Welding Productivity in Ship Building

By M. K. Mukherjee*

SYNOPSIS

Indian shipping is growing rapidly but Indian shipyards are not able to deliver even a fraction of the tonnage being added annually. Extraordinarily long building period due to poor productivity in Indian Shipyards has been attributed to be the cause of this paradoxical state.

Hull fabrication takes up major part of building effort for the types of ships in vogue to-day. Welding, playing an important role in activity of hull fabrication, has been discussed in the present paper and recommendations made for improvement of welding productivity in Indian Shipyards.

1.0. Indroduction

1.1. The phenomenal growth of international trade during the last twenty years has resulted in a manifold increase in world shipping and consequent growth in shipbuilding. The significant feature in to-day's shipping is the introduction of VLCCs, OBO carrier, very large bulk carriers, container ships and LPG carriers. As shown in fig. 1., in case of most of these ships, hull fabrication takes up over 70% of the total shipyard effort inclusive of fitting out. There are shipyards in Portugal which survive just by building the hulls of VLCCs for foreign shipyards.

1.2. Since the oil price hike in 1973, the growth of shipping has considerably paced down. To-day shipbuilding is in a tremendous recession. Any success in ship-building will depend on

(a) The quality of the ship ;

(b) Competitive cost of the ship ; and

(c) Fast production and hence quick delivery.

Whereas in most of the industrially developed countries, the quality of a ship is more or less a standardised feature, the cost and terms of payment are the outcome of varieties of national and international fiscal policies. By and large, to-day's shipping order is governed by the last factor viz., "delivery period". "World's best" building period of a ship as shown by Takezawa (2) is shown in fig. 2.

1.3. The theatre of shipbuilding in the post-war period was U.K. In the late 50's till early in 60's, the lead was taken by the Scandinavian countries, Sweden in particular. Since the mid 60's, Japan has been constantly

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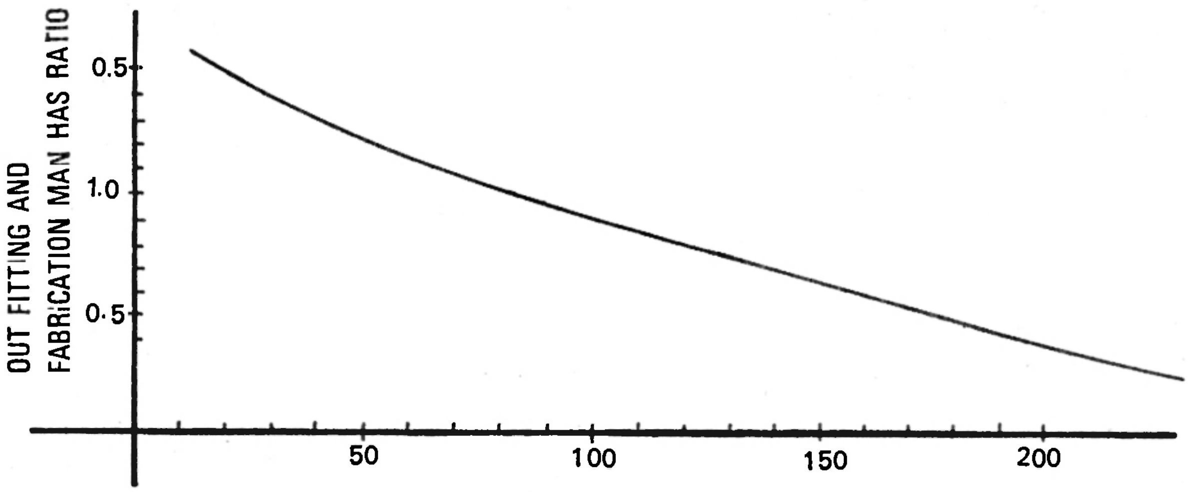

Fig. 1. DWT in thousand tonnes.

maintaining dominating position in world shipbuilding. Japan to-day is building nearly 50% of the total world shipping being added every year.

1.4. Delivery period will be attractive only when the major part of the effort viz., Hull Fabrication is fast. Hull Fabrication comprises of preparation, marking, cutting, forming and joining of steel plates and structurals and finally taking the shape of sub-assemblies and a complete hull on a building berth or in a building dock. Of all these activities, 90% will be needing welding. The leaders in shipbuilding have therefore concentrated their efforts in shortening the time taken for welding. For a good ship, there has to be various stage checks and the welding, therefore, has to be both speedy and of specified quality.

2.0. Productivity in Shipbuilding

2.1. It is worth studying the success story of Japanese ship-yards. Out of many factors attributed for the rapid growth and commanding position of the Japanese shipbuilding in the world, important factors are

(i) Technical Research and Development

(ii) Good design

(iii) Planning productive facilities

(iv) Quality control ensuring accurate individual work

(v) Development of productive methods

(vi) Investment in cost saving productive facilities.

To-day in Japan, over 60 universities are involved with Research & Development work pertaining to shipbuilding and allied subjects. Similarly, in other major shipbuilding nations in the world, significant R & D efforts in shipbuilding are evident by the rapid increase in the publication of valuable papers and articles on production technology in shipbuilding in almost all the leading shipbuilding journals and transactions. To-day's shipyards are more on the pattern of a "ship production factory" and Japan and Scandinavian countries have put concerted effort in new innovations of productive methods both in plate "forming" and "joining" techniques. ESAB of Sweden M/s. Kobe and Osaka Transformer Company Ltd., of Japan, Airco Products, USA

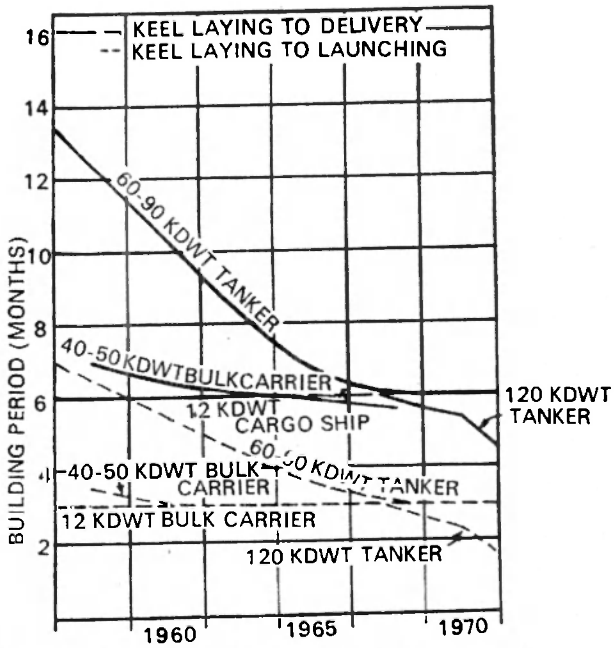

Fig. 2. Building period chart for various kinds of ships.

and Arcos of Belgium are worth mentioning in the field of development in high productive welding techniques.

While discussing welding and productivity in shipbuilding, each of above mentioned factors are equally important and perhaps leading the shipbuilding market would be the cumulative effect of all the factors.

2.2. *Technical Research & Development:* To-day's research in shipbuilding and ship design is not only in the field of resistance and propulsion, structures and material, but also in innovation of higher productivity and quicker building techniques. In the introduction, the dominating classes of present day ships have been mentioned which have been evolved because of the pattern of growth of international trade. This has resulted in introduction of new type of materials as discussed in Appendix-I to this paper. Their fabrication and welding have imposed new problems. As a matter of fact, to-day most of the leading shipbuilding nations and shipbuilding enterprises employ a large number of researchers for R & D work to increase productivity in shipbuilding which includes solution of problems of welding special steels and constantly innovating higher welding productivity.

2.3. *Design:* The vessel that the ship owner wants must be sea-worthy and commercially viable, which is ensured by the designer and the builder. But to make the same ship competitive, the designer must look into the economy of construction. To elucidate this aspect it is emphasised that it is not enough just to conceive a noble design of a ship, production of the ship at ease and at a low cost are also very much of concern for its success. The designer must therefore, be aware of the problems of fabrication and welding in particular.

2.4. *Planning—Production Facilities:* To-day's shipbuilding is no more a traditional constructional method as it used to be till the beginning of the second world war. It has already been stated that to-day's shipyards are "shipbuilding factories". Adequate planning in improving the productive facilities plays a dominant role in achieving higher productivity shipbuilding. Emphasis of this aspect will be apparent if one studies the Patton Committee Report (1) submitted before the Royal Commission in U. K. for appreciation of the gradual downfall of British shipbuilding. In a nutshell, it was reported that the British Yards were old and not able to get out of the grip of traditional building methods. Perhaps USA were the first to bring in method engineering in production of Victory and Liberty classes of ships during the war. Sweden further improved the production planning and all her shipyards were the examples of best application of productive facilities. To-day, no doubt Japan has made best use of the experiences of both the traditional shipbuilding nations and the new Scandivavian shipyards and developed their Yards on these lines. In India, in modernisation of existing shipyards and planning of the new shipyards, cognizance of these aspects is kept ; yards are also being equipped with the latest facilities.

2.5. *Quality Control—Ensuring Accurate Individual Work:* Every ship owner would like to have the best ship with best performance. All the leading shipyards, therefore, have introduced a system whereby the end product—"The Ship" is the best of their ability and also fulfills the specified requirement of the ship owner. The ships being built are all classed and inspected at various stages of production by the Classification Society representatives. Rejection of a component or production, at any of these stage checks by Classification Society Surveyor, will cause a severe set back in the production schedule. It is, therefore, in the interest of the ship builders to ensure that the quality is as per requirement and hence such shipbuilders lay down quality standards at various stages of production and employ a large number of quality control inspectors and field staff for in-house stage check. This aspect will again be discussed in detail in para 4 while discussing quality control in welding.

2.6. *Development of Production Methods:* Every shipyard and shipbuilding research establishment is constantly working for the common goal in mind to achieve higher and higher productivity. Every shipyard therefore, should be able to identify the areas where such new productive methods can be explored and new innovations introduced without any inhibition.

2.7. *Investment in Cost Saving Production Facility:* It is not enough just to identify the areas and appreciation of the need of productive methods but the Management should also be aware of the need of investment for such new innovative techniques and required equipment. Availability of funds may also be a guiding factor for timely investment in introducing cost saving production facilities.

3.0. Welding—A Guiding Factor in Productivity in Hull Fabrication

3.1. Welding has been introduced in shipbuilding gradually from the 30's and fully by 50's. The innovations for achievement of higher productivity in welding have been seen from the mid 50's. In all cases, the aim has been to obtain a higher rate of flaw-less deposit to achieve good joints. When welding was introduced in shipbuilding only MMAW was in vogue. Later introductions in the field have been SAW, GMA, multiple wire SAW, multiple wire single sided welding by SAW, electro gas and electro slag welding. A good account of the welding techniques used in shipbuilding has been given by Burman (11). In Appendix-II, a brief description of each type of aforesaid welding is given for the appreciation of the new comer in the field.

3.2. India, entering into industrial culture, needs a careful study of the productivity as practised in other nations and to make an all out effort in achieving nearest to the best. The author has the experience in absorption of technology from two different industrially developed countries and has also closely studied the transfer of technology form two other industrially developed countries. In both cases, at the initial stage, productivity out of sheer manual effort was found to vary between 1/5th to 1/3rd of that of the industrially developed nations. After a few years experience, this figure goes up to almost 2/3. The productivity of that of automatic and semi-automatic production devices is however much closer to that of an industrially developed country. Figure 3 is a typical study of one of the best shipbuilding productivity and that of an average shipyard in India. The figure for Indian productivity is based on the study made by the author in three different yards. For the survival of Indian shipbuilding before severe international competition, productivity of Indian shipyards must come closer to that of the world's best.

3.3. The discussion here is not for creating job opportunity and to raise productivity of Indian shipbuilding only by manual effort but to make Indian shipbuilding competitive in the world. The effort of BHEL is perhaps an example in a highly competitive world. India has been able to bag lucrative turn-key contracts for thermal power stations from the Middle East and Malaysia.

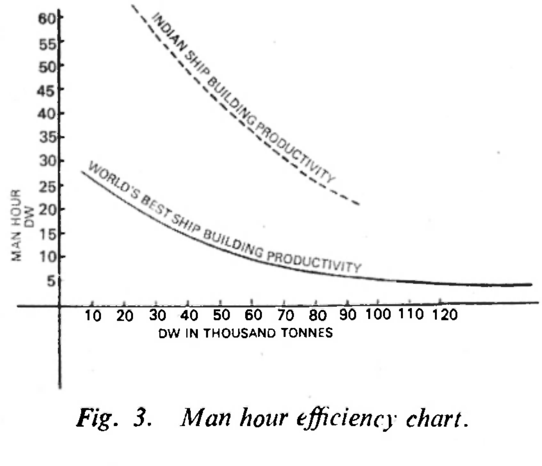

Fig. 3. Man hour efficiency chart.

The author while discussing the subject with the Senior Managers at BHEL came to realise that BHEL achievements were both due to very enthusiastic young qualified production engineers and also lack of inhibition of the authorities in introducing high productivity—production methods inclusive of semi-automatic, automatic and in many cases numerical control equipment.

3.4. All of us—in the field of shipping and shipbuilding are aware of the paradoxical state of Indian shipbuilding viz., on the one hand the Indian mechant fleet is growing rapidly but Indian shipbuilding is not able to meet even a fraction of the need of the Indian ship owners. As stated in para 1.2., Indian ship owners too will attribute "extra-ordinary delayed delivery schedule" for this sad state of affairs. Among the shipbuilders, however, many will give an exhaustive account on the causes of such delay in the schedule of delivery. But the author would like to emphasise that it is the production technique and the productivity in general which are causes of such long building period of a ship in an Indian yard. In the context of the present Workshop, the author is to high-light welding alone as one of the major factors of productivity.

3.5. The best way of gathering one's ideas would be to impose the following relevant questions :

(a) What is the total welding effort in to-day's all welded ship of different classes ?

(b) What are the means to achieve higher productivity in welding ?

and (c) What is the appreciation of the Indian Shipyards in the field of productivity in welding ?

Answers to these questions can be derived from the preceding and succeeding paras. Krishnamurthy in his report on welding in shipbuilding (4) has made a wide survey of varieties of welding being practised in shipbuilding. His appreciation is that in India, the use of automatic and semi-automatic welding in shipbuilding is only of the order of 6% to 7% as opposed to a figure of about 30% to 40% in leading shipyards in the world. Due to complexities of the joints, MMAW will always contribute the maximum towards welding effort of a ship's hull. It can, therefore, be inferred that introduction of more semi-automatic and automatic welding methods alone will increase the Indian shipbuilding productivity.

3.6. In a national seminar about a year back, the author (9) had emphasised the need for the recognition of welding as a discipline of technology in shipbuilding. To-day in most of the Indian shipyards, welding is just considered to be the activity of a welder who is able to strike an arc with an electrode and maintain the arc at a steady pace. His ability to appreciate the defects in the weld as well as to achieve the quality of weld is minimal. Due to paucity and, in many cases, total absence of welding technologists in a shipyard, tangible improvement in welding productivity is very difficult to achieve. Indian shipbuilding industry must follow the approach of BHEL and BHPV in employment of enthusiastic welding technologists both young and the experienced. It is also possible that young graduates or diploma holders in right discipline can be trained to be welding technologists in the shipyard.

3.7. Better management of field welding will increase welding productivity. For MMAW in shipyards both in the shops and in the building berth or the building dock, large number of welders are to operate simultaneously. The latest trend is the use of multi operator welding transformer rectifier. In Naval Dockyard, Vishakhapatnam, large number of 18 operator welding rectifiers are in use. Each welder is provided with a regulator. There is, however, scope in further development as mentioned by Burman (11) in miniaturisation of the control equipment and also to save the effort of the welder in shuttling to-and-fro from the location of welding to the regulator for adjustment of current setting. It is understood that a number of indigenous welding equipment manufacturers are manufacturing such multiple operator sets. Many production engineers even suggest that a shipyard should have a busbar net work of feeding O. C. voltage 60—and welders are able to tap welding supply from any point through portable regulators. While discussing field management, it is not out of place to mention that if the welders are aware of the environmental problem and make sure that the joints they are to weld are clean and free of moisture and grease, quality and productivity of welding will improve. They are also to ensure that the electrodes they carry to the site are in moisture proof containers. In extreme weather conditions in India both during the summer as well as in the monsoon, higher productivity on the building berth can also be achieved by provision of standardised portable sheds.

3.8 In a ship there are large number of components and sub-assemblies of structures that hardly need shipyard plant and machinery for forming. A small scale fabricator employing qualified welders and using specified welding consumables may be able to produce such structures or sub-assemblies economically and deliver at the assembly bay or the building berth and thus help in reducing the fabricating time of the complete hull. Therefore, all shipyards should encourage formation of an industrial estate next door and permit small entrepreneurs to flourish as fabricators and subcontractors for the shipyards.

4.0. Quality Control in Welding in Shipbuilding

4.1 The right appreciation of the quality of weld needed in different parts of the ship's hull and many components is lacking almost at every stage of production in a Yard. As a result, there is a tendency to over-quality-consciousness in welding as brought out by Harrison and Young (7) and Balamanohar (10). It is necessary that both the shipyard Quality Control Inspector as well as the Surveyors of Classification Societies have a right professional background to understand the functions of respective components and parts of the ship's structure being inspected and are able to make "Engineering Critical Assessment" of the various welds on a ship. Various Classification Societies lay down the rules and specified acceptable standard of welds (13 to 17). But the individual discretion and appreciation of the components which are load carrying or probably underdesigned, forms an important feature of the quality acceptance. As stated in para 2.7, to a Manager-in-Charge of production aiming at a high rate of production, rejection of a weld at the stage quality check and consequential set back in completion of other scheduled activities can be irritating. For the quality consciousness in welding at different parts of a typical large bulk carrier or a tanker, recommendations of the International Institute of Welding are given in Appendix III.

4.2. While talking about quality standard at every stage of production, the author wishes to draw the attention of all Hull Fabricators to usual disputes between the plater and the welder on the correct edge preparation and maintenance of gap. It is regretted to state that the onus of a good weld is always thrust on the welder. It must be remembered that the welder will be able to produce a quality weld only if the edge preparation and the gap between all the jointing surfaces is regular. Automatic gas cutting or rotary shearing machines will give a smooth edge for the plates to be welded. Manually operated gas cutting is still being practised giving a rough and uneven edge which is difficult to weld. Investment in automatic cutting equipment therefore is a requirement for improving welding productivity.

4.3. Mention has been made in earlier discussions regarding achievement of higher productivity in welding by single sided SAW. However, knowing that MM-AW shares major part of the welding activity in shipbuilding, multi pass as well as welding of the reverse side of the joint and quality thereof should also be kept in mind. In both these cases, before the commencement of welding, the surface preparation viz., pneumatic gouging or grinding is essential for ensuring quality of weld as specified by the Classification Societies. For radiographic quality of weld, the author's experience is that the preparation of the joint and also preparation for the second and third run of weld takes up fourfold the time of actual welding operation. Grinding by high speed light weight pneumatic grinder is recommended. Such light weight grinder has been developed in Naval Dockyard, Vishakhapatnam and has proved a very versatile tool for use in all positions. For achievement of quality weld and maintaining welding productivity where multiple pass MMAW has to be used, the shipyards must equip themselves with such versatile tools. Appendix IV gives the details of various non-destructive testing methods used for quality assurance of welds.

5.0. Special Welding

5.1. Electro Slag Welding : New problems have emanated with the growth in the size of ships. One of the typical examples is that of the manufacture of a huge rudder stock of a VLCC. Casting or forging of such a large single unit is a difficult proposition. Varieties of fabrication methods have been considered and electroslag welding with multiple electrodes was found to be an ideal solution in welding of cast or forged components of such a large rudder stock as reported by Brosholen, Skaug and Visser (8).

5.2. Electro Gas Welding : Electro gas welding is another innovation introduced by Airco Products of USA. This technique has also been harnessed by many other welding equipment manufacturers mentioned in para 2.2. and also research organisation like BSRA and sets are being marketed under different patent names. Almost all the leading shipyards in the world are using this technique for improving productivity of welding butts on the building berth or building dock.

5.3. MMAW by Contact Electrodes : Contact electrodes have been developed to reduce the skill required for welding. Further improvement in welding productivity has been achieved by use of such electrodes with gravity welders.

6.0. Welding of Higher Strength Shipbuilding Steels

6.1. So far the discussion has been very general. In to-day's VLCC and specialised craft (as shown in Appendix I) each and every Classification Society specifies use of higher tensile shipbuilding steels. Their welding imposes unique problems. Chadbund and Salter (6) have very aptly presented the techniques of welding of such steels. In naval construction, particularly in submarine building, the welding, however, imposes different problems. With reference to the quenched and tempered steels, the author (9) had discussed the problem of welding in naval construction. It goes without saying that the environment of shipbuilding is perhaps one of the most hostile as far as welding is concerned. The steel which is weldable in laboratory, or may be also in workshop conditions, may impose tricky problems when welding on a building berth or in a building dock. Here the productivity will be guided by well trained welders and technologists, and use of the right technology, equipment and consumable.

6.2. The environmental factor need not be taken lightly by the ship-builders. It is a worth introducing standard practice in a ship-yard to keep electrodes in dry environment. Humidity control is probably an expensive device. Storage of electrodes for the day's consumption in a dry oven after pre-heating the basic coated electrodes to a temperature range from 150°C to 200°C is recommended. A dry electrode in clean and ideal environment will give at least 15% higher productivity. By clean environment, the author means a habitual practice of wire brushing the joints and use of hot torch to make the area dry prior to welding by MMAW. Similarly while using the automatic and semi-automatic methods of welding, the operator and Quality Control inspector must ensure that the area is free from dirt and grease.

7.0. Rate of Welding per Operator

7.1 In welding productivity, it is not the mere production of running metre of weld per hour per individual but also achievement of high rate of weld deposit and formation of sound joints. In MMAW, there is about 75% increase in the rate of welding by adoption of basic-metal powder coated electrodes. This however, is no match to the high speed welding achieved by multi wire—SAW. With the advent of GMA welding although the speed was found to be much higher than MMAW, due to copper coating on the welding wire, the weld was found to be full of spatters. This was overcome by the introduction of flux cored wire in association with GMAW. Without gas shield, hollow-flux-cored welding wire has also been used to achieve higher welding productivity. India planning new shipyards and modernising older yards must also fall in pattern of the national endeavour in creation of employment opportunity. Manual and semi-automatic devices will occupy the field for time to come. Therefore increased use of both metal powder coated electrodes in MMAW and flux cored electrode with or without shield should be considered to raise the welding productivity in shipbuilding in India.

7.2. Japanese shipyards have tried out the gravity welders with long contact type electrodes and have achieved high productivity when each trained welder is able to used as many as 7 gravity welders. It is hoped that the Indian welding consumable manufacturers will show interest in marketing suitable long contact type electrodes for use with gravity welders. There are however associated problems like quick engagement and ready formation of arc, absence of distortion of the electrode towards the end of the run due to effect of the heating and lastly possibility of introducing basic metal powder coated electrodes to get the best deposit rate. As per the experience of two Indian Shipyards having tried to use gravity welders, an Indian welder should be able to use 4 to 5 such gravity welders.

7.3. In case of SAW, higher productivity has been reported by Mohanti & Muthu Krishnan (12) by using hot wires. Their work needs to be further harnessed and if welding productivity is consistently found to be better, Indian welding equipment manufacturers should show interest to develop such welding machines.

8.0. Ship Repair and Welding Productivity

8.1. To-day almost all major Shipyards are also maintaining dry docks and undertaking lucrative business of ship repair. Unlike shipbuilding where material specifications and the requirement of welding consumable are known to the shipbuilder, in case of ship repair for the vessels built in foreign yards and under the Class of different classification societies, the type of consumable to be used may not be easily available. In such cases, perforce, reliable and expensive basic powder metal coated electrode of low temperature type (with higher arc stabilizer in the flux coating) is recommended. The definition of productivity in ship repair is however different to that of the shipbuilding. Here the aim is to complete the job at the earliest with sound welded joints. Cost of the joint often takes the least priority.

8.2. In ship repair business, the yards are also required to carry out varieties of repair of machines and equipment components by welding. Here again a quick analysis of the material will only give the guideline in selection of the welding consumables. The knowledge of load on the component and likely stresses being encountered by the component is more useful in selection of the welding consumable. The choice of electrode is always that of having mechanical property better than the parent material. However, the likely improved fatigue or brittle fracture characteristics can be achieved in the weld pool if the grain refining elements are present in the electrode or in the flux coating.

8.3. While carrying out repair by welding, distortion due to excessive heat has to be safe-guarded. Here again, low heat input electrodes marketed by almost all the leading welding consumable manufacturers are useful. Latest introduction in the field is the use of pulse-TIG welding so that the heat in-put is regulated. Such machines are also indigenously available.

9.0. Off Shore Drilling Platforms and Oil Rigs

9.1. The latest entry in the shipbuilding world is the fabrication of Off Shore drilling platforms and oil rigs. Here the use of grain refined micro alloy steels of dfferent kinds having very superior mechanical properties is common. The welding of such steels poses problems similar to that of welding of varieties of HY steels. This subject had been discussed by the author in National Welding Meet 1977 at Vishakhapatnam (9). Very low hydrogen electrodes are used in association with pre-heating or post-heating to get a crack-free radiographic quality weld. Welding productivity in such cases also calls for meticulous care of the welding joints particularly its cleanliness.

10.0. Conclusions and Recommendations

10.1. From the foregoing, it can be concluded that the Indian Shipyards can capture larger share of the addition of new shipping tonnage under Indian flags only if the productivity of Indian shipbuilding can be of the standard of that of the major shipbuilding nations of the world. Welding productivity so far has not been given a serious thought in Indian Shipyards. Without losing any more time, it is imperative that all out attention is given to shorten the fabrication time. To achieve this, following recommendations are made :

(i) All shipyards should establish a welding technology cell and give due recognition to the cell. This section will be responsible for selection of consumables, equipment, innovating productive welding techniques, investigating the cause of frequent defects and finding solution to obviate such defects.

(ii) Shipyard authorities should carry out study on cost effectiveness of new high productivity welding equipment and should have no inhibition in introducing such equipment.

(iii) For MMAW, higher welding productivity by iron powder coated electrodes should be aimed at.

(iv) In Indian conditions, complete automation of welding in shipyards may be against the national policy of creation of employment opportunity. Semi-automatic welding— particularly with flux cored electrode should be introduced in wide scale application in Indian shipyards.

(v) Shipyards should aim at higher welding productivity by improving field management for welding and also by farming out simple components to sub-contractors for fabrication.

(vi) All hull fabricators right down to the level of the plater should be given an in-house training on the quality requirement of welding in ship-building. This will enable all concerned to be aware of the requirement of tolerances in sub-assemblies and joint gaps etc., and this will reduce the onus of producing quality weld only on the welder.

(vii) Both the shipyard Quality Control inspectors and the Classification Society surveyors should have right background to be able to make an "Engineering Critical Analysis" on the quality requirement of the component structures of a ship.

(viii) The shipyards should standardise their requirement of welding consumables and have periodical discussions with the indigenous consumable manufacturers so that good quality high productivity consumables can be readily available indigenously.

(ix) The welding consumable manufacturers as well as the welding equipment manufacturers should organise periodical Seminars in shipyards to acquaint the latest trend of development in the range of their production.

Acknowledgement

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References :

1. Patton Committee Report on Productivity of British Shipbuilding 1961.

2. Takezawa "Management Control in Ship-building in Japan" RINA 1967.

3. Mukherjee and Gokarn "Education and Research for Indigenous Ship Production" Transport Journal—Oct and Dec. 72.

4. Krishnamurthy R. K. "A report on welding in Ship-building" 1972.

5. Mukherjee M. K. "National Policy on Ship-building and Research" Publication of National Shipping and Ship-building Conference—Jan 73.

6. Chadbund and Salter "The Welding of Higher Tensile ship-building steels" RINA 1973.

7. Harrison and Young "The Acceptability of Weld Defects" RINA 1974.

8. Brosholen, Skaug and Visser "Electro Slag Welding of large castings for Ship Construction" Welding Journal Aug 1977.

9. Mukherjee M. K. "Quality Aspect of Welding in Construction" National Welding Meet, Nov 77, Vishakhapatnam.

10. Balamanohor "Some aspects of quality requirements in welding ships' main hull structure" National Welding Meet, Nov 77, Visakhapatnam.

11. Burman S. K. "Welding in Ship-building Industry" Engineering Times Shipping Supplement, 11-18, May 1978.

12. Mohanti and Muthukrishnan "Hot Wire SAW" Welding Seminar 78, Tiruchirapalli.

13. Rules for Building and Classing of Steel Vessels —American Bureau of Shipping.

14. Rules and Regulations for the Construction and Classification of Steel Vessels— Bureau Veritas.

15. Rules for the Construction of Classification Steel Ships—Det Norske Veritas.

16. Rules for the Classification and Construction of Sea going steel ships. Vol. III Materials "Welding" Germanischer Lloyd.

17. Rules and regulations for the Construction and Classification of steel ships—Lloyd's Register of Shipping.

18. AWS Welding Note Book.

APPENDIX—I.

1. Combined stresses on a ship with large deck openings

Moments acting on a ship are :
SWBM — Design Still Water Bending Moment
VWBM— Design Vertical Bending Moment

HWBM — Design Horizontal Bending Moment
Torisonal Moments
(Torque) T — Hydrodynamic Torque

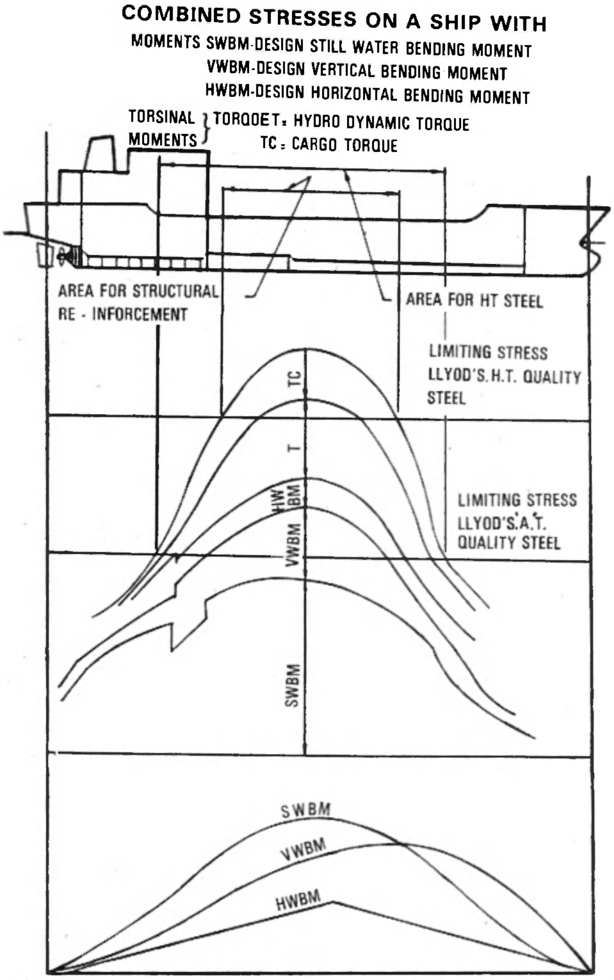
Tc — Cargo Torque
Stresses due to above moments and torques superimposed on a typical ship are shown in fig 4.

2. High Tensile Shipbuilding Steels as specified by different Classification Societies :

Lloyd's Register of Shipping — AH. DH, EH (Gd. 27, 32, 34 and 36)
Bureau Veritas AH. DH and EH
Det Norske Veritas — D and E
American Bureau of Shipping — EH

3. International Association Classification Societics (I. A. C. S.) H. T. Ship-building Quality Steel :

	%		%
C	0.18 max	Nb	0.015—0.05
Mn	0.90—1.60	V	0.03—0.10
Si	0.40 max	Cu	0.35 max



HIGH TENSILE SHIP BUILDING STEELS AS SPECIFIED-DIFFERENT CLASSIFICATION SOCIETIES
LLYODS REGISTER OF SHIPPING-AH, DH, EH,(GD. 27, 32, 34&36)
BUREAU.VERITAS - - - - - - - AH, DH, & EH
DET NORSKE VERITAS- - - - -D 36, E 36
AMERICAN BUREAU OF SHIP BUILDING - - - - EH

Fig. 4.

S	0.04 max	Cr	0.20 max
P	0.04 max	Ni	0.04 max
Al	0.02—0.06	Mo	0.08 max

4. Micro Alloyed Steels :

Having fine grained structure obtained by addition of small amounts of Niobium or Vanadium or combination of both. Also subjected to controlled rolling leading to precipitation hardening with increased yield strength.

Such steels are widely used in the construction of oil rigs, oil lines and tanks etc.

APPENDIX-II

VARIOUS TYPES OF WELDING PREVALENT IN SHIPBUILDING

1. Manual Metal-Arc Welding : MMAW is the most commonly used welding process for low and mild carbon Ship-building quality steels. ISI has a comprehensive specification for mild steel covered arc welding electrodes. Indian welding consumable manufacturers produce electrodes to both ISI and Classification Society specifications. Selection of proper size and type of electrodes is, however, made on the following basis :

(i) the welding requirement ;

(ii) the chemical composition and mechanical properties of steel ;

(iii) scantling of the sections and plates being jointed;

(iv) joint geometry ; and

(v) welding position.

The flux coatings are either 'Rutile' or 'Basic'. Hydrogen evolution in ml/100 gm of weld deposit is over 20 in case of the former and between 2 to 10 in the latter.

For high deposition rates, iron powder coating is used. Indian electrode manufacturers allege that the cost of imported Iron powder being high, indigenous iron powder coated electrodes are expensive.

Recent development in MMAW is contact electrodes which can be used by comparatively less skilled welders. Extension of use of the contact electrodes are the gravity welders for welding straight line down hand welding.

2. Gas Metal-Arc Welding. GMAW is widely used for joining shipbuilding steels. The shielding gases most commonly used are argon, argon-oxygen, carbon dioxide and argon-carbon dioxide mixture. Metal transfer is generally by spray, globular or short circuit depending on the shielding gas used. GMAW is used both in semi-automatic and automatic processes.

To regulate heat input, a recent development in the field of GMAW is the pulsing mode of metal deposit.

AWS-A5.18 specifications for carbon steel filler-wires used in this process are given in the following tables :

3. Submerged Arc Welding. SAW is one of the most widely used automatic welding processes in use in ship-building since last 30 years. A wide range of electrode compositions and fluxes are available. AWS A5.17 gives the most comprehensive specifications for bare M. S. electrodes and fluxes for SAW.

The SAW electrode—flux combination should be selected according to composition, scantlings and cleanliness of the base metal and the mechanical properties required of the weld joint.

Higher deposit rate can be achieved by use of tandem wire and a recent development is the introduction of 'hot wire' in SAW.

This process is limited to down hand position and good fit up of parts is required. Weld properties are improved because of the slower cooling rate (due to the flux blanket), lower stress concentrations (derived by smooth external bead contour) and the inherent good bead cross-section.

With tight fit copper chill-bar backing and 'Vee' joint preparation, 'single sided SAW is a recent innovation in shipbuilding. All consumables are indigenously available. Multi-wire SAW plants may also attract Indian welding equipment manufacturers if the demand is high.

4. Flux Cored Arc Welding. FCAW with tubular, flux filled electrodes with or without separate shielding gas are also extensively used in ship-building. This process has a high deposition rate and both semi-automatic and automatic devices are in use.

AWS A5.20 gives the specification for M. S. electrodes for FCAW.

One of the Indian welding consumable manufacturers is likely to market FCAW M. S. electrode shortly.

5. Gas-Tungsten Arc Welding or Tungsten Inert Gas Welding. GTAW or TIG welding utilises a non-consumable tungsten electrode to maintain the welding arc. Filler metal may or may not be used. Argon, helium or a mixture of the two gases are used for shielding the arc. The welding current is straight polarity D. C. for steel and to reduce heat input A. C. is used for Aluminium and thinner guage material.

AWS has grouped tungsten electrodes in five different types viz.,

EWP	99.5% (Min) Tungsten
EW Th-1	98.5% tungsten+0.8 to 1.2% thoria
EW Th-2	97.5% tungsten+1.7 to 2.2% thoria
EW Th-3	98.5% tungsten+0.15 to 0.40 thoria
EW Zr	99.2% tungsten+0.15 to 0.40% zirconium

Plain tungsten electrode is preferred by manual welders because the electrode top forms into a ball upon use. This produces a soft arc and the tip of the electrode is easily seen.

Thoriated tungsten electrodes are usually ground to conical shapes at their tips. Such tip shape lasts for a considerable time before redressing is required.

Zirconiated tungsten electrodes are often preferred for A. C. welding because of better arc starting and greater stability.

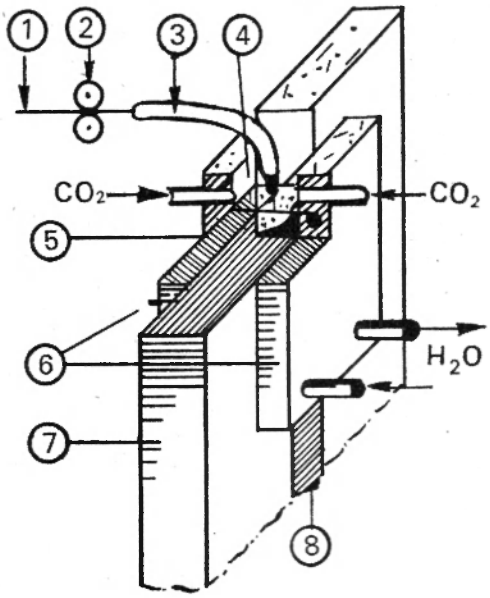
To reduce heating of the tungsten electrodes air cooling or water cooling arrangement is provided in the torch.

6. Electrogas Welding. In this process, flux cored wire produces a visible arc in carbon dioxide gas shield between copper shoes cooled by water. Fig. 5 shows the principle of electrogas welding.

This process in automatic device can be used for welding of vertical joints (butts). Japanese welding equipment manufacturers have tried to develop equipment using this process for welding horizontal seams on a building berth.

7. Electro Slag welding. Electrode is fed through a consumable guide between the gap of the two jointing parts and water cooled copper shoes. The arc is maintained in the molten slag floating at the top. Schematically, the principle of the process is shown in Fig. 6.

Further improvisation has been made in the process by using multiple electrodes. The process is very useful for fabricating large components which are difficult to forge or cast in a single unit.



1. Flux-Cored wire. 2. Wire Drive Roller. 3. Wire Guide Nozzel. 4. Protective Gas. 5. Molten Metal Pool. 6. Mobile Watercooled Shoes. 7. Parts to be welded. 8. Welding Bead.

Fig. 5. Principle of Electrogas Welding.

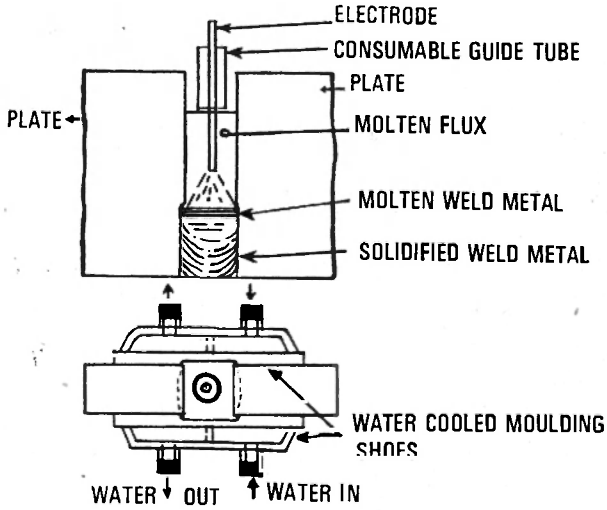


Fig. 6. Principle of Electroslag Welding.

APPENDIX-III

Recommendations for the Quality Control of welding for the ship-building industry (as per the International Institute of Welding). Fig. 7.

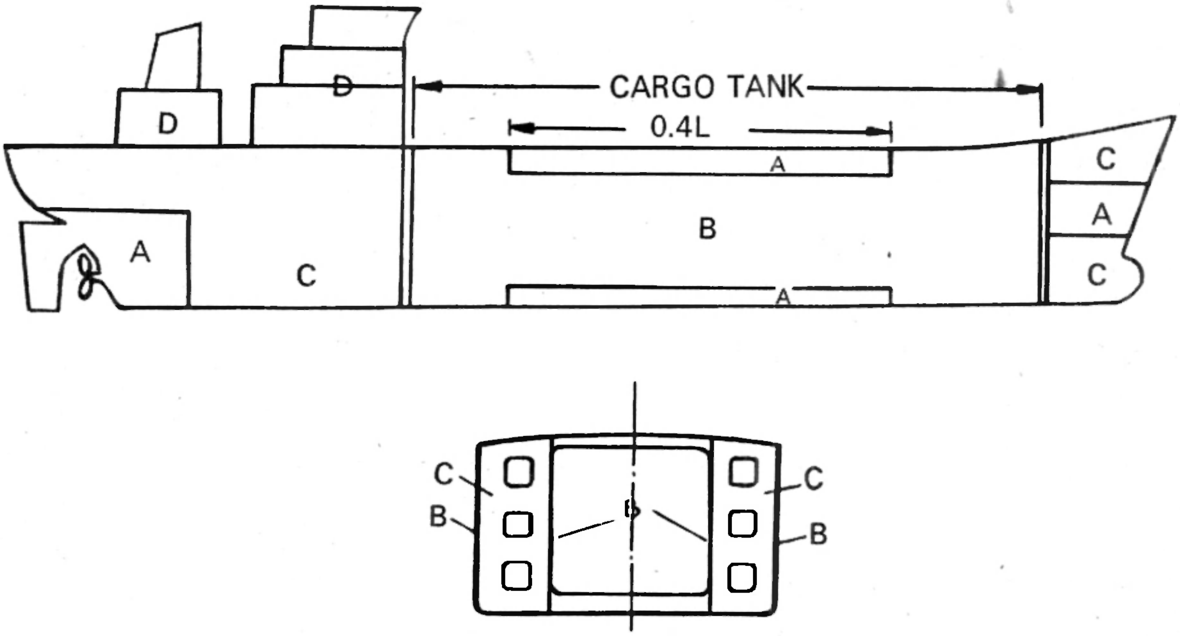


Fig. 7.

1. Each basic ship design can be divided into various areas for the purpose of quality control and acceptance. Figure above is taken for a 210,000 ton tanker divided into 4 quality areas.

2. In quality area "A", 100% NDT should be carried out. Two levels of quality should be established. The quality control standard should require a reasonable high standard of workmanship but some changes could be made to existing requirement without any deleterious effects. It should be clearly defined and not left to the individual surveyor. The ECA (Engineering Critical assessment) level should be established by the Naval Architect based on the BSI approach. Seams better than the quality control standard may be immediately accepted. Seams whose quality falls between the two levels need not necessarily be repaired. The decision could be in the hands of the Surveyor and repairs could be called for if he felt that there was a general tendency towards a reduction in quality.

3. In quality 'B', NDT would be carried out at seam intersection only. The quality control standard could be same or somewhat looser than that of area 'A,. The ECA level would almost certainly be lower. For welds with defects between the two levels, repairs would not necessarily be required but steps would be taken, the reason for the loss of quality would be established and the trend would be corrected. The implication of finding the defect below the ECA level during spot radiography is serious. It should certainly lead to further NDT possibly upto 100% and of course all defects below this level must be repaired.

4. In quality area "C", spot NDT would be carried out on a low percentage basis as a quality control measure only. It is likely that the ECA quality required would be low so that it is very unlikely that any repairs would be called for.

5. In quality area "D", no NDT would be called for. Visual inspection only would be sufficient to ensure that the welds were of good appearance.

6. As a general recommendation both quality control and ECA requirements should be as precise as possible so that ship builders and surveyors may know beforehand what is needed.

7. Thought should be given to the substitution of other NDT techniques for Radiography. Since it will be seen from the above recommendation that NDT should be used mainly for quality control rather than for acceptance, it becomes important to carry out NDT as soon as possible after welding as possible so that undesirable trend can be corrected immediately. Radiography is of necessity carried out sometimes after welding. The extra cost of the alternative techniques themselves would be off-set by the fact that it would now be unnecessary to clear part of the berth for safety reasons.

APPENDIX—IV

Table No. 1.

Method of NDT	Usage	Advantages	Remarks
1. X-ray	For examination of internal soundness of welds	1. Gives good definition upto 75 mm thickness 2. Gives a permanent record indicating nature of defects 3. Offers established standards of interpretation	1. Necessity of protective precaution in the surrounding 2. Trained personnel needed to take exposure and to interpret the film
2. Gamma-ray	For examination of internal soundness of welds	1. Equipt is portable 2. Suitable for larger thickness 3. Lower initial and maintenance cost 4. Gives permanent record 5. Offers established standards of interpretation	1. Govt. license is required for possession & use of isotopes 2. Protective precautions necessary 3. Trained personnel needed to interpret the film
3. Magnetic crack detection	For locating surface and subsurface defects that are not too deep	1. Useful for components where use of radiographic techniques are difficult 2. Reveals small surface defects 3. Useful for weld repair	1. Useful only for magnetic material 2. Not suitable for defects parallel to magnetic field
4. Dye penetrant test	For locating surface defects	1. Especially applicable for non-magnetic material 2. Useful for the inspection of components where radiographic tests are difficult	1. Only for defects that are open to the surface
5. Ultrasonic inspection	For detecting defects in welds & plates	1. Portable equipment 2. Good for detection of laminated plates 3. Reveals small root cracks & defects not indicated by radiographic film	1. Training required for visual inspection and interpretation 2. Rough surface has to be made smooth for the probe to make proper contact with the part 3. Photograph can be taken for permanent record 4. No set standards yet established.