APPLICATION OF WELDING TO INFRASTRUCTURE INDUSTRY (SHIPBUILDING)

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INTRODUCTION

Ships have been used since times immemorial for trading purpose across the high seas, carrying cargo from one port to another port. The building of ships has seen sea change in the construction methods adopted. The shipbuilding industry has undergone a drastic change, over recent decades; from being a "heavy industry, it has turned into a high-technology information-dominated industry. The age old time consuming methods have given way to modern shipbuilding techniques such as unit-by-unit construction, plasma arc and CNC cutting machines, latest welding processes. Such integrated approach has contributed substantially to completion of project and early delivery of a ship, thus bringing economic benefits to every one.

THE SHIPBUILDING INDUSTRY

A ship is more than a mere welded steel; it consists of several sub-systems, which must work smoothly together to guarantee a faultless functioning of complete ship. It is a combination of electronics. Information technology, and several materials, pieced together in a yard in order to fulfill certain functions at sea.

The problems involved in the design of floating structures are different from those, which confront the designers of bridges, buildings and other land structures. The utmost economy in weight of material is important. Any excess of material over minimum required for structural strength, including adequate margin for corrosion and wear diminishes cargo carrying capacity and speed.

Production of a Ship

Contrary to popular belief, shipbuilding is no longer a labour intensive, mainly blue-collar heavy industry. It extensively depends on R& D and innovation activities, which is out-sourced from outside the yard for its productivity gains. There may be few top shipbuilding countries in the world such as South Korea, Japan, Germany, China, but all of them are depending heavily on its product and process linkages from other industrialized countries.

The production process can be divided into three steps.

Planning phase: project planning, design and construction.

Production phase: project co-ordination and production

Finishing phase: finishing, testing and inspection.

In the planning phase the shipyard plans the complete shipbuilding project. This includes outlining the financing of the project, the design and construction of the ship, procurement of material and equipment.

The second stage, i.e. the production phase constitutes following activities

- Receipt of materials, storage
- Plate cutting
- Paneling (welding of plates to panels)
- Hull construction
- Conservation of hulls and sections
- Outfitting (electronics, equipment, motors, etc.)

In the finishing phase the final work is done before the ship is delivered to the ship owner. This phase includes sea trial, final finishing work, etc.

The paper deals \with paneling and hull construction aspect of production phase, since this is the area where welding plays a very crucial role during hull construction. Since welding is a determining cost factor of the overall production process, continuous attention is devoted in improving efficiency and reducing cost. An attempt is made in this paper to present what are the current strategic steps followed in the shipbuilding industry. These are

- Increase the degree of automation resulting in a higher \welding productivity and a reduction of process duration.
- Emphasis on quality both in steel preparation/fitting and welding itself. This is a central issue considering that small inaccuracies accumulate to increase the time for a single welding process by 3 to 5 times.
- Research and development of innovative welding techniques.

THE SHIPYARDS GENERALLY USE THE FOLLOWING WELDING PROCESSES.

SMAW (Shielded metal arc welding) process, widely used in the past is getting replaced by more productive methods. This accounts for 20% of the total welding effort. This process though versatile, has certain limitations like

- It is unproductive
- High percentage of repairs
- Not cost effective
- Low deposition rate
- Poses environmental and health hazards and operator fatigue.

In the early 1930s, having realized the need for mechanized welding and having recognized its potential advantage, attempts were made to mechanize the arc welding process. What emerged was submerged arc welding and the process became a commercial success in mid and late 1930s. Shipbuilding industry also did not lag behind and employed this new welding process in the fabrication.

SAW (Submerged arc welding) process is carried out. using semi-automatic devices. It is generally adopted for butt welding of large panels and welding the reinforcements on the same. It accounts today for about 15% of the total welding employed on the ship. The process is extensively used in shipbuilding and other heavy industries because of the following advantages.

- Absence of smoke and arc flash
- High weld metal quality
- Smooth and uniform weld finish with no spatter
- Extremely high deposition rate and welding speed
- High electrode deposition efficiency
- Welders' manipulative skill not needed, less operator fatigue

The use of submerged arc welding for fabrication and erection joints in flat position has resulted in increase in productivity.

GSAW (Gas Shielded - Arc Welding) process: There are two variations of this process, one is known as gas tungsten-arc welding, also known as TIG and the other one is referred to as gas metal arc welding. This is termed as MIG (Metal Inert - Gas / CO2 Arc Welding). This welding process overcomes the restriction of using small lengths of electrodes as in manual metal arc welding and overcomes the inability of the submerged arc process to weld in various positions. This process is more \widely used and currently accounts for about 40 to 50% of the total welding in hull construction and its use is still increasing. The process is carried out using semi automatic welding heads and dedicated machines. The increased deposition rate obtained by using this process has lowered the construction cost, has reduced the time required for fabricating a given structure / panel by almost half of whatthan what would normally require by SMAW process.

TIG (Tungsten Inert Gas) welding is generally used for piping fabrication.

FCAW (Flux Cored Arc Welding) semi-automatic wire proccsses are dominant in some of the shipyards. It is a modification of MIG/CO2 welding. in which the continuous solid wire is replaced by a continuous flux-cored electrode wire. i.e. a tubular wire filled inside with flux. The flux performs essentially the same functions as the flux coating of a metal-arc welding electrode. In some of the shipyards it has almost completely replaced the stick electrode. (MMA).

Electro-slag and Electro-gas Welding are two similar processes. but quite different from the arc welding processes. Processes are fully automatic, the plates to be joined are kept in the vertical position. i.e. axis of the weld joint is vertical. The entire weld joint is completed in one pass and without interruption. These two processes enable heavy section-section welds to be made in one pass.

The various welding processes described are used for welding of hulls, which are of carbon steel or high strength low alloy steels. With the advent of aluminium and its alloys, they have been extensively used in workboats,. fast ferries. high-speed crafts. pleasure crafts and deck houses in large passenger ships. Increasingly. aluminium is being used in shipbuilding to reduce weight. Aluminium can be welded by both fusion and resistance processes. It can be gas welding, if it is a fusion process and under resistance welding, metal-arc welding, argon-arc welding or inert gas shielded metal-arc welding can be employed.

When it comes to joining aluminium superstructures to steel decks or aluminium decks (or even bulkheads) to steel hulls. explosion bonding is employed to join dissimilar metals. Essentially. the process involves the use of the transient application of extremely high pressure at the interface between the two metals to produce the bond.

Fig.1. Shows a new concept of prefabrication workshop

Fig.2. Refers to various activities taking place in a shipyard and are briefly described here

- Large panels. 16 x 16m or more-plate butt-welding is carried out by automated one-sided welding systems utilizing the SAW' process. Two welding heads are used. Two important phenomena to be kept under control; the loss of flatness and dimensional shrinkage.

- Sub-assemblies (first-level components, typical size 5x5m). GSAW welding Process is common. Sub-assemblies are built normally in a dedicated area.

- Flat open blocks (large dimension complex components). GSAW is used mainly in Downhand position fillet welding, vertical upward fillet welding and down-hand position butt-welding. An important factor in this fabrication area accuracy of the preparation of various components to be welded.

- Curved open blocks (large dimension complex curved components). The GSAW Welding technology is used for shaped plate butt-welding and for fillet welding of reinforcements and intemal structure.

- Connection of assembly units in the building dock: Butt-welding of two units is carried out by dedicated machines running/ sliding vertically or horizontally on tracks arranged/positioned at the side of the seam. GSAW welding, using ceramic backing has been commonly adopted. To maintain the accuracy control check by theodolite system is carried out. This is done in order to check the matching of the physical edges with the CAD model.

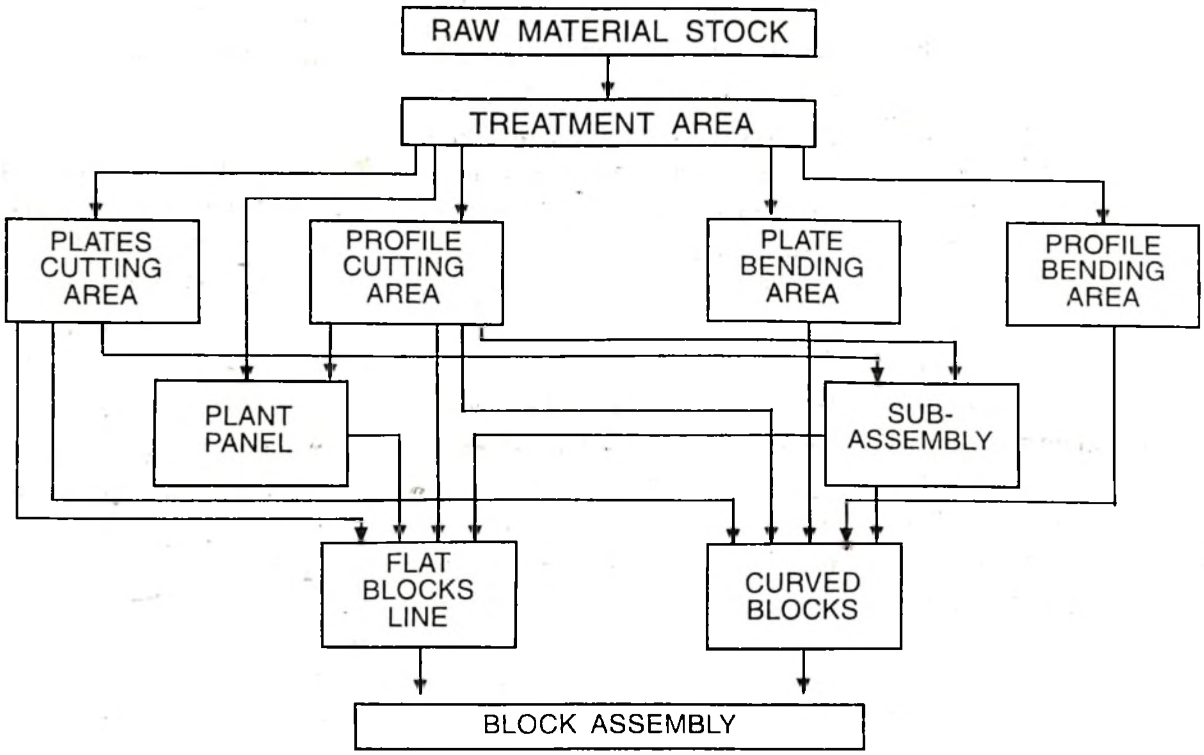
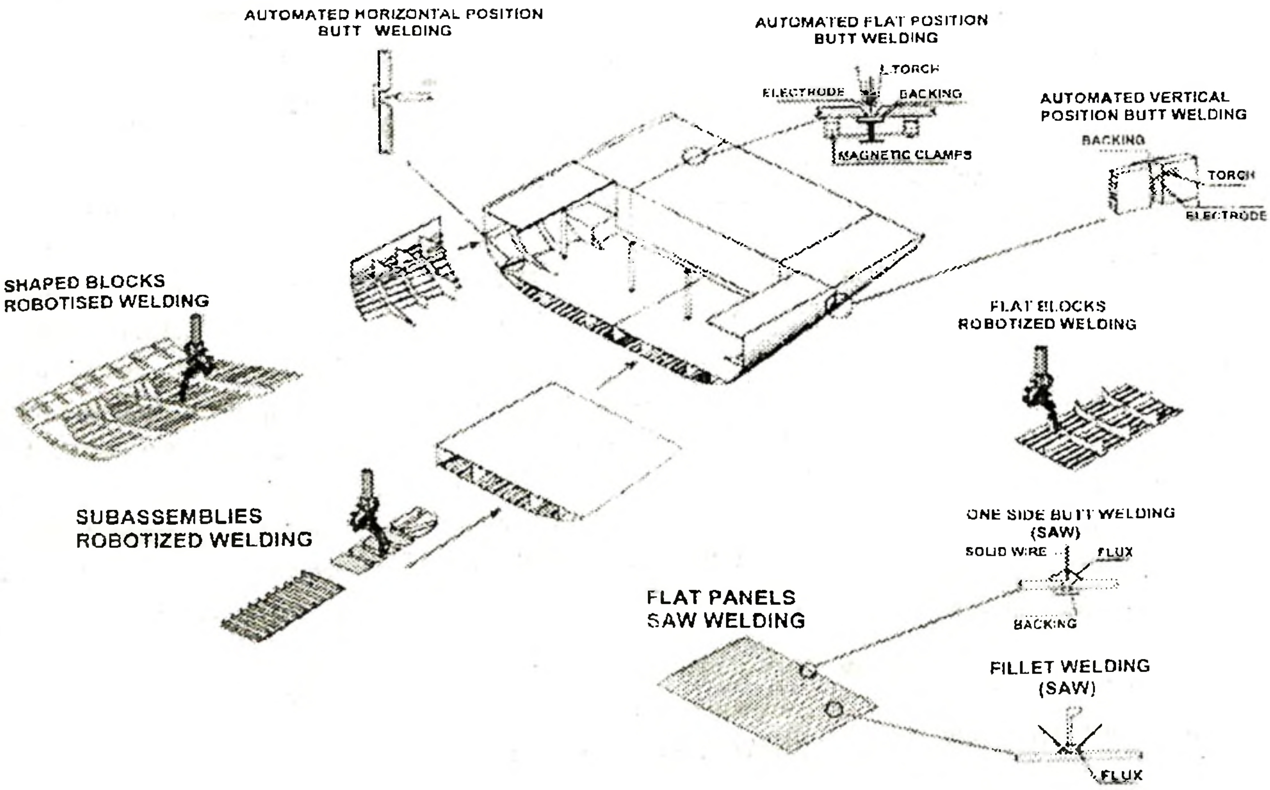


Fig.1 : Prefabrication workshop



NON-DESTRUCTIVE TESTING METHODS FOR INSPECTION OF HULL WELDS DURING SHIPBUILDING

In order to ensure quality control of ship hull welds during construction certain critical areas of weld joints are selected for weld joints. These joints are butt welds, T-joints, corner and cruciform joints with and without full penetration, fillet weld joints and field or erection joints. The inspection of welds during shipbuilding is based on following guidelines.

Type of material

- Normal and high strength structural steels
- Hull castings and forgings complying with Class Rules

Welding Process

- Gas metal arc, gas tungsten arc, flux cored arc, shielded metal arc, submerged arc, electroslag and electrogas welding.
- Consumables

Types of weld joints

- Butt, tee, corner, cruciform and fillet - with or without full penetration

Type of discontinuity

- Porosity, slag inclusion, undercut, underfill, excessive reinforcement, overlap, cracks, lack of fusion, incomplete penetration and lamellar tears.

Examination Methods

For detection of surface defects

- Visual Examination (VE)
- Magnetic particle Examination (ME)
- Liquid penetrant Examination (PE)

For detection of embedded discontinuities

- Ultrasonic Examination (UE)
- Radiographic Examination (RE)

JOINT CONFIGURATION GROUPS

The different types of weldments are divided into four groups of weld joint configurations with respect to the applicability of methods for detection of embedded discontinuities.

Group A

Weldments for which both UE and RE are applicable

Normally this group includes butt weld joints of full penetration, in plates of minimum 10 mm thickness.

Group B

Weldments for which only RE is applicable

Normally this group includes butt-welded joints in plates of less than 10 mm thickness.

Group C

Weldments for which only UE is applicable.

Normally this group includes T-joint. corner joints and cruciform joints of full penetration, in plates of minimum 10mm thickness

Group D

Weldments for which neither RE nor UE is applicable.

Normally this group includes T-joints. corner joints and cruciform joints of part penetration or plate thickness less than 10 mm thickness and fillet welds.

The extent of examination of weld joints either by RE or by UE is generally 2-4% of weld length. The weld lengths should be examined in sections of length in the range of 200 mm to 500 mm for RE and about 1000 mm in case of UE.

THE SCENARIO IN INDIAN SHIPBUILDING INDUSTRY

The shipbuilding industry in this country though slow to adapt themselves to changing technology and new emerging trends in the welding methods have equipped themselves to improve the productivity in their respective shipyards. This they are able to achieve either by employing latest welding techniques or by carrying out improvisation of the existing welding processes / practices

The methods employed are :

a) Complete butt-welding of large plates used for blocks is done from one side by using multiple

Table 1 : Recommended Acceptance Criteria for VE, ME and PE

Type of Surface Discontinuity	Acceptance criteria
Prosity : Max. Pore diameter - d Min distance to adjacent pore	 3 mm 2.5*d
Undercut Max. Depth	 0.5 mm
Underfill (see notes 1 and 2) Max Depth Max Length	 1.5 mm 0.5 * t
Excessive Weld Reinforcement (see note 3) Max. Height Overlap (see notes 1 and 2) Max Length Cracks Lack of fusion	 B/t-6 mm max t Not acceptable Not acceptable
Incomplete penetration (see notes 1 and 2) Max. Height Max Length	 t / 10, 1.5 mm max. t

NOTES : Discontinuities on a line where the distance between them is shorter than the longest discontinuity are to be regarded as one continuous discontinuity.
t = Plate thickness of the thinnest plate in the weld joint
3. b = Width of weld reinforcement

Table 2 : Recommended Acceptance Criteria for RE

Type of Surface Discontinuity	Acceptance criteria
Porosity, Isolated (see note b) Max. Pore diameter - d Min distance to adjacent pore	 t/4, 3 mm 2.5*d
Porosity, Clustered (see note a) Max. Depth dia d Max. Length of cluster	 3 mm 25 mm
Slag inclusion (see notes a - d) Max Depth Max Length	 3 mm t, 25 mm max
Undercut and underfill Cracks and lack of fusion	As per Table 4 Not acceptable
Incomplete penetration (see notes a,b,d) Max Length	 t, 25 mm max

NOTES : Discontinuities on a line where the distance between them is shorter than the longest discontinuity are to be regarded as one continuous discontinuity. t = Plate thickness of the thinnest plate in the weld joint
If the distance between parallel slag inclusions, measured in the transverse direction of welding, is less than 3 times the width of the largest slag inclusion, then the slag inclusion are regarded as one discontinuity.
Excavation and repair not necessary for length up to t.

welding heads and flux copper backing. This technique enables at a time to weld 4 plates simultaneously.

b) Electro gas welding with ceramic welding having V-profile is being used extensively for vertical and down-hand welding

c) SAW and CO2 welding with ceramic backing for main deck and accommodatioin Decks.

d) Plasma arc cutting has replaced the CNC cutting and this has resulted in increasing the output by 4 to 5 times more than what would have been achieved by CNC machine. This eliminates the need for post dressing operation as surface finish is of very high quality.

e) Most of the welding is now being carried out in assembly shop, thus reducing the welding in the building block considerably. In one particular case out of the total weld length of 420 km, a mere 25 km of welding length is done in the building block.

f) Use of inverter power sources and automatic machines for simultaneous blasting and painting.

Thus by employing modern welding methods a particular shipyard has been able to save nearly 5 lacs man hours.

6. The future trend may see the use of Laser Welding technology as productivity intrinsic to Laser Welding is 4 times that of any of the traditional electric arc welding techniques and more over, panel deformation is dramatically reduced because of the low heat input specific to Laser Welding process.

CONCLUSION

Shipbuilding is a complex and logistically intensive production process. The shipbuilding industry has been able to shed the old image of 3D's (demanding, dirty and dangerous) and attract young talent. Innovation and automation are calling the shots in every industry. Since welding processes are replacing human skill in achieving a sound quality weld it is imperative for welding industry to bring in more automation, achieve more productivity and introduce cost effective welding processes so as to bring down weight of the metal deposited by welding with minimum use of consumables.

Table 3 : Recommended Acceptance Criteria for UE

Echo Height	
0 -100%	> 100%
Indication to be disregarded, irrespective of length	Max. Length of indication = t, 25mm max.

NOTES :

t = Plate thickness of the thinnest plate in the joint.

The length of an indication is to be measured as the length where the echo height is above the specified value.

The indications from one or more discontinuities on a line where the distance between the indications is less than the length of the longest indication are to be regarded as one continuous indication.

Excavation and repair is not necessary for length up to t.

OBITUARY

Mr. PRABHAT KAMAL MITRA

a Life Member of

The Indian Institute of Welding

has expired on 25th February, 2002 due to cardiac arrest.

During his service life he was associated with Eastern Railway, Head Wrightson, Simon Carves, Otto India, Simplex Engineering and Foundry Works, etc.

He is survived by his wife, daughter and two sons.

May his soul rest in peace.