RECENT DEVELOPMENTS OF WELDING AUTOMATION AND ROBOTICS IN SHIPBUILDING

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ABSTRACT
The introduction of newly developed intelligent and user-friendly robotics has opened a new era in shipbuilding. Together with traditional and low-cost mechanization a record level of welding automation rate has been achieved in the construction of cruise vessels.

In the paper modern applications and recent developments of welding automation and robotics in shipbuilding have been described and some forecast for the future trends are given.

Development in the field of shipyards will be continued with accelerated speed and we shall have interesting prospects for the near future. New laser techniques can boost the shipyards in a revolutional way when production is rapidly changing, materials will be lighter and quality demands are becoming more strict.

KEYWORDS
Shipbuilding automation, robotic, machine vision, friction stir welding, tandem-MAG welding

1. Introduction

Kvaerner Masa-Yards develop and build luxury cruise ships and passenger-car ferries. Over the years some 70 ships of these types have been designed and built and among them, some 25% of the world's cruise ships. The largest of the Kvaerner shipyards, Turku Shipyard, is currently building a series of 5 Voyager class cruise ships for Royal Caribbean. The fifth of these vessels is currently under construction, and at 142,000 GT and capable of carrying 5,000 passengers and crew, they are the largest cruise ships in the world. Helsinki Shipyard (KMYH) continues the building of a series of six 86,000 GT Panamax-Max Spirit-class cruise liners for Costa Crociere and Carnival Corporation. Masa-Yards has also a wide experience of ice-going vessels, liquefied gas carriers and other sophisticated special purpose tonnage.

Current technology trends and developments in the production automation of welding can be seen in the yards. Improvements in producing dimensionally more accurate piece parts and sub-assemblies boost not only productivity and quality but reduce drastically downstream assembly and erection cost. Furthermore newly developed machine vision guided robotics in Helsinki may give a much higher return than other advanced automation investments in hardware or software.

2. Utilization of all levels of automation

A high cost/performance efficiency and quality level can be achieved with newly developed intelligent robotics and improved conventional process applications by using flexible combinations of robotized and mechanized welding systems and equipment with new innovations. All levels of automation is needed to utilize to reach the goal in the future shipbuilding.

2.1 Light mechanization

A wide range of low-cost but high efficiency mechanization equipment is available for all position assembly welding. Cutting torch and welding gun carriages with track and pinion drive may travel along rigid or flexible tracks, which accept either magnetic or vacuum track mounting devices. A variety of control system options and accessories are available as well. [1]

KMYH has recently achieved close to 100% coverage to mechanized assembly welding of all grand block joints in the area of hull erection. Light aluminium bridges and studwelding guns are used by fitters for easy mechanized welding by torch carriages in all positions and shapes. In addition to considerable productivity increase also weld quality is improved. Low-cost automation equipments are widely used also in the grand block assembly shops (fig. 1).

The biggest relatively productivity increase is achieved in welding of block boundaries in flat (PA) position. Reason for that is additional metal powder, which is added just before welding. Metal powder makes also possible to weld with submerged arc welding (SAW) carriage by one run without any manual backing.

2.2 Welding automation of stiffeners by tandem MAG

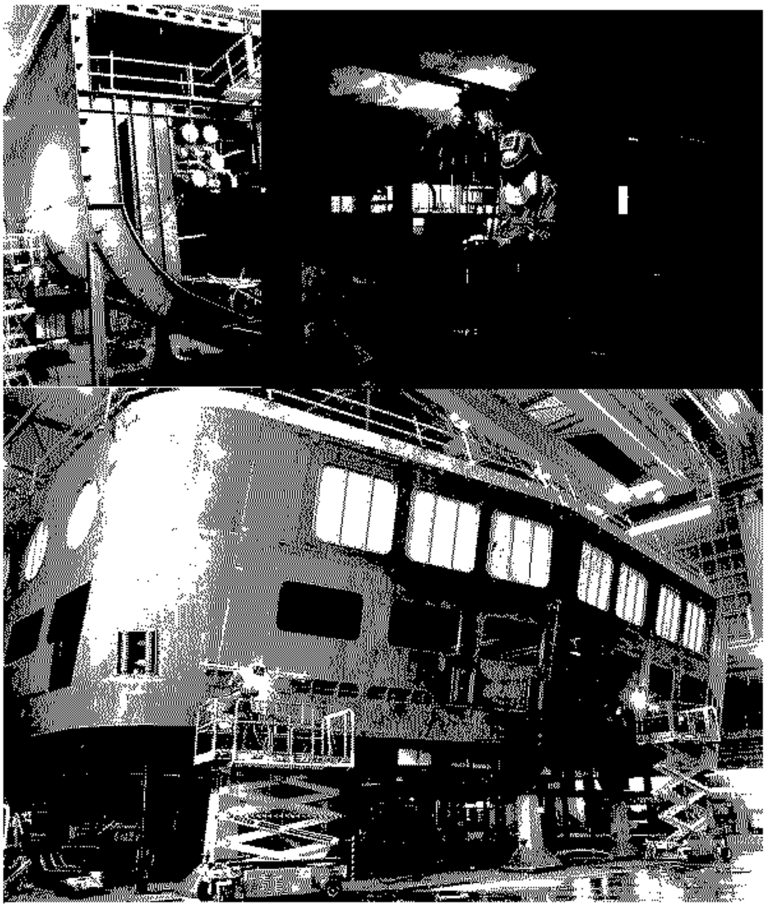

Figure 1: Low-cost mechanization in grand block assembly

Traditionally stiffeners are welded on to the panels using stationary or movable gantries with SAW or GMAW processes.

In Helsinki the stiffener welding gantry is mounted on to the rail and equipped with one double fillet welding carriage. The welding process is tandem-MAG with 1,2 mm metal cored wire and shielding gas mixture of 15/85%. The carriage is equipped with two high capacity double wire torches. The torch adjustment is by electro-mechanical cross-slide and tactile sensor. The portal may have from four synchronized pulsed arc power sources. The welding portal is equipped with PLC-controller with one numerically controlled axis, so that features of the welds can be easily programmed.

The welding speed and other parameters are optimized for welding on primer which is not removed either from plate or stiffeners. Experience with the tandem-MAG welding has been good. The main advantage has been productivity, decreased heat input and low speed of wire feeding despite rather high deposition rate.[2]

KMY is participating a Finnish laser welding research project where use of GMA-hybrid laser process for butt and fillet weldings are reserched. Use of laser process together with GMAW methods seems to be very promising. By combining of two processes the advantages of both can be utilized and disadvantages can be avoided. The results of the projects shows that biggest advantages can be achieved in field of tolerance demand and distortions. The new techniques can boost the shipyards in a revolutional way when production is rapidly changing, materials will be lighter and quality demands are becoming more strict.

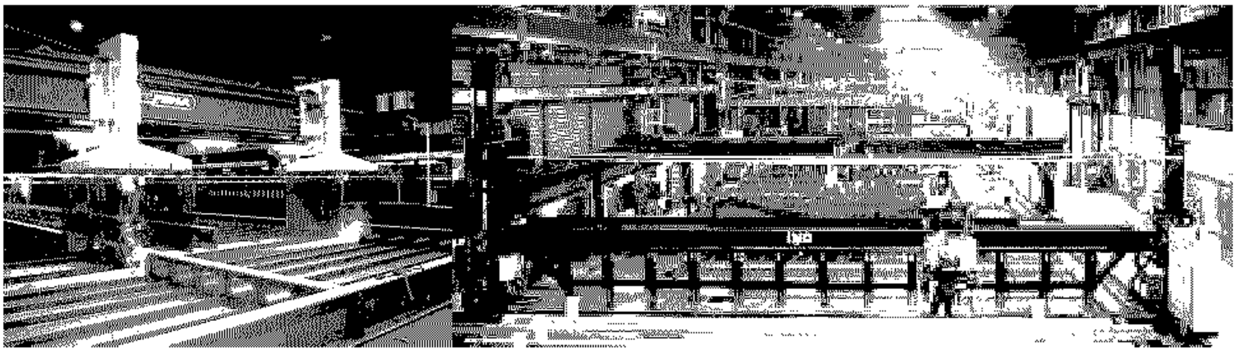

Figure 2: The robot welding gantry with 2 robots and the stiffener welding gantry with tandem-MAG

2.3 Robotic welding of T-beams on to the large stiffened panels

A Spirit class cruise liner includes over 40 km welded T-beams and the number of the corresponding T-beam-bulb-deck plate joints is huge; more than 100 000 pieces/ship.

Dimensions of the joints differ a little but features like shapes and demandings are equal to each others. That is the reason why KMYH has started to develop a programming system that is based on scaling macros which means that programming can be almost avoided.

The system is based on the fully utilization of modern robot technology and finding series inside single product. The same method is applied to all the robots implemented during the year 2002. Welding robot gantry with 2 robots is installed in the panel line application (fig.2). Following small portable robots may be used in a flexible way in those assembly shops with fixed welding floor only (fig. 3).

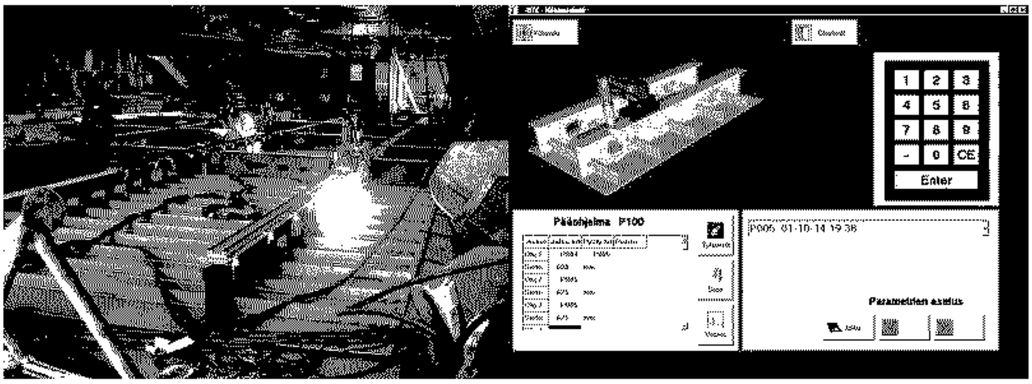

Figure 3: The portable robot in welding work with easy to use user interface

All operation like tacking, programming, setup and quality control are done at shop floor by operator who will manage two robots at the same time with easy to use user interface Fig. 3.

2.4 Robotic welding of subassemblies

Most small stiffened sub-assemblies of the ship's inner hull and accommodation bulkheads are nowadays fabricated on specially designed 'micro' panel lines. The stiffeners may be fitted and welded on to the panels using an automated process with robots, manipulators and transportation.

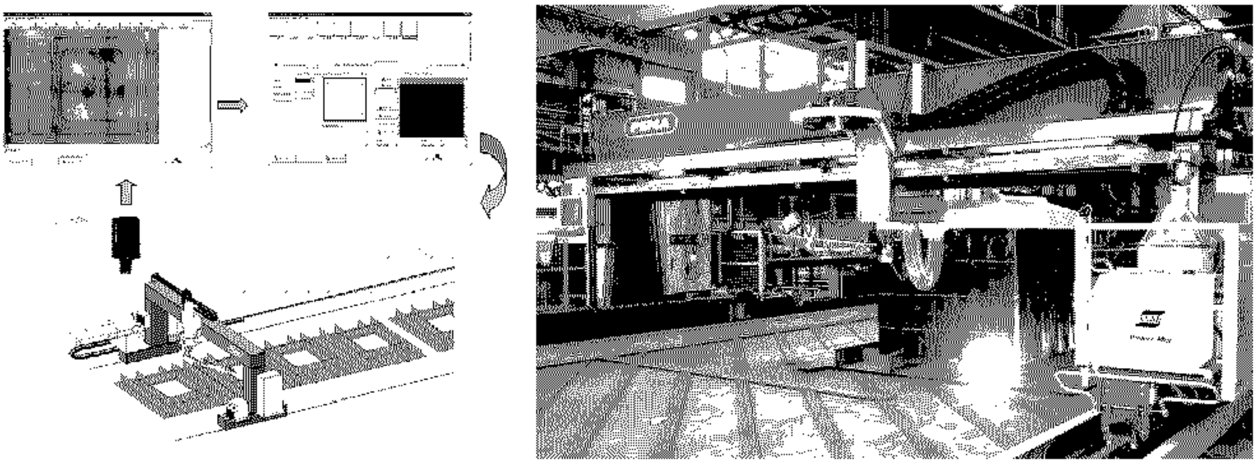

Figure 4: The principle of KMYH machine vision controlled welding robot and picture from the shop floor

A state of art development of robotic sub-assembly welding has started at KMYH during 2002. A single robot gantry is controlled by an advanced machine vision guided programming system instead of traditional efforts & time consuming off-line and preprogramming systems (fig.4).

The system is based on high sophisticated macros, which will get features from machine vision system that is included in the gantry. Achievable arc time ratio is equal to other offline programmed systems, but no programming is requested. The system is very flexible because no information about product is needed and operator can choose optimal order of welding. Welding can be started before tack welding is completed or several products can be programmed at once.

A high welding automation & robotization ratio may be achieved in the cruise liner construction of various types of stiffened panels (fig.5).

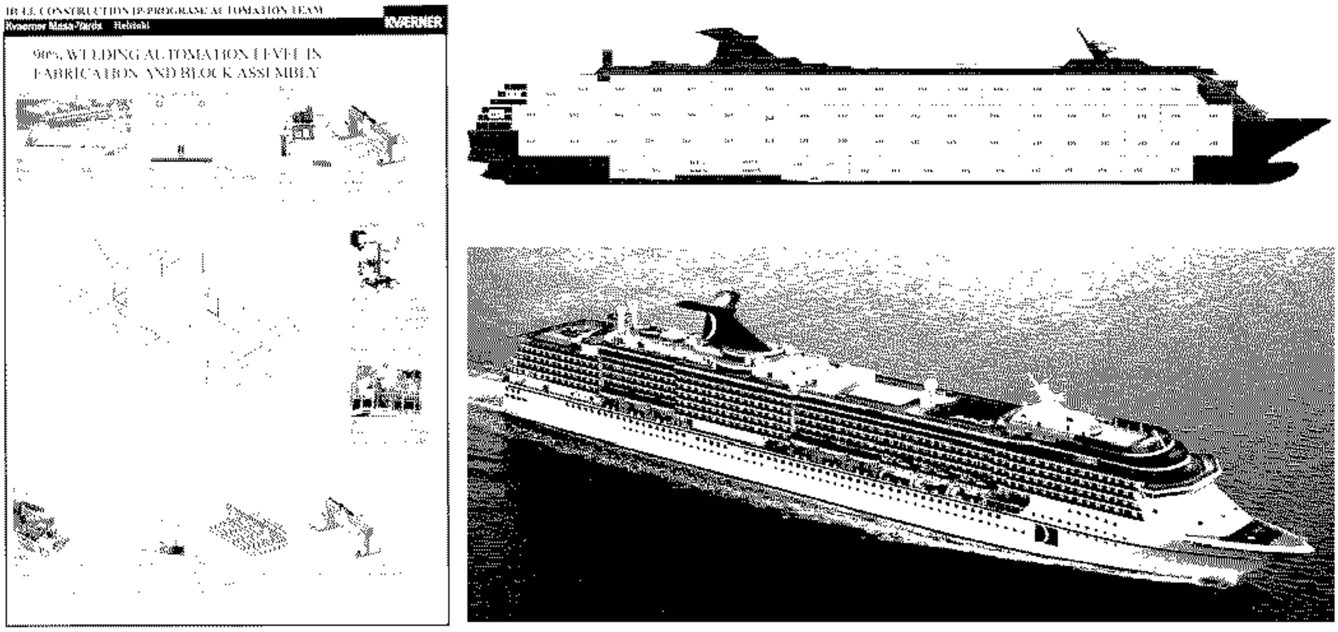

Figure 5: Current status of welding automation in various types of stiffened panels

3 Status of robotic welding application development process

Current status of welding robots, characteristics and performance are shown in the following Tables 1 and 2 to give a general view of the different development steps.

Application	Throat thickness	Welding speed	Electrode type and dia	Arc time ratio [%]	Utility ratio [%]	Weld output [m/h]	Programming time ratio
Micro panels, (KWW-95)	4 mm	72 cm/min	1.4 mm Metal core	65-70	75	30 (2 gantries with 3 robots)	1:20 (1:100 series)
Double bottom sections, (KWW-95)	5	44	1.4 Flux core	75	80	16 (1 gantry with 2 robots)	1:5 (1:20 series)
Sub-assemblies, (KMYT-97)	3	50	1.2 Flux core	75	75	18 (1 gantry with 1 robot)	1:40 (1:100 series)
Double bottom, (KPSI-01)	5	40	1.2 Flux core	75	75	30 (1 gantry with 2 robots)	1:5 (man.) 1:50 (autom)
Sub-assemblies, (KMYH-02)	3	70	1.2 Flux core	70	75	22 (1 gantry with 1 robot)	N/A
Stiffened panels portable robots, (KMYH-02)	3	50	1.2 Flux core	60	50	9 (each robot)	N/A
Stiffened panels, gantry robot, (KMYH-02)	3	50	1.2 Flux core	65	75	29 (1 gantry with 2 robots)	N/A

Table 1 Robot welding application in various yards (N/A = not applicable) [3,5]

	Sub-assembly (bulkheads etc)	Plate butt joints (panel line)	Longitudinal profiles (HP)	T-beam stiffeners	Block boundary butt joints
Weld length	2 x 465 m	136 m	2 x 384 m	2 x 152 m	48 m
Automation rate	100 %	100 %	100 %	85 %	80 %
Welding process	Robotic FCAW &GMAW	Autom. SAW	Tandem MAG	Robotic FCAW	Robotic FCAW &GMAW

Table 2 Welding automation of a typical cruise liner hull block construction at KMYH [5]

4. FS welding in aluminium super structures
The advantages of the FSW compared to traditional MIG have increased the use of extruded aluminium panels in the topmost superstructure of cruise liners at KMY yards. It may also mean a remarkable reduction of number of the parts, production time and welding distortions. [4]

Extruded sections of aluminium alloy 6082-T6 are used e.g. in the building of six Spirit-class vessels totally 450 tonnes. 5 mm thick deck panels may be 11,3 x 2,4 m wide with 100 mm high stiffeners. Prefabricated FSW panels are practically distortion free and result smooth deck surface after final assembly at shipyards.

5. Conclusions
The introduction of newly developed machine vision guided robotics helps to achieve the new targets for productivity improvement and may reduce the pre-programming to zero. The use of machine vision in the shipyard environment will open totally new application where time or money can be saved.

New technology makes shipbuilding also more attractive to young generation workforce since recruitment has become difficult in industrialized high cost level countries due to poor public image of shipbuilding. Availability problem of the future workforce boost the yards to increase the general level of automation.

Laser-hybrid processes may start a new era in shipbuilding in spite of the high investment cost. First applications are already in daily use, but big potential of process benefits can be added when all advantages can be exploited in industrial application.

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