Recent Trend of Welding Technology in Japanese Industry

Dr. Syuzo SUSEI
President
The Japan Welding Society

1. Introduction

In the past 50 years, welding technology has made a substantial contribution to the development of the shipbuilding and other industries in Japan. Great efforts have been made in the development of state-of-the-art technology to drive industrial development. These efforts have seen the diffusion and specialization of technology associated with sophisticated industrial products. The cumulative effect of these factors has contributed to the overall diversification and maturity of technology. Unfortunately, oversupply in the heavy industrial sector has slowed economic growth and depressed society. Therefore, a range of serious problems is anticipated.

As the 21st century approaches, I expect welding to further contribute to the development of industry by taking advantage of the opportunities that IT and globalization present. To understand contemporary demands, it is necessary to be aware of the need for multi functions, lower costs, and higher standards of welding. Other factors such as material technology, and the process technology of components, system and management, must also be considered. From the standpoints of the areas of hardware, software and human resources in the heavy and welding industries, I would like to present my personal view by referring to the lessons learnt over the last 50 years.

2. Changes in Welding Technology over the Past 50 Years

2.1 Welding Technology in the Shipbuilding Industry (from riveted joint to welded joint)

In the middle of the 20th century, we witnessed a change from riveted joint to welded joint as the joint method for large-scale hull structures. This change could be understood as a paradigm shift, which greatly influenced the shipbuilding industry. This paradigm shift enabled a shift to smaller vessel weights, more efficient structure joint methods and innovations in production processes, especially the large-scale block building method. As a result, Japanese shipbuilders' methods were recognized as being of the highest standard internationally. (Fig. 1, Fig. 2, Fig. 3)

It is particularly important to recognize the contribution of domestic steel makers, who played an important supply-side role to the shipbuilding industry and developed high-quality steel and welding materials. Furthermore, they paved the way for industrial development by taking advantage of the superior Japanese version materials that were available.

The scaling up in production of vessels, which is represented by very large crude carriers (VLCCs) (Fig. 4), the development of various types of vessels including LPG and LNG carriers (Fig. 5), and the application of an automatic arc welding method, has

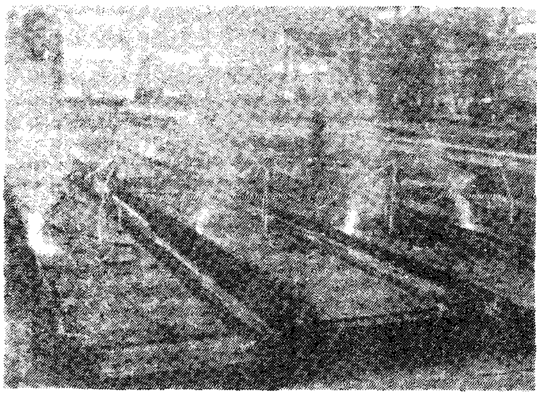

Fig. 1 Gravity Welding

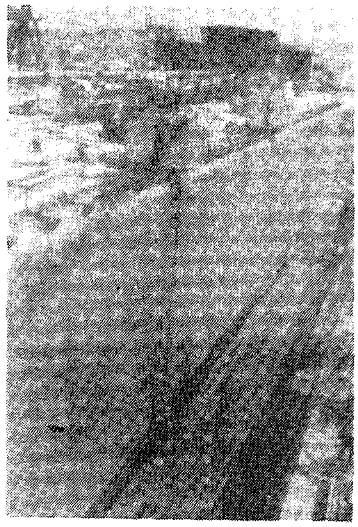

Fig. 2 Application of Electroslag Welding to ship structure

diversified and expanded the industry. Japanese shipbuilders broke new ground in the application of various steel materials and aluminum alloys while developing welding technologies. The welding technology used for an extra thick aluminum alloy spherical pressure vessel in the MOSS type LNG vessels is a new development in automatic aluminum alloy welding. Further developments have been made in materials, equipment, construction technologies, and human resources. Recently, titanium alloys and super high tensile steel were used in the production of ultra-high-speed hydrofoils such as jetfoils and Techno-Superliners (TSL) (Fig. 6), for which practical use has been realized.

2.2 Diverse Japanese heavy industry originated in shipbuilding

The shipbuilding as a system product has had the impact on a divers range of Japanese-style heavy industries. A range of process and assembly industrial products, which are based on plant manufacturing, originated from development and innovation in the shipbuilding industry.

Fig. 3 Four-run one-side Automatic Arc Welding Machine

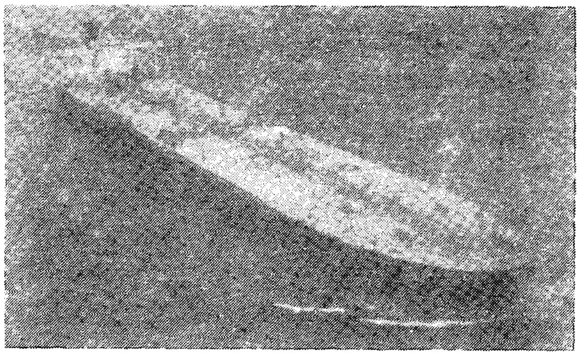

Fig. 4 VLCC

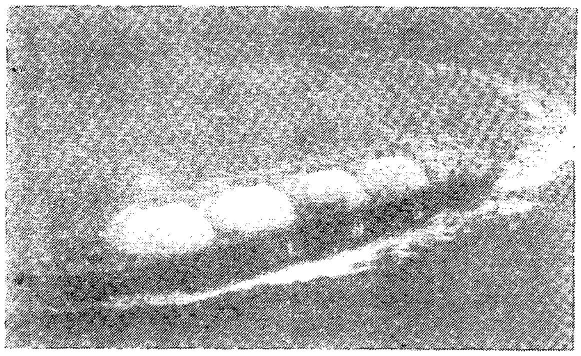

Fig. 5 LNG Carrier

Shipbuilders of heavy industrial companies manufactured a variety of structural products such as pressure vessels, penstocks, watergates, bridges, and steel frames for construction purposes (Fig. 7). Furthermore, shipbuilders expanded into the production of mechanical products such as prime movers, engines, vehicles, material handling equipment, civil work machinery, and airplanes. Heavy industrial companies competed directly with manufacturers that specialized in a narrow range of products. Initially, companies diversified their business by obtaining licenses from pioneer manufacturing in the West. Technological development was promoted; thus unique and superior products were realized by placing emphasis on quality, cost, and delivery (QCD).

Some of these products, especially structural system products, are the result of a synergetic effect among welding technologies developed by shipbuilders, high strength steel materials, and improved welding characteristics of materials.

In the construction of large-scale bridges in Japan, represented by the Akashi Kaikyo Bridge (Fig. 8), the world's longest suspension bridge, a relatively large proportion of high tensile steel was used. Also, Japan has come to lead the world in the standardization of the usage of high tensile steel in bridge construction. In the middle of the 1970s, high tensile steel plates were used in the construction of the Minato Ohashi Bridge (Fig. 9) in Nanko Port in Osaka; thus the foundation for the practical use of this material was laid. Previously, three Japanese heavy industrial companies jointly undertook the construction of the Auburn Forest Hill Bridge in the suburb of Sacramento, USA. The welding technology employed, which was performed on HT80 steel plates

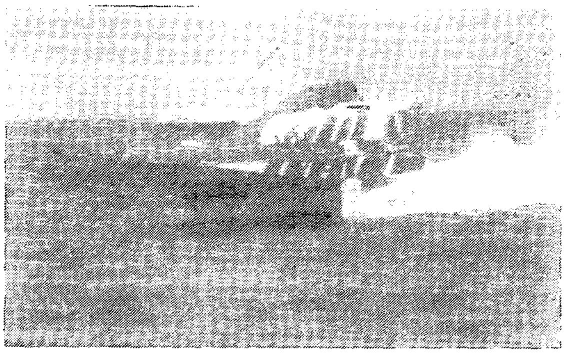

Fig. 6 Techno-Superliner

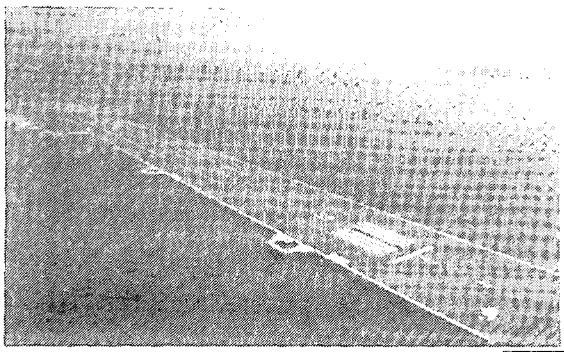

Fig. 7 Mega-Float

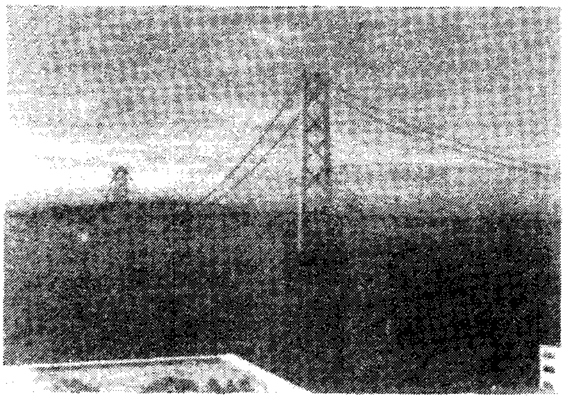

Fig. 8 Akashi-Kaikyo Bridge

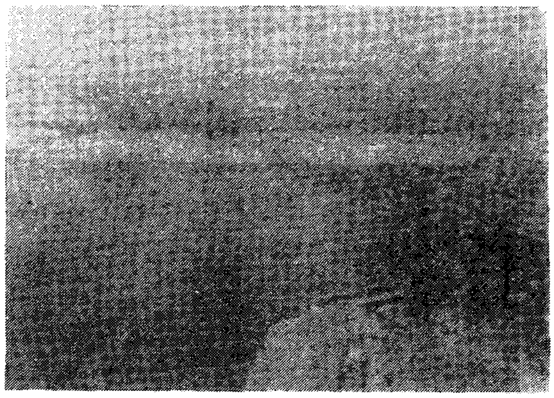

Fig. 9 Minato-Ohashi Bridge

(equivalent to T-1 steel ASTM A517 or JIS G3128) up to 4 inches thick, represented a technological leap in welding.

As in the case of large-scale bridges, domestic heavy industrial companies also played an important role in the development of the welding technology for high tensile steel plates used for large penstocks for dams with high heads and high pump heads. In this field, a full-arc, one-side automatic welding method that uses gas-shield, type-arc welding was developed. This method laid the groundwork for the all-position automatic welding method.

In the production of steel frames for skyscrapers, these companies took the initiative in improving the efficiency of electroslag welding and multi-run high heat input welding. Furthermore, they contributed to the development of high-efficiency systems in production lines, and the development of systems to automate and mechanize gas-shielded arc welding works at construction sites.

3. Perspective for Welding Technology

3-1 Automation and Robotization of Welding Process

First, I would like to present the automation and robotization of welding technology.

It used to be the situation that Japanese shipbuilders took the initiative when investing in R&D, which was later put into practical uses in other industries. However, we cannot expect shipbuilders to continue to carry this R&D burden. From now on, individual industries should develop their own automation and robotization strategies. And, as far as I can see, such strategies would be divided into two categories:

-an attempt to make a paradigm shift,

-or the introduction of technology and equipment, which have been evaluated for potential.

Whichever direction individual companies take, the key factor will be cost competitiveness.

The pioneers in the robotization of production lines in Japan were automakers. People soon understood the added value that could be gained through a wide range of application of robots.

Domestic shipbuilders are already beginning to adopt the automation and the robotization of welding processes. However, robots for building berths for large hull structures are a huge investment at this stage, and how to keep the net operating rate at a reasonable level is a big problem. Shipbuilding is, by nature, an industry that customizes vessels to diversified client requirements to satisfy end-users' needs; shipbuilders need an independent man-to-machine interface for each order. If a wide selection of user-friendly ready-made robots for large-scale structure builders becomes available, and demand in the market is high, robotization in the shipbuilding industry will rapidly become sophisticated and popular.

Automation and robotization of production lines will improve working conditions and shop-floor organization. This can be achieved by shifting from labor-intensive factories to technology-intensive factories through downsizing such as automation and the development of simple easy-to-operate processing systems such as easy-to-learn panels and remote control functions for entry level workers. To ensure that difficult welding work is carried out safely and easily, sensors and arc monitors should be employed.

3-2 Advancement of Technology

Greater precision, higher efficiency enhanced performance, and higher reliability can be achieved through sophisticated technology. With regards to higher precision, we have already seen a great improvement in the precision of members after the introduction of laser cutters. I expect an extensive application of these cutters in the cutting of plates to grooves. I would like to see new concepts of welding fabrication lines from simulations on the cumulative precision of assembly work achieved by developing and applying production technologies, which will contribute to better precision.

In order to create production lines of high precision and efficiency, it will be necessary to install group-controlled robots and to establish highly precise, rapid-beam welding method such as laser beam welding (Fig. 10). Structural designs and joint

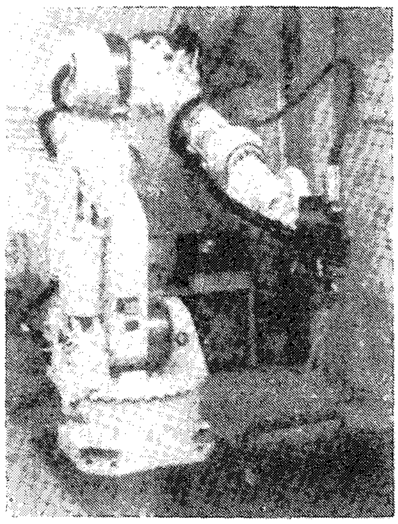

Fig. 10 Laser Robot (Optical-Fiber-Transmission Type)

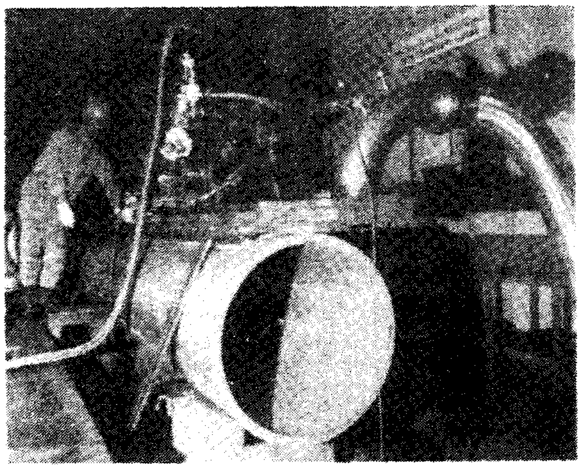

Fig. 11 Electron-Beam-Welding Machine
(Partial Vacuum type)

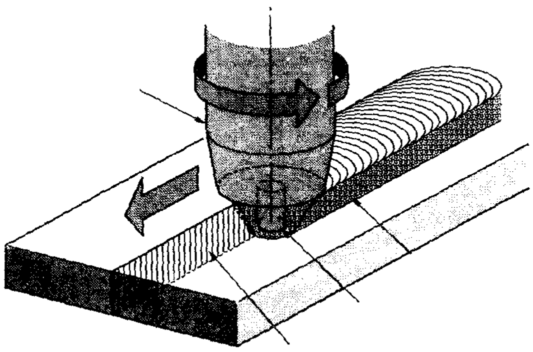

Fig. 12 Friction Stir Welding (FSW) Process

structures will need to be developed for such beam welding. I expect such efforts will open the gate to a paradigm shift equal to the change in the steel joint method from riveted joint to welded joint. Needless to say, we should not expect shipbuilders alone to do this task when considering the severe conditions that the industry is facing. Rather, it should be a collective project through the production of heavy industrial products. Moreover, in order to achieve this goal, a cumulative approach to the development of new technologies should be adopted. It should be an approach where individual cases of practical application of theories undergo rigorous evaluation and then become standardized just like the application of welding dynamics and arc physics theories did.

The fatigue strength of structural products with welded joints tends to depend on jointed parts. Strengths of welded joints have reached the same level as those of base materials, but it is still a common practice to make a considerable deduction of design allowable stress of jointed parts in use. This is another area where we can expect a paradigm shift to take place -- a new welding technology is developed, which allows the design of structures whose welded parts and joints have the same reliability as the base materials.

Welding is not used in the construction of airplane bodies; rivets or snaps and adhesives are used instead. This is because of the low level of reliability of welded joints and the difficulty in weld deformation control. I would like to see the highly reliable beam welding method (Fig. 11) and the friction stir welding (FSW) (Fig.12) method applied in the future.

It is expected to develop standard base materials and joints whose reliability distribution widths in S-N curves for weld fatigue strength are extremely narrow.

Most structures have parts subjected to high stress, hot spots, or weak points of some kind. If partial problems of this kind can be effectively overcome, the limits of a structure's performances will widen, which will then lead to improvement in durability and life. This will also contribute to the preservation of the environment. To give an enlightening example, in the production of blade parts of gas turbines, single crystal, fluid cooling, and wing surface coating are all combined to overcome problems of the kinds I have just mentioned.

Examples of attempts to enhance the performance of structures by the maximization of material characteristics and the treatment of local parts and surface can be found in the production of prime movers. This is the fruit of R&D, which has maximized the reliability of welded joints. In the future, I would like to see extensive research programs to develop process technologies and basic engineering technologies for the practical application of members, functionally gradient materials, and composite materials.

3-3 Application of IT to Production

It takes a continuous and thorough analysis of in-factory and out-factory information to substantially reduce costs. For this purpose, design engineers, who are in the upstream of the line in relation to their shop-floor counterparts, must be knowledgeable about the workings of the shop-floor. It is necessary to employ the value engineering (VE) approach to achieve such cost reductions. Furthermore, it is necessary to introduce powerful computer-integrated manufacturing (CIM) functions for the design section to be more deeply committed to technical and informational aspects. Shop-floor quality control (QC) should be fully mobilized to give feedback to the upstream line besides solving immediate shop-floor problems.

Shipbuilders are providing their yards with information network systems and also making efforts to enhance production through the faster collection of feedback information about each vessel and better problem solving at each level of production.

Another important consideration is the improvement in functions of real-time processing of information about unfinished stocks and the member setting and quality information about precision and workmanship at each stage.

The precision of members and their cumulative effects greatly affect the quality of production of vessels on the slips and, therefore, the productivity at the slips. Accordingly, the further improvement of measuring technologies is expected, in particular, optical measuring methods in order to collect and trace precision information about members.

4. Approaches to New Fields

It is our social responsibility to meet environmental standards proposed by AGS (Alliance for Global Sustainability) and other organizations. We will be required to run our business from a broader perspective. We will have to pay attention to everything ranging from planning, research, and design to service, maintenance, and the recycling of our products. For example, we will not be able to afford to ignore lead-free solder and recyclable "easy-to-attach-and-separate" joints as part of our strategic products. Manufacturers will have to convert themselves into product-life-cycle conscious companies who seek business opportunities in any stage of the product life cycle. At the same time, concepts such as life cycle assessment (LCA) and life cycle cost (LCC) will become more important.

Let's turn to new materials. Any materials for structural purposes will be able to find their way into application anywhere. On the other hand, enhanced performance materials will be applied to catalysts, solid fuel cells, super conductors, and sensors according to their unique characteristics.

New developments are expected to occur in engineering sectors using and applying information technology, while mechatronics sectors, such as the robot industry and the logistics industry, are going to expand their activities into new fields through the creation of equipment and systems.

As for the software industry, we will be able to capture business opportunities offered by multimedia-oriented products such as simulators. We should also try to participate in public works projects, utilizing analytical engineering technologies and processing technology for public complex information. Furthermore, we will have more chances to enter the markets of automated transportation systems, such as ITS and natural disaster prevention.

Engineers from different technical backgrounds are interested in welding, but there do not seem to be many design engineers among them. Welding technologies have technical merits that enable the construction of highly complex structures, from which economic benefits can be generated. In the construction of structures using welding, quality assurance is a critical factor. This alone gives engineers every reason show more interest in welding.

5. Conclusion

I would like to conclude my view by reiterating that welding is a basic technology, but is an important process that can ensure high quality and reliability of a structural product. Therefore, I think we can create products of sufficient quality at competitive prices using sophisticated welding technologies. Design engineers can take full advantage of these technologies. Further sophistication of welding technologies to meet contemporary challenges, such as environmental conservation, recycling, and extension of product life, is expected by industry and the public.

I strongly hope that the younger generations of engineers to take the initiative in the development of dream technologies, call them "magical technologies" if you like, for example, distortion-free welding, welded parts, which are easy to disassemble and recycle.