMig is easily mechanised using the built-in connectors for both Railtrac and Miggytrac. ELP (ESAB's LogicPump) gives automatic starting of the water pump when a PSF water-cooled welding gun is connected, thereby eliminating the risk of overheating the welding gun.

NEW ORBITAL TIG HEADS FOR HIGH QUALITY TUBE WELDING

ESAB's new PRH orbital TIG tube-welding tools are easy to operate and capable of connecting thin-walled tubes with butt welds of the highest quality, regardless of material; titanium can be welded as easily as stainless steel.

For efficient, quality assured welding comprehensive gas shielding around the tube is provided using a system based on the chamber principle. All rotating components including the tungsten electrodes are enclosed in a sealed chamber formed by the outer casing, which also incorporates clamping elements to locate and align the tubes being welded.

PRH tools are available in three sizes, enabling welding of tubes between 3mm and 76.2mm diameter. Each PRH tool is water-cooled and forms a complete unit incorporating the return conductor.

The welding heads are driven by encoder motors for the precise positioning of each sector when welding with different sets of parameters.

PRH thus provides a highly efficient means of producing high quality welds on metal tubing used in the most demanding applications.

The equipment is designed for industries where weld seam finish is

a key determinant of the quality of the product. It is well suited to chemical, food and pharmaceutical industry applications in which smooth, even internal and external weld seams are mandatory to satisfy hygiene considerations.





ESAB LAUNCHES ALL-NEW PORTABLE WELDING MACHINES FOR TIG AND MMA

ESAB's latest welding machines are the OrigoTig 150 and the OrigoArc 150 designed for the user who wants simplicity of operation, reliability and high welding performance from a compact, robust, easily portable machine. Suitable for use both indoors and outdoors, the all-new machines operate from a single-phase 230V power supply and can be used with long mains

leads to give access to areas distant from the power supply. For TIG welding mild steel, stainless steel or many other weldable metals, the OrigoTig units offer several sophisticated features on the back of ESAB's proven inverter technology. With a choice of high frequency ignition or lift arc, the user is assured of a reliable, safe start.

Furthermore, adjustable post gas and ramp-down helps to avoid cracks and oxidation. The OrigoTig machines can also be used for MMA welding, in which mode the functions include an automatic hot start, arc force and ArcPlus™ to ensure excellent weld quality with simple settings.

Users who do not require TIG welding capability, the OrigoArc is a simpler machine, though still benefiting from ESAB's inverter technology and ArcPlus™ for easy starting and excellent weld quality. Suitable for use with alloyed and non-alloyed steel, stainless steel and cast iron, the OrigoArc 150 can be used with electrodes up to 3.25 mm in diameter. Very straightforward to use, the OrigoArc simply has a current setting on the front panel.

Modern materials and innovative design ensure that both the OrigoTig and OrigoArc machines are compact, robust and easily portable. A carrying handle is provided on the top of each unit, and the simple, quick controls enable the user to move into position and start welding very rapidly.

UNIQUE MODULAR LEGIO™ FRICTION STIR WELDING EQUIPMENT

A major development in the field of Friction Stir Welding, the LEGIO™ modular FSW machines.

With the launch of the LEGIO™ modular friction stir welding (FSW) machine concept ESAB is making the FSW process applicable to a much wider industrial base.

Use of FSW has hitherto demanded substantial investment in a custom-engineered machine. By contrast, a LEGIO™ machine is built from standard modules capable of satisfying most applications. The system is capable of welding materials from 1.2mm thickness to 65mm thickness from one side.

ESAB has been the world's leading developer of FSW equipment since the process was first commercialised in 1992. A large number of SuperStir™ machines are now in

service worldwide. The LEGIO™ FSW machine concept retains the same level of functionality but modular construction allows faster delivery at significantly lower cost. In essence, the customer determines the working area, the bed configuration, the clamping arrangement, and the number of heads. Several options are then available to satisfy the application requirements, whilst the control system has been developed specifically to handle the FSW process.

The potential market is very large as the process is extremely versatile and requires no special surface preparation. As well as welding two components of the same grade of aluminium, the FSW process can join dissimilar alloys or even join two completely different metals. In many cases FSW can be used to join materials that cannot be welded by any other means.

The relatively modest cost of LEGIO™ machines will allow fabricators to consider FSW for small batches of products. Industries likely to benefit from the equipment include automotive, aerospace, marine, architectural, construction and general engineering.



WELDING WIRE FEEDERS GIVE CUSTOMERS AMPLE CHOICE

An exceptionally broad range of rugged welding wire feeders and controllers is being launched by ESAB for use with a variety of different types of welding machine. There is a choice of three alternative feeding mechanisms and nine controllers for use with step-controlled or thyristor-controlled power sources.

For wire diameters up to 1.2mm, the ESABFeed 30-2 feeder is a two-wheel-drive unit with 30mm diameter feed rollers. While the 30-4 feeder has the same size rollers, it benefits from a four-wheel-drive arrangement that enables wire diameters up to 1.6mm to be fed. If wire up to 2.4mm is to be fed, ESAB offers the 48-4 four-wheel-drive feeder that has 48mm rollers and a pair of drive motors.

Regardless of which of the nine control panels is selected, all feeders include features such as two/four stroke, adjustable burn-

back time and creep start. Certain combinations of control panel and power source also deliver the following additional functions: a digital voltage/current meter; crater filling; 14 pre-programmed synergic lines; and a facility to create two customised synergic lines.

To keep the set-up time as short as possible, all of the connection cables are of the quick-connect type, and standard connection cables are available to enable the working zone to be extended as far as 35m from the power source. Irrespective of the length of the connection and return cables, ESAB's TrueArcVoltage system ensures that the welding current and voltage are always measured correctly, thereby helping to ensure a consistent weld quality.

If a water-cooled welding gun is being used, ESAB's LogicPump (ELP) starts the water pump automatically as soon as welding commences. Moreover, if the wire feed-



er is to be used as part of a semi-automated welding system, a remote control output provides a 42V AC power supply, start/stop control and remote monitoring and control of the welding current and voltage, depending on the power source employed.

To assist with portability, the feeders can be equipped with an optional counterbalance, lifting eye or wheel kit.

More information is available in a new brochure.

CADDYTIG AND CADDYARC WELDING EQUIPMENT IS RUGGED, PORTABLE, AND IDEAL FOR THE MOBILE PROFESSIONAL WANTING HIGH QUALITY WELDS

ESAB's latest CaddyTig 150 and CaddyArc 150 welding machines are designed for use by professional welders who are out and about, working both indoors and outdoors. Moreover, the portability and flexibility does not come at the expense of weld quality, which remains high thanks to the incorporation of proven ESAB inverter technology and several sophisticated features.

Both the CaddyTig and CaddyArc machines benefit from an integral voltage and current meter so that the user can closely monitor the welding process, and a remote control facility enables the welding parameters to be adjusted from the torch, in addition to a remote on/off switch.

Suitable for both TIG and MMA welding, the CaddyTig 150 has high-frequency ignition and Lift Arc, allowing the user to select the optimum setting for the ideal start; con-

trol of the pre and post gas flow and the ramp up/down also helps to ensure the weld quality is excellent at the start and finish as well as during weld passes. When used for MMA welding, there is a further facility for adjusting the hot start, arc force and ArcPlus™ parameters. Up to four sets of welding parameters can be stored in the user-friendly controller's memory of the CaddyTig, two for TIG and two for MMA. These parameter sets can either be selected from the control panel or via the TIG torch switch. Users have the choice of pulse programming and/or manual pulse switching when switching between the two TIG parameter sets.

For those who do not need TIG capability, the CaddyArc 150 can be used for MMA welding of most ferrous metals, including alloyed and unalloyed steels, stainless steel and cast iron. The CaddyArc 150 han-

dles electrodes from 1.6 to 3.2mm diameter and has adjustable hot start, thereby ensuring easy, reliable starts. Furthermore, the adjustable arc force and the ArcPlus™ helps to maintain an excellent weld quality, and the high power reserve allows a long mains lead to be used.

ESAB's CaddyTig and CaddyArc machines all operate from a standard 230V power supply and are equipped with a sturdy carrying handle. If a unit is to be frequently moved, an optional shoulder strap and trolley are available.





MULTIPLE-WIRE ELECTRODE SUBMERGED ARC WELDING MACHINE

ESAB's Multiple wire SAW machine is primarily designed for the production of longitudinal and spirally welded pipes to maximise the welding speeds. This is beneficial for the customer to achieve the ultimate rate of production without any deterioration in weld quality.

The travel speed capability is up to 10 m/min. This is used for single wire GMAW (Buried arc transfer)

continuous tack welding with a large diam. (4.0mm) CO₂ shielded wire. Common GMAW welding speeds reaches 1.7 m/min.

The Machine handles up to six wires and can produce deposition rates towards 100 kg/ hr, (compared to 14 kg for single wire operation) this at welding speeds in excess of 2.6 m/min on pipes with a 15mm wall thickness.

The increased welding speed means lower heat input, thereby still retaining the desirable mechanical properties, if the right selection of

the applicable flux and wire combination is made.

The Machine is used at ESAB's Process Centre in Göteborg, on an ongoing basis to develop customised welding procedures. This includes new processes such as ESCW (Electrical Synergic Cold Wire) as well as the development of new Flux and Wire combinations for high quality line pipe steels such as X-70 and beyond.

The PEH welding controller incorporates all pre-settable and storable welding parameters, start and stop sequences, heat input, welding speed and the flux on off and recycling functions to ensure a reliable and repeatable operation.

The welding joint is tracked mechanically (GMD) or with Laser for higher accuracy at higher welding speeds to avoid welding wire misalignment defects in the weldment.

Computerised data logging is available to store all welding parameters for each welded pipe to enhance the record keeping in support of the Quality Assurance department.

COMPLETE RANGE OF ESAB COLUMNS AND BOOMS

ESAB has launched an expanded range of Column and Booms (CaB) for mechanised welding of beams and profiles, large-diameter tubes, vessels and windmill towers. The equipment can be configured for applications ranging from basic to the ultimate customer specific solution.

The ESAB CaB range now provides column and booms in sizes from 2x2m to 10x10m or any permutation within that envelope. Column width dimensions are 300, 460 and 600mm for the support of various specifications of welding heads, control equipment, operator chair and flux handling equipment.

Systems are available in three specification levels:

"S" is the standard range with moderate flexibility to support the basic

needs of a CaB welding station. These products support general purpose customer needs for conventional welding.

"M" is the modular range offering high flexibility to support most customer requirements for a Column and Boom welding station. These systems meet most demands in terms of performance and handling.

"C" is the customer specific range. This offers very high levels of flexibility to support the specific needs of the customer. Systems are tailor made according to the specified application and welding requirement.

All ESAB CaB products are fully compatible with the ESAB range of positioners and roller beds.



ESAB'S NEW MATTE STAINLESS STEEL MIG WIRES IMPROVE WELDING PERFORMANCE



ESAB has developed a new generation of solid stainless steel MIG welding wires that feature a matt surface appearance. These wires provide improved welding properties and lead directly to enhanced MIG welding performance.

The matte appearance results from a new surface treatment that is part of an improved manufacturing process. In addition to the surface being matte, rather than shiny, the diameter has a tighter tolerance and the stiffness is higher. Furthermore, strict control of the cast and helix – both of which are important properties for spooled wires – leads to additional benefits.

Taken together, these product characteristics give the new wires greatly improved feedability and a very stable welding arc, resulting in dependable performance for the MIG process, consistently high weld quality, and minimal post-weld cleaning. ESAB matt stainless steel MIG wires are available in a range of diameters

for most commonly used grades of stainless steel. The wires are supplied in 15kg basket spools for semi-automatic welding and 250 or 475kg MarathonPac bulk drums for mechanised and robotic welding.

As one of the world's leading suppliers of welding equipment and consumables, ESAB manufactures its own solid wires for stainless steel, un-alloyed and low-alloyed steel, and aluminium. The new matte stainless steel MIG wires have been developed as a direct response to demand from the marketplace for improved welding performance, drawing upon ESAB's extensive experience and specialist knowledge of the production technologies involved.

OK AristoRod - A NEW GENERATION OF COPPER-FREE WELDING WIRES FROM ESAB



ESAB has introduced OK AristoRod, a new family of solid copper-free MAG welding wires that enables fabricators to get the best out of their welding stations, whether they are semi-automatic, mechanised or robotised.

Due to the absence of a copper-coating, there is less risk of clogging of guns and liners with copper flakes, resulting in less maintenance and a higher duty cycle. Excellent gliding properties, low feeding forces, optimal current transfer, reduced contact tip wear and improved corrosion

resistance are provided by ESAB's Advanced Surface Characteristics Technology, ASC.

The new wire produces an exceptionally stable and spatter-free welding arc. In addition to enabling higher duty work cycles, resulting in increased productivity, this spatter-free welding arc also reduces the necessity and cost of post weld grinding.

Contact tip wear, a traditional problem with copper-free wires, has been improved to a level superior to copper-coated wire, so arc stability is guaranteed over a longer period and downtime for tip changing is limited.

An environmental advantage that comes with copper-free wires is the greatly reduced amount of copper in the welding fume and its contribution to a healthier environment in and around the welding workplace. Increasingly health authorities in many countries are advocating the

use of copper-free wires whenever possible to improve the safety of the workplace environment.

The new AristoRod range currently comprises OK AristoRod 12.50 (EN G3Si/ER70S-6), OK AristoRod 12.57 (EN G2Si/ER70S-3) and OK AristoRod 12.63 (EN G4Si/ER70S-6). The range is available on 18kg adapter-free basket spools and in environmentally recyclable, octagonal cardboard drums, 250 or 475kg MarathonPac. These are specifically suited for mechanised and robotised stations, because downtime for spool changing is considerably reduced.



A2 TRIPLETRAC, THREE-WHEELED SAW TRACTOR FOR PRECISION JOINT TRACKING
 ESAB's new A2 Tripletrac is a three wheel tractor developed for superior tracking during highly demanding internal circumferential welding of large diameter cylindrical objects, using the submerged arc welding (SAW) process.

Minimum internal diameter for operation of Tripletrac is 1300 mm. Its key feature is the combination of a steerable front wheel with positioning of the welding head on the same axis. This enables the machine to track the joint with superior precision.

Welding performance of Tripletrac is similar to that of the highly regarded four-wheel A2 Multitrac. The machine is suitable for use with ESAB's PEH or PEI process controllers, and is equipped for single wire SAW as standard.

ESAB AUTOMATION DELIVERS CHAIN WELDING MACHINE TO KOREA.

During February 2003, ESAB AB, Welding Automation delivered a type ZFKA 12 flash butt welding machine to Dai Han Anchor Chain Mfg. Co. Ltd. in Korea, for the production of heavy chains. Dai Han is one of the biggest chain manufacturers in the world and a long-term ESAB customer. ESAB's first contract with Dai Han dates back to 1978 and, since then, eight flash butt welding machines, from size 5 up to size 12, have been delivered.

WPS DATABASE

Over the years, ESAB's many support services have developed innumerable Welding Procedure Specifications (WPS) for customers, worldwide. These are now being entered into an unrivalled database that can be accessed by both ESAB's technical marketing teams and customers. This database comprises WPSes that have proved successful in actual fabrication welding at customers from a variety of industrial sectors or that have resulted from application research.

The database is accessible through esab.com, under the section "Knowledge Centre", using the entry code "WPS:es", and a password. To enhance the search process, you will be asked for information such as process, type of steel, position and plate thickness. Subsequently, the database will tell you when there are WPSes that match your specific application. You will then be directed to your local ESAB sales organisation for further information. In this way, our specialists will be able to verify that the suggested procedures can be used as they are, or need modification.

STAINLESS STEEL WORLD WINS AWS AWARD FOR ESAB ARTICLE ON THE THREE GORGES DAM PROJECT

The internationally renowned technical magazine Stainless Steel World has earned the AWS 2003 Silver Quail award for the best editorial coverage on the subject of welding, published by magazines outside the field of welding. The nominated article, written by ESAB authors Leif Karlsson, Nils Thalberg and John van den Broek, describes the high deposition welding of Francis turbine runners for the Three Gorges dam project in China. The award was presented during the 2003 AWS International Welding and Fabrication Exposition and 84th Annual Convention in Detroit, Michigan. The article was also published in Svetsaren 2002/2.

WELDING PROCESSES HANDBOOK

The Welding Processes Handbook is a concise, introductory handbook providing detailed coverage of the most common welding processes.

The publication of this guide to welding was originally prompted by a desire to provide an up-to-date reference to the major applications of welding as they are used in industry.

The contents have been carefully arranged so that it can be used as a textbook for European welding courses in accordance with guidelines from the European Welding Federation or International Institute of Welding. Welding processes and equipment necessary for each process are described so that they apply to all instruction levels required.

The author, Klas Weman, has made a conscious effort to ensure that both the text and illustrative material is clear and arranged in a user-friendly way. He concentrates in particular on providing a clear guide to the most important aspects.

Klas Weman is an engineer with great experience in the area of welding obtained both from his work at ESAB and as professor at Royal Institute of Technology in Stockholm.

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Contents:

- Arc welding – an overview
- Gas welding
- TIG welding
- Plasma welding
- MIG/MAG welding
- Metal arc welding with coated electrodes
- Submerged arc welding
- Pressure welding methods
- Other methods of welding
- Cutting methods
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- The weldability of steel
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- Welding costs

USING MARATHONPAC WITH 37M LONG LINERS. A WORLD RECORD?

By: Jussi Halonen, ESAB Oy, Finland.

Kvaerner Masa Yards in Turku, Finland, owned by the industrial conglomerate Kvaerner ASA, is one of the world's largest and most modern shipyards, designing and building advanced cruise ships, passenger-car ferries and other technically demanding vessels. On their stiffener Twin/Triple* arc SAW welding station, they use 37m long liners to feed OK Autrod 12.22 wire from 450kg Jumbo MarathonPac. A world record to our best knowledge. We invite all our readers to beat this record and deserve a special mentioning in Svetsaren.

Both sides of the stiffeners are welded simultaneously onto huge 22m plate fields. The portal is equipped with two hanging welding carriages with each two welding heads. Per welding head three arcs can be ignited, so there is the possibility to have 12 arcs burning at the same time. The welds are continuous or intermittent fillet welds with a throat thickness of 2.5-8mm and are deposited with a very high travel speed.

It stands to reason that arc disturbances or feeding irregularities are unacceptable in such a highly efficient welding station and that any downtime of the system is to be avoided. ESAB SAW wire, in this case OK Autrod 12.22 diameter 1.6 or 2.0mm, fed from 450kg bulk packaging is the ideal consumable for this kind of high duty welding.

The special coiling technology used by ESAB in the production of MarathonPac ensures that the wires provide optimum and dependable feedability in great lengths of liners and at high wire feed speeds, and leave the welding gun perfectly straight providing exactly positioned straight welds. No straightening devices are needed. The low friction of the wires in the liner also provides excellent re-

strike properties which is very important for intermittent welding. Last but not least, the downtime for spool changing, as frequently occurring with standard 30kg wire spools, is brought back to an absolute minimum by the use of 450kg bulk packs, which stands for a major contribution to the efficiency of the welding station.

Kvaerner's welding foreman, Mr. Sakari Saarenpää, confirms that his fabrication enjoys all of the benefits described above, but he wanted to underline one specific property.

"When we do intermittent welding, we have up to 7500 arc starts per day. Start defects are now minimised. Also the positioning of the arc has improved a lot, resulting in very few weld defects. This, together with the drastically reduced downtime for spool changing, has improved the productivity of the complete stiffener production line tremendously".

Mr Saarenpää's team developed a creative solution to control long liners when the welding carriage is moving as far as 22 meters across the plate field. They made the liners roll in a channel (Figures 2 and 3) according to the principle of so called "energy chains", a very common model in electrical engineering. Since the welding portal could not carry 5.4 tons of extra MarathonPac load, the bulk drums were placed on the floor near the station.

We declare the longest liner record to be in the hands of Kvaerner Masa Yards. Anyone using MIG/MAG wire, cored wire or SAW wire from MarathonPac or Jumbo MarathonPac is challenged to break it.

* Triple Arc is a further development of the Twin Arc process by Masa-Yards. There are three wires connected to one power source.

CONFERENCES

ESAB specialists will address lectures at the following conferences:

- **American Welding Society 4th Weld Cracking: Causes & Cures Conference - September 9 - 10, 2003 New Orleans, Louisiana USA**

Tony Anderson, Technical Manager AlcoTec Wire - Cracking In Aluminum Alloys

- **Joining of corrosion resistant material, 2-4 October, 2003, Opatija, Croatia.**

Leif Karlsson: The Synergic Cold Wire (SCW) Submerged Arc Welding of Highly Alloyed Stainless Steels.

- **Stainless Steel World 2003 Conference & Expo, 11-13 November 2003, Maastricht, The Netherlands.**

Leif Karlsson: The Synergic Cold Wire (SCW) Submerged Arc Welding of Highly Alloyed Stainless Steels.

Leif Karlsson: Controlling Segregation in Ni-base Weld Metals by Balanced Alloying.

- **Fabtech International 2003 Conference - November 16-19, 2003 McCormick Convention Center Chicago, Illinois USA**

Tony Anderson, Technical Manager AlcoTec Wire - Welding Aluminum (2 Hour Presentation).

- **ET '04 8th International aluminum extrusion technology seminar, Kissimmee, Florida 18-21 May 2004**

Kari Erik Lahti: Wider Extrusions at Lower Cost by Friction Stir Welding.



We started our company developing solutions for the shipbuilding industry. And we still do.

ESAB's commitment to the shipbuilding industry is as old as the company itself. Today we are a leading supplier of complete cutting and welding solutions.

Based on our knowledge and long experience we work closely together with our customers to develop modern and productive solutions for them. Our world wide presence means there is qualified cutting and welding support available in almost every country where shipbuilding and offshore construction take place.



Your partner in welding and cutting



Svetsaren, Esab AB, Marketing Communication
c/o P.O. Box 8086, 3503 RB Utrecht, The Netherlands
Tel. +31 30 248 5223. Fax. +31 30 241 1535
Internet: <http://www.esab.com>
E-mail: info@esab.se