Environmental concerns are driving the development of the welding processes and applications

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Abstracts

Higher productivity, high and consistent quality and improved working environment have been the main key drivers for continuous improvement of welding. Nowadays sustainability has become another important driver. The current environmental awareness in the welding industry is fairly low. The society is however much more concerned about environmental aspects. These drive for continuous development of the welding processes and applications. Some described applications from the shipyard, wind and nuclear power and automotive industries will illustrate the progresses.

1. Introduction

Sustainability is today an important factor in all our activities. Almost all initiated R&D programmes launched in European Union (EU) are covering objectives with environmental requirements.

The objectives for the Aeronautics & Space programme totally on €1.075 million includes:

- Reduction of CO_2 by 50 % per passenger-km in the long term
- Reduction of NOX-gases by 20 % (80 %) in the short (long) term
- Reduction of external noise by 4-5 dB (10 dB) in the short (long) term

Similar objectives are presented for the shipyards projects:

- Lower weight 40 % by use of high strength steel (690 grade steel)
- Lower running cost 30 %
- Reduction of CO_2 emissions 15 %
- Lower manufacturing cost 20 %

The German government announced after an oil catastrophe near the Spanish coastline an eight-point programme to improve safety at sea, including the banning of single-hull tankers carrying heavy oil or other dangerous goods from its ports.

The automotive industry is facing tough challenges e.g.

- Significantly improved fuel efficiency: 3,2 – 4,5 litre/100km
- Lower CO_2 emission: 86 – 108 g/km
- Low environmental impact - 80-85 % recyclable by 2006

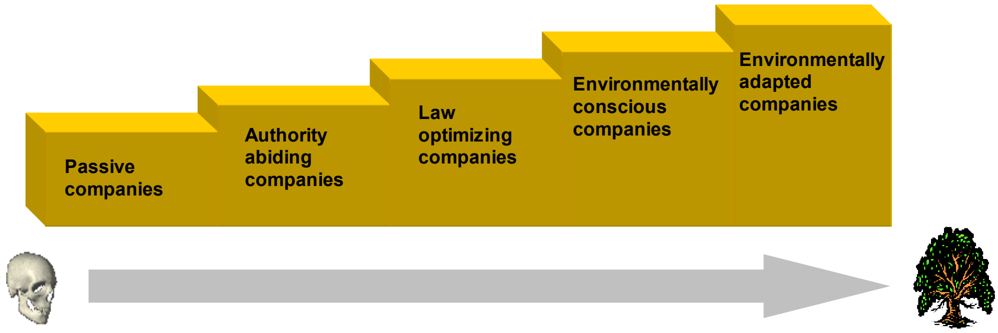
We are also seeing a lot of environmental influenced projects in the energy sector. Installation of wind power stations is rapidly growing 30-50 % per year. Safe storage of nuclear waste is another a major issue in many countries resulting in long-term R&D projects.

These environmental requirements are demanding development of the joining processes and applications, which will be illustrated in this paper.

2.Environmental awareness in the welding industry

The environmental awareness varies very much between companies. The differences can be segregated as in (Figure1).
Functionality and service are the major concerns, when buying welding and cutting products. Welding is primarily considered a “health and safety” problem, which is noted in the allocation of responsibility for environmental matters. Appointed persons often cover beside the environmental programme also health and safety matters.

Companies segregated according to their environmental awareness



Increased environmental awareness

Figure 1

Welding is judged to have a small environmental aspect compared to other manufacturing processes. Even though we are fairly slow in implementing environmental programmes in the welding industries we have major challenges in developing the joining processes. The impact of the environmental requirements is manifold as shown in (Figure 2).

INFLUENCE ON INNOVATION
- Research and development
- Life-cycle assessment
- Eco-design guidelines
- Environmental aspects in product standards
- Education and training
- Transfer of knowledge

INFLUENCE ON DEMAND
- Environmental statements
- Eco-labels (ISO type I)
- Eco-declarations (ISO type II)
- Eco-declarations (ISO type III)
- Purchasing and public procurement
- Price elements
- Product panels

INFLUENCE ON SUPPLY
- Codes of conduct
- Long-term agreements
- Environmental management systems
- Supply chain management

INFLUENCE ON THE END-OF-LIFE PHASE
- Market-driven recycling
- Take-back systems

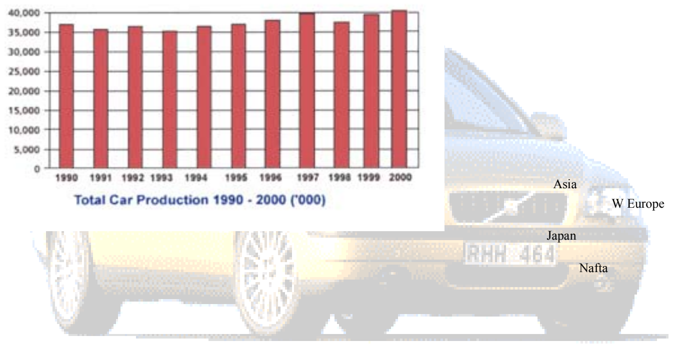
Figure 2
Impacts of an environmental programme

Much of the listed information in this figure must be considered when developing the joining processes and systems.

3.Joining the automotive industry

In this industry sector an intense development of joining processes is ongoing as a very large volume of cars a produced (Figure 3

The car industry is welding much

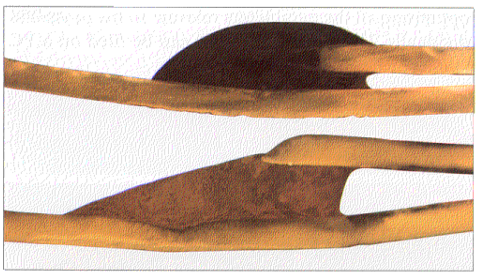


Annual growth 2,1 %

Figure 3

By studying the developments in this sector one can fairly well forecast what new joining processes we can expect to see applied in other sectors. The automotive industry is the most important driver of continuous improvement of and innovations in joining.
MIG-, laser- and plasma-brazing are processes (1) attracting a lot of interest for welding of zinc-coated steel. The corrosion surface remains intact without any evaporation of the zinc next to the seam when brazing (Figure 4).

MIG brazing with different gaps
Material thickness = 0,8 mm



Wire	Cu	Si	Mn	Melting range °C
OK Autrod 19.30	Basis	3.0	1.0	910-1025

Figure 4

The brass solder over bridge gaps well as a consequence of the capillary action. The joint is produced without any spatter and porosity and the joint appearance is attractive.

We can expect more applications in other fields for MIG-brazing e.g. ventilation, household equipment, fire-resistant doors, roof and facade components in the building industry etc.
The mechanical joining methods; clinching and self-piercing riveting; are increasingly used in this industry especially for Al-cars like Audi A2 (Figure 5). It contains

- YAG-laser welding 30 m with P = 4 kW, v = 5,5 m/min
- MIG-welding 20 m v = 0,7 m/min
- Self-piercing rivets 1800 pieces

Figure 5
Audi A2 completely in Al

The line has 220 robots and the degree of mechanisation is 80 %.
The countermeasure against the higher use of Al by the steel industry is the introduction of Advanced High Strength Steels (AHSS), which is developed in project Ulsab financed by 33 steel companies. Porsche Engineering ending up with made the conceptual design

- Meeting anticipated crash safety requirements for 2004
- Significantly improved fuel efficiency: 3,2 – 4,5 litre/100 km
- Lower CO_2 emission: 86 – 108 g/km
- Low environmental impact – recyclable
- High volume manufacturability at affordable cost
- Demonstrating effective design concepts in AHSS: - 200 kg lighter

Tube structures and tailored blanks (40 % of structures) are used. 85 % of the body is made in AHSS. The traditional manufacturing processes can be applied

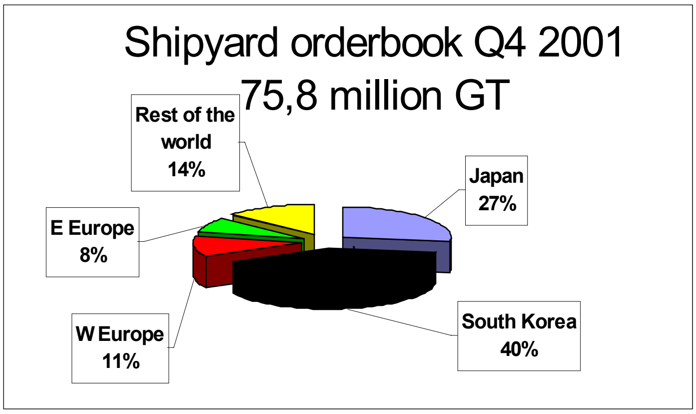
- Stamping
- Spot welding
- Laser welding
- Hydro forming

It will be interesting to follow how these new options into the automaker's arsenal will be applied to improve safety, performance of lower fuel consumption without hitting the car buyer in the pocketbook.

4.Welding in the shipyard industry

South Korea is by far the largest producer of ships (Figure 6).
The market has during the last 15 years annually grown on average with 4,6 %. PRC is expected to increase its market share while in Europe Poland and Croatia is doing the same.

Arc welding will remain to be the dominating joining process but with a higher degree of mechanisation to deposit the entire weld metal corresponding (2,2-2,3) % of the steel weight in the ship.
One side SAW is the dominating process for the butt joints in the panel lines. Cored wires are often used and as well iron powder addition to increase the welding speed.
For welding the stiffeners we note more use of MIG/MAG welding robots (Figure 7), which is since years very common in the Japanese shipyards



Annual output 28,7 million GT
Figure 6

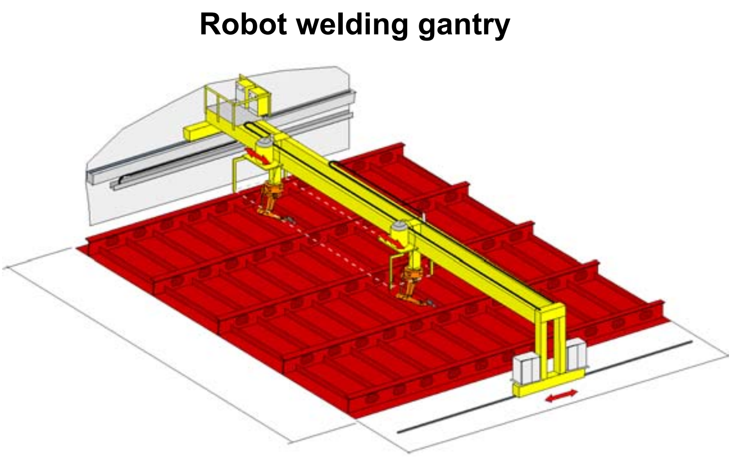


Figure 7

A similar set-up with a gantry and suspended robots is used for curved panel welding stations. Tandem MAG-welding (2) is becoming a common process in shipyards and construction industry. There are already about 100 installations running in production mostly in Germany (Figure 8).

Tandem MAG welding of Panel Stiffeners

Welding data

Electrodes = 1.2 mm
Throat thickness = 4.5 mm
Stickout = 20 mm

Parameters		Electrode 1	Electrode 2
Welding voltage	V	29.5	30.5
Welding current	A	385	301
Wire feed speed	m/min	18.2	13
Travel speed	**m/min**	**2. 45**	

Figure 8

The Tandem solution has inherently greater freedom in varying the welding parameters like using different electrode diameters or mix with cored and solid wires besides the ordinary parameters for voltage, currents and travel speed. In order to reduce the spatter and the interference between the arcs, pulsing with phase shifting is introduced.
There are additional efforts in Europe increasing the degree of mechanisation of welding. The EU-project DockWelder has the objective to demonstrate a flexible modular automation applied in welding ship sections in the dock (Figure 9).

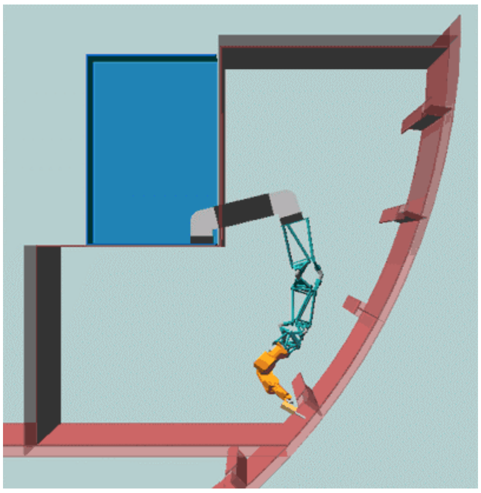


Figure 9
Artistic illustration of the DockWelder

The project has the following participants

- Amrose Denmark
- APS Germany
- Cybenetix France
- Lindö Shipyard Denmark
- Ficantieri Shipyard Italy
- Inst. For Production Technology

An optical sensor for joint tracking is used in this installation

Many European shipyards have jointly investigated the feasibility introducing laser welding of ship panels and classification bodies have been involved for approvals of the welding procedures. Few installations with CO_2-lasers combined with cold wires were made some years ago. The accurate joint preparations with a gap < 0,5 mm required was a major obstacle. The level of impurities of sulphur and phosphor was another hindrance.

The latest process development with a combination of arc and laser welding; a hybrid process; is offering a more tolerant process with larger groove gap allowed 1,0 mm. The heat input is partly also reduced (10 %)
Besides a more tolerant hybrid process the travel speed can be drastically increased; up to 4 times for butt-welding of plate with t = 5 mm.
Such a hybrid set-up is in addition requiring a lower investment than a pure laser installation.
We are now seeing a technical breakthrough for the laser hybrid process at Meyer Shipyard in Germany. Figure 10 is an artistic sketch covering both butt-welding of the panels and fillet welding of stiffeners
The panels are manufactured with closer tolerances and much less distortion.

Ship panels 20x16 m welded with the hybrid laser MIG process

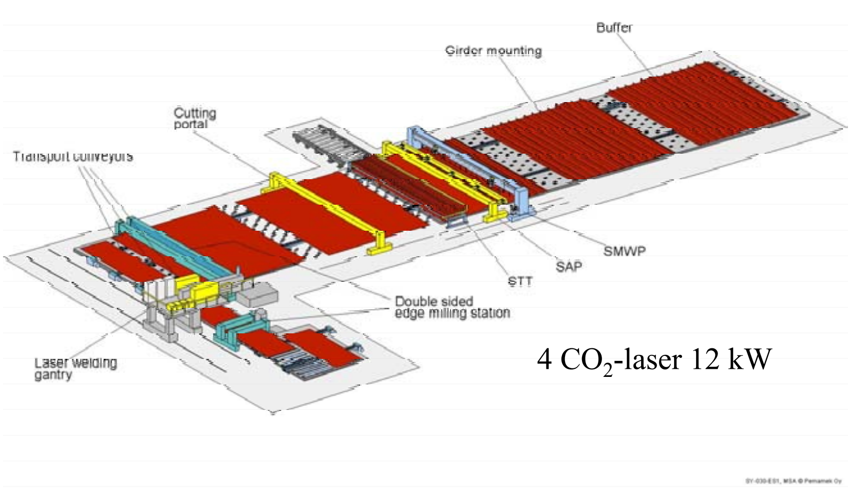


Figure 10

There are other European shipyards also working with this process and close to invest in a laser panel line.
The next development phase has already started by developing a YAG-laser station for welding the webs and other structures on the ship (Figure 11 below).

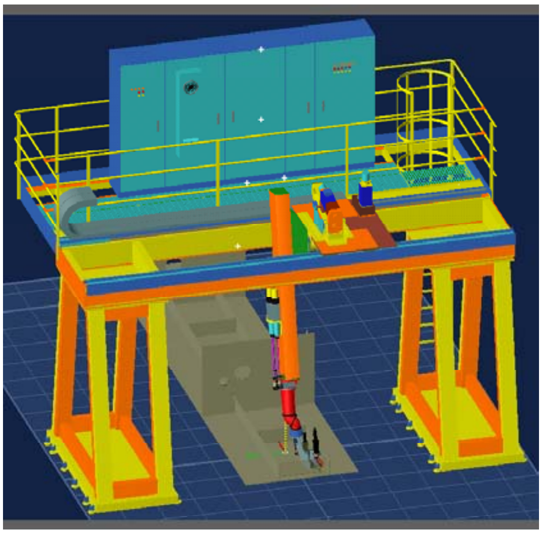


Figure 11
In this case a YAG-laser with the welding head mounted on an articulated robot is used thanks to the higher flexibility allowed by using an optical fibre delivering the light beam to the welding position. The wavelength is 1,06 µm compared with the wavelength for CO_2 light beam 10,6 µm, for which an optical fibre cannot be used.

5. Welding in power generation industry

The environmental sustainability objectives are among all resulting in an increased number of installed wind power stations, which contains currently a lot of weld metal on average 1500 kg. The SAW process is hence used when possible to get a high deposition rate. Then the welds must be made in down hand position with a root pass from inside and the capping passes from outside, for which two electrodes DC and AC are mostly used. Figure 12 shows typical joint preparations for the material thickness between 8-50mm.

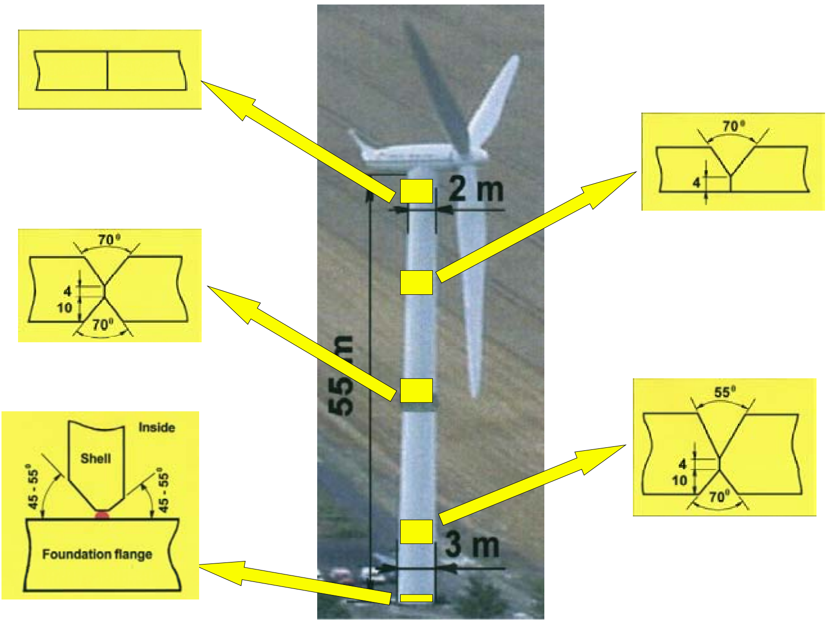
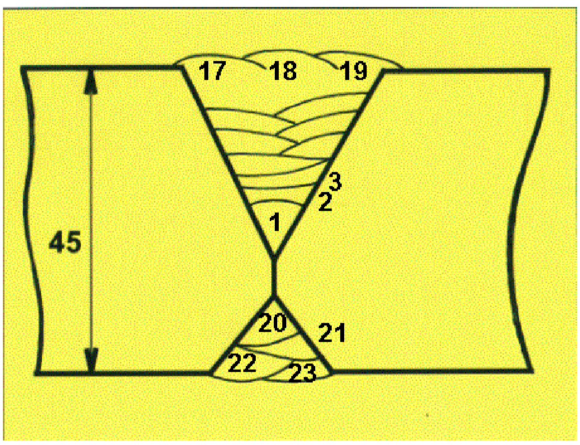


Figure 12
Typical joint preparations

Some welding data are listed in table 1.

t=45 mm, X-joint



Run No.	Wire diam. mm	Weld current A	V	Speed cm / min
1	4	600	24	50
2	4	600	25	50
3	4	600	26	50
5-12	4	600	27	50
13-19	4	600	30	50
20	4	750	26	50
21-23	4	600	30	50

Table 1

Tapering between shells of different thickness is recommended in order to reduce the stress concentration at the weld joint.
Systems similar to the one shown in figure 13 are often installed. As in other SAW applications metal-cored wires are introduced

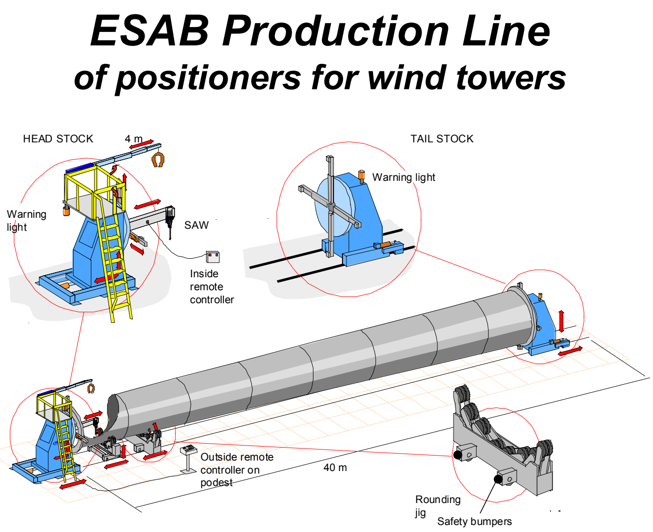


Figure 13

In contrast to the “clean” wind power the nuclear power produces dangerous waste, which must be safely disposed. In Sweden the Swedish Nuclear Power and Waste Management Company (SKB) is carefully evaluating the Electron Beam Welding and Friction Stir Welding processes for encapsulation of the waste in durable canisters in Cu. These will be stored in a deep repository in the Swedish bedrock. The Cu canister consists of a five centimetre thick Cu casing. Inside, there is a coast iron insert to provide mechanical strength. The canister (Figure 14) is close to five metres long and has a diameter of about one metre. A canister filled with spent fuel weighs about 27 tonnes.

Figure 14
Cu-canister for nuclear waste

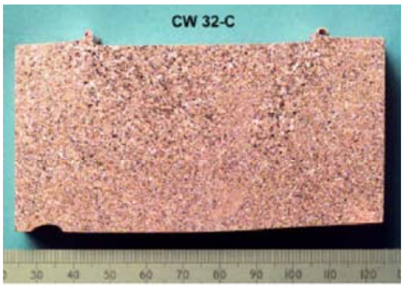
A full-scale Electron Beam Welding tests have been performed. In 1998-1999, a test rig was built at TWI for the Friction Stir Welding of mock-up canisters. A fixture holds the canister and rotates it during welding. The lid is pressed down with four hydraulic cylinders. The welding speed reaches 150 mm per minute. The FSW process has functioned well and SKB has ordered an installation, which is sketched in figure 15.

Figure 15

The welding head rotates during the process around the fixed canister

Figure 16 shows the weld result.

Welding of a lid to Cu-canister for nuclear waste with = 50mm in Sweden



A transverse metallurgical section through 50 mm thick Cu stir weld

A 120 degree weld segment

The early stages of a Cu canister weld. Note that the tool is operating at read heat

Figure 16

6. Conclusions

The described applications prove that sustainability is requiring development of the joining processes and applications. The driving forces behind these demands are among all

1. Productivity
2. Quality
3. Flexibility
4. Working environment
5. Sustainability
    - Reduction of energy consumption
    - Use of renewable energy sources
    - Safe disposal of waste
    - Safety

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