NIPPON STEEL TECHNICAL REPORT No. 65 APRIL 1995

UDC621. 79 "71"

Progress in Welding and Joining Technology and Its Future Prospect

Nobutaka YURIOKA*1

Abstract:

This report reviews a history of the development of welding and joining technologies since the invention of arc welding in 1885, and also describes the future trends of the technologies. Welding and joining, which have a hundred-year history in their development, have made a remarkable progress in the last ten years, and owing to the concurrent research and development (R & D) of welding metallurgy, welding materials and welding processes, further development of the technologies will be no doubt expected. The R & D on welding and joining in Nippon Steel has been intended to contribute to the development of its enterprises of steel products, engineering and new materials. The following two will be requested more intensely than ever to the welding R & D group: one is to promote the steel business through a timely supply of the welding materials and technologies suited to steels to the steel customers and; the other is to support the engineering divisions of Nippon Steel and its cooperative companies through the development of the exceptional technology of welding robotics.

1. Introduction

Most of steel products are welded to fabricate steel structures or steel members in our customers. Therefore, the welding R & D group of Nippon Steel has been demanded to make a timely development of welding processes and welding materials suited to the newly developed steels. The welding automation has been increasingly important in the Nippon Steel engineering divisions and its cooperative companies. Joining have turned into a key technology in manufacturing goods in the newly diversified business of Nippon Steel. The welding R & D group has deeply involved in the development of welding and joining technologies for theses businesses. The group have been always very busy in solving the imminent problems and thus, the group researchers may have not considered their most important responsibility deliberately.

On the occasion of publishing a special issue on welding technologies, the author would like to review the welding technologies so far developed in Nippon Steel and to find its trends and future prospects. On the bases of a review of the history and future trends, he would like to think over the role of the welding R & D group in contributing to the development of Nippon Steel enterprises including steels, engineering and diversified businesses.

2. Progress of Modern Welding Technology

Table 1 shows the history of the inventions of welding and joining processes. Electric resistance welding was invented in

*1 Fellow, Technical Development Bereau

Table 1 Modern welding process inventions

Year	Process	Country	Inventer
1885	Carbon arc welding	Russia	Benardos
1886	Electric resistance welding	USA	Thomson
1886	Flash butt welding	USA	Coffine
1892	Metal arc welding	Russia	Slavianoff
1895	Thermit welding	Germany	Goldschmidt
1901	Oxyacetylene welding	Germany	LeSchaterii
1907	Shielded metal arc welding	Sweden	Kjellberg
1909	Metal spraying	Switzerland	Shouve
1928	High-frequency induction welding	USA	Osborn
1930	TIG welding	USA	Hovert
1930	Submerged arc welding	USA	Kenedy
1948	Cold pressure welding	UK	Soder
1950	MIG welding	USA	Hobert
1951	High-frequency resistance welding	USA	Crofordrad
1953	Electroslag welding	USSR	Volochkevitch
1953	CO_2 gas shielded arc welding	USA	Smith
1956	Ultrasonic welding	USA	Biron
1956	Electon beam welding	France	Stoul
1957	Friction welding	USSR	Ichejikoff
1963	Plasma arc welding	USA	Jinanii
1965	Laser beam welding	USA	Mayman

1886 in United States. There are two methods in this welding process. One is butt resistance welding and the other is spot resistance welding. The latter had never changed its form since a hundred year ago until a spinning electrode spot welding process was invented in Joining Technology Lab. of Nippon Steel in 1990. Thermit welding, which was invented in 1895 in Germany, utilizes heat generated by chemical reaction of iron oxide and aluminum. It has been used exclusively to weld rails, and little changes also have been made in the thermit welding process since its invention. However, rails themselves has been considerably improved in their metallurgical properties and thus, researches on the development of new portions (welding material) for thermit welding of newly developed rails have been continued. Arc welding, which is presently most used in welding practices, originates in the carbon arc welding invented in 1885 in Russia. Consumable electrode arc welding was invented also in Russia by substituting a carbon electrode into a consumable metallic electrode. Covered electrodes were completed in 1907 when a Swede invented to cover flux on a metallic electrode.

After the invention of a covered electrode, TIG welding was invented in 1930, MIG welding which uses a consumable wire electrode was invented in 1950, and CO_2 welding which use CO_2 gas instead of argon as shielding gas was invented in 1953. These three processes were invented in the United States. TIG, MIG and CO_2 welding are called gas shielded arc welding. Intensive researches have been recently made on shielding gas, wire materials including flux cored wires and welding electric power sources including an inverter type. It follows that a remarkable progress has been achieved on the welding productivity and maneuverability in gas shielded arc welding. Thanks to the improved maneuverability, an unskilled technician can practice gas shielded arc welding without difficulty.

Submerged arc welding (SAW), another arc welding process in which welding arc is buried in covered powder flux, was intensively studied in Russia, but United States succeeded in the practical use of SAW in 1942 ahead of Russia. The application of this welding is limited to the horizontal and flat positions but its productivity is very high. SAW is still one of the important welding processes and it is extensively used for welding not only UO pipes and spiral pipes but also ships, bridges and buildings. Electroslag welding (ES), which use resistance heat of molten slag, was invented in 1953 at Paton Institute in the Soviet Union. Then, ultrasonic welding, plasma welding, friction welding, and explosive welding were invented from 1955 to 1963 in the Soviet Union and the United States. Their application is limited but they are still important welding and joining processes.

As to the recent inventions, electron beam welding and laser welding are important. Electron beam welding was invented in the Saclay Nuclear Research Institute in France in 1965. Since electron beam is emitted under high vacuum, active metals and dissimilar metals are exclusively welded by this process. Due to its high energy density, heavy section steels can be welded by one pass of electron beam. Laser, which was invented in 1955 in Hughes Institute in the United States, has increased its power year by year and laser welding will be certainly used to welding not only steel sheets but also thick steel plates in near future.

As shown in **Table 1**, all the welding processes presently used were invented until 1965 and unfortunately no Japanese name is found in **Table 1**. After 1955, however, welding technologies in Japan have been greatly progressed in accordance with her industrial developments. They have markedly contributed to the development of practical welding technologies in the world.

3. Progress in researches on welding and joining in Nippon Steel

A modern welding technology in Japan started before World War II when Suwamaru was built as a completely welded ship in Nagasaki Shipyard & Engine Works of Mitsubishi Heavy Industries, Ltd. In 1950 after the war, a submerged arc welding technique was introduced into Nagasaki Shipyard & Engine Works from Linde Company in the United States and a block shipbuilding method was settled. Then, welding completely replaced riveting in shipbuilding. At this time, plates of a rimed steel were used for shipbuilding and sulfur cracking occurred when welding the rimed steel plates. It was not until then that welding engineers noticed the significant influences of steel elements on the welding performances. Then, a term of weldability emerged. When a boom of exporting ships arose in 1955, plates for shipbuilding changed from a rimmed steel to a semi-killed or killed steel and then a high strength steel of a 490 MPa grade was developed. The welding of ship plates was the main subject in the welding researches in Nippon Steel (Yawata Iron & Steel and Fuji Iron & Steel at that time).

Around 1965, shipbuilding companies announced to construct new shipbuilding yards in order to export a number of ultra large oil carriers. To fulfill the duty of supplying high-quality weldable steels for the large tankers, Nippon Steel founded the Welding Research Center in Product R & D Laboratories in Sagamihara in 1970. The Welding Research Center consisted of not only researchers of Nippon Steel but also those from Nippon Steel Welding Products & Engineering Co., Ltd. and instructors at

Sector	1970	1975	1980	1985	1990	1995
Plates	500,000-ton tanker construction; One-side SAW; Automatic welding	Ships to offshore structures	Welding of TMCP steel; Weld metal oxide metallurgy	Nuclear steel, TiO steel, fire-resistant steel; Offshore structures for North Sea; Welding prediction system; Welding of NS110, medium- and high-temperature pressure vessel steels	Offshore structures for icy sea	
Sheets		Spot weldability of automotive high-strength steel; Flash weldability	Spot and seam welding of new coated steels; Mash seam welding of new container steels	Welding of vibration-damping steel; Arc welding of zinc-coated steel	Butt welding of high-strength steel; Laser beam welding	
Pipes and tubes	Startup of Kimitsu UO pipe mill; Welding of high-toughness pipe		Increased UO pipe welding speed; Increased SR pipe welding speed; ERW*1 phenomenon analysis	Defect-free UO pipe; Prevention of hot cracking of low-carbon steel	Sour-service and low-hardenability UO seam welding; Welding of boiler tubes(NF616, 709)	
Wire, rods, bars, and shapes	Pressure gas welding of reinforcing bars		Weld cracking of jumbo H-shapes; Flash butt welding of high-strength chains	Welding of high-strength rails; Continuous casting of steel for wire electrodes	Automatic field welding of rails (USA, JRs)	
Stainless steel	Welding of high-nitrogen stainless steel		Welding of ferritic stainless steel (YUS190)	Welding of corrosion-resistant, heat-resistant, cryogenic, and seawater-resistant steels; Plant welder training in Taiwan	Welding of MN316; Welding of automobile exhaust pipe	
Titanium and aluminum				Welding of commercially pure titanium; Welding of titanium alloys	Titanium-clad steel for bridge piers of Trans-Tokyo Bay Highway; Deep submersible vehicle; Welding and joining of aluminum	
Engineering divisions group	Welding of steel plant equipment by PMD*2	Welding of storage tanks by PMD*2	Lay barge welding of underwater pipelines by CEMCD*3; Welding of nodes in offshore structures for Iwaki and Exxon SYU projects		Automatic field welding of gas pipelines by CEMCD*3	
Construction materials	Welding of UB boxes for Ashiyahama project			Field welding robots(NS Robo and NS stud welding machine)	Response to domestic demand expansion; Welding of steel frames for high-rise buildings in China	
New materials				Bonding wire; Diffusion bonding by HIP*4; Joining of MMC*5	Development of FGM*6; Brazing of metal supports for catalytic converters	
Affiliated companies	Training of welders and welding operators			Seam welding of drums; Repair of turbine bladesby JTT*7	Welding of building column diaphragms; Welding of road decking; Welding of stainless steel drums	

*1 ERW: electric resistance welding, *2 PMD: Plant & Machinery Division, *3 CEMCD: Civil Engineering & Marine Construction Division, *4 HIP: Hot isostatic pressing, *5 MMC: Metal matrix composite, *6 FGM: Functionally gradient material, *7 JTT: Japan Turbine Technology

Fig. 1 History of joining technology developments

Welders Training Center. Its task was an overall welding development of researches on steel weldability, welding materials, welding processes and welding engineering as well as welders training, while its main subjects being the welding of shipbuilding plates.

Fig. 1 shows the changes in main welding research subjects in Nippon Steel after the foundation of Welding Research Center in 1970. The first oil crises begun in 1973 plunged shipbuilding companies into a long recession lasted to 1988. In 1973, a UO line-pipe mill was completed in Kimitsu Works and some members of SAW researches in the Welding Research Center changed their subject from shipbuilding welding to pipe seam welding. During the shipbuilding boom, considerable lack of welders took place. Thus, the development of welding automation were considered very important. Many automatic welding technologies were developed and put into practical use. However, the research on welding automation was decided to be stopped during the shipbuilding recession era because a shortage of welders was peaked out.

From 1975, Japan entered into a stable economic growth era. Since then, welding researches on steel sheets for automobiles became high-lightened. New types of high strength steel sheets were developed and it became increasingly important for Welding Research Center to research electric resistance spot welding and flush butt welding for the newly developed steel sheets. After 1980, one of the most important subjects was the development of spot welding techniques for zinc-coated steel sheets which were newly developed to ensure long lives of automobiles. There were tin-coated sheets for steel cans other than zinc-coated sheets. Another important themes at that time were the investigation of mush-seam can welding phenomena and the evaluation of mush-seam weldability of the newly developed tin-coated sheets.

Main topics in the shipbuilding welding researches were the welding of special ships such as LPG and LNG carriers as well as offshore oil-and-gas platforms. In 1980, a new process of TMCP (thermo-mechanical control process) was introduced to produce hot-rolled steel plates. By this process, highly tough and highly weldable steels for offshore structures and line-pipes to be used under sever conditions were developed. The sale of the TMCP steels was promoted by providing their customers with welding materials and welding technologies suited to the TMCP steels. Competing steel companies payed strong attention to this package sale. At the same time, the Welding Research Center attempted to clarify mechanisms of a toughness improvement of Ti-B (titanium and boron bearing) weld metals and found out that oxides formed in a molten weld metal play a crucial role on grain refining of the Ti-B welding metal. This discovery inaugurated an interdisciplinary research activity called oxide metallurgy in Nippon Steel. Furthermore, a HAZ hardness estimation formula and a preheat determination method were proposed, and Nippon Steal carbon equivalent, CEN was stipulated in the Canadian Industrial Standard. It is no exaggeration to say that Welding Research Center of Nippon Steel became a worldwide leader in welding metallurgy in an aspect of practical application.

After 1985, the plate sale division required to develop the welding materials and welding technologies for the newly developed plates including nuclear pressure vessels steels, high temperature reactor vessel steels, low-temperature use storage tank steels, deep submersible steels, and fire-resistant steels. The welding theme concerning pipes and tubes was the development of low-hardenability high-toughness seam weld metals for UO line-pipes for sour gas service, besides the development of welding materials for boiler tubes, double-wall pipes and clad pipes. The other important subject was the development of high speed welding and defect-free welding of UO pipes and spiral pipes. All the required tasks were completed without delay.

As to stainless steels, the demand for the development of welding materials and welding technologies considerably increased, because a wide variety of stainless steels were developed such as corrosion resistant, heat resistant, sea water resistant, sulfuric acid resistant and cryogenic stainless steels. It is characteristic to the stainless steel welding research that the major duties were the welding technical service or trouble shooting to customers for conventional stainless steels such as SUS316 and YUS190.

When the Japan National Railways was split into several private companies (JRs), the Welding Technology Lab. began to carry out the researches on rail welding, of which Railway Technical Research Institute had taken charge.The new tasks were the improvement of rail weld metal properties and the development of the rail field welding technology. The welding researches have performed the rail field welding training of newly developed rails for JRs and the other private railway companies with the cooperation of Welders Training Center of Nippon Steel.

In 1983, Nippon Steel started a new materials business in which the manufacturing of processed goods were regarded as important. The welding and joining technology played an important role in the new business, e.g., brazing was for metal carriers for automotive exhaust gas catalyst; wire bonding for integrated circuits and; transition liquid phase joining for repairing of turbine blades. In 1987, Welding Technology Lab. was renamed into Joining Technology Lab. in response to the diversification of welding and joining activities.

Since 1989, the ship building industry revived and the domestic construction business prospered. A boom came again to the welding-related heavy industries. However, many competent welders had been transferred to the jobs which did not need welding skills and the remaining welders had aged. The shortage of welders became a deep concern again. Furthermore, applicants for trainees at the Welders Training Center increased but their abilities were in a rather lower level than those of the shipbuilding prosperity time. For the promotion of steel marketing for domestic constructions under the circumstances of the welder shortage, it was increasingly important to develop welding robots and welding automation for the civil engineering steel constructions. The objective of the development of welding robots was to increase steel structures in civil construction while preventing concrete structures from expanding. Unlike the welding automation development era in '70s, there arose the remarkable development of electronics, computers and sensing techniques and the development of the completely unmanned welding technology could be in sight.

Meanwhile, it became increasingly important to reduce weight of welded members of automobiles. Then, butt arc welding gradually replaced spot welding in which lap joints are inherent resulting in a weight increase. Zinc-coated corrosion resistant steel sheets were exclusively used for automobiles and one of the most important tasks was the development of the prevention technology of blow holes and pits in arc welds of the coated sheets.

The author has reviewed the history of R & D of welding and joining in Nippon Steel as described above. This history is summarized in **Fig. 1**, indicating how deeply the weld and joining technology have been related with a progress of the steel business, the engineering business and the new material enterprise of Nippon Steel. Especially after 1985, the R & D activities of welding and joining increasingly expanded in accordance with the diversification of steel products and the business growth in the engineering divisions and the new business divisions of Nippon Steel. Great efforts of promoting continuous processing in every stage of steel making had been made and thus, cutting and joining became very critical processes, although **Fig. 1** does not describe. TIG, MIG, AC(alternative' current)-MIG, flush butt and laser welding have been applied to join bars and coils in steel making processes. The researches also have been made for the improvement of joint performances and speed-up of joining bar and coils.

The overlaying welding which is used in chemical plant vessels and steel mill rolls always had been an important theme. As a technique to replace the overlaying welding, a surface coating technology by low pressure plasma spraying and hybrid plasma spraying has begàn to be a new subject. This technology is expected to help the life extension of continuous cast molds and other steel making equipments.

Researches on welding materials have been conducted in cooperation with Nippon Steel Welding Products & Engineering Co., Ltd. One of the important tasks in the welding group, that consists of Nippon Steel, and Nippon Steel Welding Products & Engineering Co., Ltd. and Welders Training Center, has been the timely supply of the welding materials suited to the newly developed steels including plates, pipes, tubes, rails, stainless steels, and coated steel sheets. For one newly developed steel, many kinds of welding materials to be used in many welding processes including SMAW, MIG, CO_2, SAW, and others have to be developed. In this respect, it is inevitable to do cooperative researches with Nippon Steel Welding Products & Engineering Co., Ltd.

Fig. 2 shows the change in the production of crude steels and welding materials for the last twenty years. As seen in **Fig. 2**, the change in production of welding materials completely coincides with that of crude steels and this implies that the significance of welding technologies to the steel business never changed. As already described, it is an important task to prepare many kinds of welding materials suited to newly developed steels. Also, it is further important to provide steel customers of Nippon Steel with the improved welding materials suited to previously developed

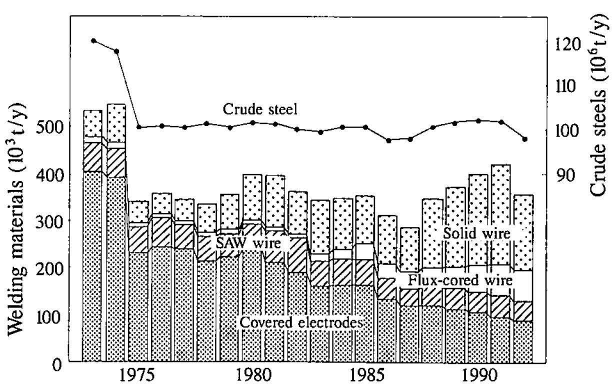


Fig. 2 Production of crude steel and welding materials in last 20 years

steels or conventional steels. For instance, a 9%Ni-steel for LNG tanks was developed more than twenty years ago, but since then the welding technology for LNG tanks has been continuously developing. Therefore, the provision of new welding materials and advanced welding technologies plays a key role in sales of steels. In the twenty years history of welding researches in Nippon Steel, the development of welding materials has always been very important while so has the development of welding processes.

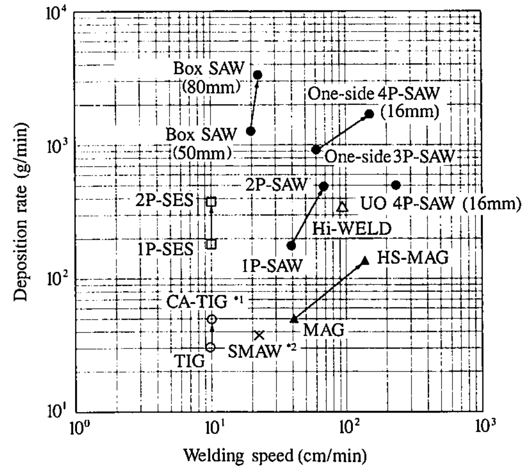
4. Future Prospect of Welding and Joining Technology

Most of welding processes use welding consumables (welding electrodes and filler wires) except resistance welding, laser welding and electron beam welding. The melting rate of the consumables is the deposition rate, that is an index of the welding production efficiency together with the welding velocity. **Fig. 3** shows the deposition rates and the welding velocity of various welding processes. TIG welding provides high quality of welds. However, it is not of a consumable electrode type and its thermal efficiency is quite low because a welding rod is inserted into a TIG arc stream. Even in the low efficient TIG welding, an improvement of its deposition rate has been made by making use of a double shield nozzle to concentrate TIG arc stream.

It had been considered that the welding velocity improvement of SAW was completed in 1980 when high speed SAW seam welding of UO pipes was established. However, the high speed SAW welding has been recently developed in one-side uranami welding of plates in shipbuilding. Its welding velocity is 2.5 times as high as that of the conventional welding. In gas shielded arc welding, a HS-MAG method has been developed which uses two electrodes of flux cored wires to form a molten weld metal heap between the two electrodes. The formation of the weld heap makes it possible to increase fillet welding velocity from 50 cm/min to 150cm/min. The HS-MAG welding has been contributing to the improvement of the production efficiency in the fabrication of ships and bridges. Another recent development of gas shielded arc welding is a rotary arc welding method in which the tip of an electrode wire spontaneously rotates under the high welding current and Ar-CO_2-O_2-H_2 mixture gas shielding. However, the high current welding under mixture gas shield emits violent arc light. Then, a Hi-Weld method with soft arc has been developed. This is a high-current high deposition rate CO_2 gas shielded welding process which uses a flux cored wire with flux including arc stabilizing substances. In electro-slag (ES) welding, a two-electrode ES welding method with a deposition rate twice as high as that of the conventional process has been developed.

The arrow marks in **Fig. 3** denotes the improvement of the welding production efficiency in the process above described. The processes shown in **Fig. 3** was developed in the last five years and all the methods except CA (concentrated arc)-TIG were developed by the Nippon Steel welding group.

A last-twenty-years history of the welding materials production is shown in **Fig. 2**. As already pointed out, an increase in the welding materials production linked with that of crude steels. Although its total production has remained unchanged, a production share of welding material types has substantially changed as clearly seen in **Fig. 2**. The manual electrode shared 75% of the total production in the beginning of '70s, but now it does as low as 20% or less. The solid wires for gas shielded arc welding



*1 CA-TIG:Concentrated arc TIG
*2 SMAW:Shielded metal arc welding

Fig. 3 Improvement of production rates of consumable electrode welding

gradually replaced the manual electrodes. This is because of a considerable improvement of maneuverability of solid wire welding, thanks to a precise control of welding droplet transfer in a one-drop to one-drop manner owing to improved welding power sources.

Furthermore, various types of flux cored wires for gas shielded arc welding have been increasingly manufactured, because the use of flux cored wires prevents spattering and it minimizes blow holes in welds even without removing primer coatings on plates. Flux cored wires for the exclusive use to stainless steels has been also developed. In recent years, flux cored wires have been expelling manual arc electrodes. As seen in the change in the welding material production, the welding technology is still changing and developing. A further development of gas shielded arc welding will be expected by the concurrent development of a welding current wave control with improved welding power sources.

Field welding is inevitable in the welding of steel rods, steel pipes, rails and steel buildings. In the era of a competent welders shortage, it is not allowed us to cause declined sales of these steel products or the market invasion of the materials other than steels due to field welding problems. Therefore, one of the most important tasks is the development of the automation of field welding or welding robots. The Nippon Steel welding group has already developed the welding robots for butt welding of steel rods, line-pipes and rails as well as for column-to-beam welding and colulmn-to-column welding of buildings.

Gas shielded arc welding is exclusively used in welding robots in Japan. However, huge flash butt welding machines are used to field girth welding of large diameter line-pipes in the Soviet Union, and flash butt welding machines with powerful upset units as shown in **Photo 1** are used for field welding of rails in the Unites States. These large scale welding units employ welding current as high as 200,000 A for very short time, and they are quite different from a Japanese way in which multi-pass welding is conducted using small welding current of 300 A or thereabouts. It is desired to realize rapid and simple welding of heavy structures or so called one-shot welding of column-to-column of high-rise buildings or large diameter steel pipe piles. For one-shot

Photo 1 Flash butt welding equipment for in-track welding of rails

welding, high energy instant welding such as flash butt welding must be developed. In this respect, the most prospective process is YAG laser welding in which power can be transferred by a fiber cable, although YAG is insufficient in power at the present time.

As to welding metallurgy, oxide metallurgy in steel making researches was inaugurated form a discovery in Welding Technology Lab. as already described. Oxides in weld metals are quite globular unlike those in steels and their contents vary from 20ppm to 1,000ppm depending on an employed welding process. Therefore, it is considered that weld metal oxides may be utilized as ODS (oxide dispersion strengthening) other than intragranular ferrite nucleation sites which facilitate grain refining. Oxide metallurgy researches are thus very promising in welding. In general, mechanical properties of a weld metal is required to be not lower than those of a parent metal. Instead, metallurgical overmatching, which means that alloy contents is higher in a weld metal than in a parent metal, is permissible to some extent in welding. Especially in welding of stainless steels, a weld metal tends to be of a high alloy type, resulting in the possibility of a wide variety of selection of alloy element combination. Therefore, computational metallurgy based on a thermodynamics database must be applied to alloy designing of a weld metal. The stainless steel welding strongly expects the development of computational metallurgy that enables us to design the suitable combination of alloy elements in welding materials considering the balance of the strength, heat resistance and corrosion resistance of welded joint without conducting a lot of experiments or making costly trial products.

Although significant progress has been achieved in the welding technology, know-hows in welding fabrication and experiences of welding practices are indispensable to develop new welding technologies and especially welding robots with satisfactory performance in practical applications. These know-hows cannot be obtained by short time experiences. Therefore, it is very important to receive the cooperation of trainers in the Welders Training Center and engineers in Nippon Steel Welding Products & Engineering Co., Ltd. who have long experiences in welding practices. The researches on the development of welding and joining technology should be performed in the concurrent cooperation bases of welding metallurgy, welding process and practice experiences. As a matter of fact, some welding machinery companies realized the significance of welding know-hows and the knowledge of welding materials in order to develop welding robots and they have asked the cooperation of the Nippon Steel welding group.

5. Conclusion

The history of the modern welding technologies and their recent developments were reviewed. Then, the future trends of the technologies were discussed and how the welding technologies have contributed to the diversifying business of Nippon Steel was reviewed. What is most important to the welding & joining R & D group of Nippon Steel is to maintain a world leading level of researches of the welding basics (metallurgy, arc physics, etc.) as well as the applied technologies concerning welding materials and welding processes, fulfilling the following four tasks:

1) To provide the customers satisfaction with the users of Nippon Steel products through the timely supply of welding materials and welding technologies suited to not only newly developed steels but also conventional steels;
2) To expand a market for newly developed steels through the development of new technology (e.g., coated steel sheets through the development of new arc welding technology);
3) To create new businesses through the development of new welding or joining process (e.g., a civil engineering construction business by an automatic stud welding machines);
4) To expand a market for conventional steels through the promotion of welding process automation in Nippon Steel cooperative companies (e.g., stainless steels by the development of an automated welding process of stainless steel drums).