PROSPECT OF WELDING RESEARCH AND TECHNOLOGY IN THE 21ST CENTURY– BASED ON ACTIVITIES IN JAPAN–

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ABSTRACT

The modern welding technology have more then 100 years history, and during that period, the welding has been playing an important role in the development of the manufacturing processes/systems as a key technology. In the time we enter the 21st century, it is question how to develop the innovative and attractive welding technology, in particular by the younger generation. The present report discussed the future trend of welding engineering mainly in Japan after reviewing the previous growth of welding engineering.

KEYWORDS

Welding engineering, Welding research, Trend of welding technology, New century, Future manufacturing

1. Introduction

It is appreciated all over the engineering field that "welding" has been one of the essential key-technologies in the manufacturing process. In the middle of 19th century, arc welding technique was firstly invented, and main welding process passed from gas to arc welding. From the end of 19th century, steels became one of the main industrial materials and lots of steel structures had been made. In the fabrication of the steel structures, "welding technique" had been more and more basic and essential. In particular, the development in Japan during the last 50 years in the welding engineering is spectacular.

On the other hand, in the end of 20th century, it is said that the shift of the leading industry in the economy system from the heavy industries to light and information controlling industries can be seen. Although welding technique must still be one of the key-process of the manufacturing process in the years ahead, there is a little misgivings problem for the continuation of welding engineering. At the present stage, we have to cast about in our mind for a good plan on the future research system according to the new economy age.

The present report is, at first, reviewing the current situation of the conditions of industries and welding engineering in the manufacturing in mainly Japan, and then discussed on the possible tendency of the research and technology in the immediate future.

2. Trend of Japanese Economy and Industries

The Japanese industries have been progressing in the last 50 years, in particular it is accepted, as being beyond doubt the development in the field of heavy industries was splendid. Figure 1 gives the general tendency and characteristics in the development of Japanese economy, and the future view in industries. On the whole the Japanese industries changed from light to heavy field, and then in the recent environment, it is believed that the change from heavy to "new" light might be occurred. It is question what is new.

	Before 2nd War (1900－1930middle)	After 2nd War (1950－1990)
Import ratio for GNP	~２０％	~１０％
Export ratio for GNP	~２０％	１５％－２０％
Main products	textile goods etc.	Heavy & Chemical products
Characteristics	Balance between raw materials and products	Value added products to raw materials

Fig. 1 Trend of Japanese industries and future

In the last 50 years, the main leading industries have been changing as shown in Fig.2. That is, the industries dependent on labor and high energy transformed into ones achieving the high-productivity and controlling the global information. Nevertheless, the expansion of the scale of Japanese economy based on GDP is steady in the recent years comparing it of 10-20 years ago, as shown in Fig.3. A lot of discussion on the problems in the recent Japanese industries has been carried out. For example, the typical problems in Japanese economy can be given in Fig. 4. As given in Fig. 4, the recent typical change of the business model results in the mismatching in the various areas and the myth of post-industrial economy has been common. The most typical requirements in the recent years are the materialization of high productivity and the correspondence to globalization. As compared in Fig. 5, the productivity in Japanese industries in the recent year is not necessary highest in the big economic countries.

In this new century, based on the recent change and problems to be solved, what is the essential point for Japanese industries? Figure 6 gives the main essential 6 points in the Japanese industries of 21st century.

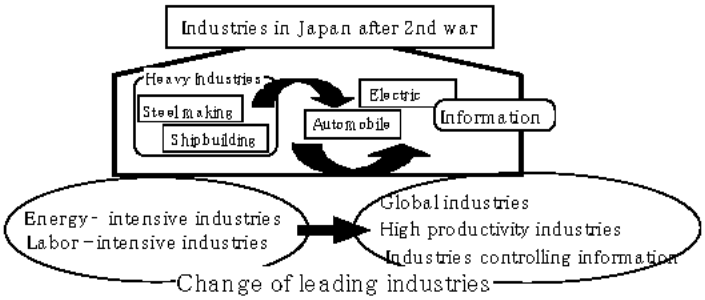


Fig. 2 Change of leading industries in Japan

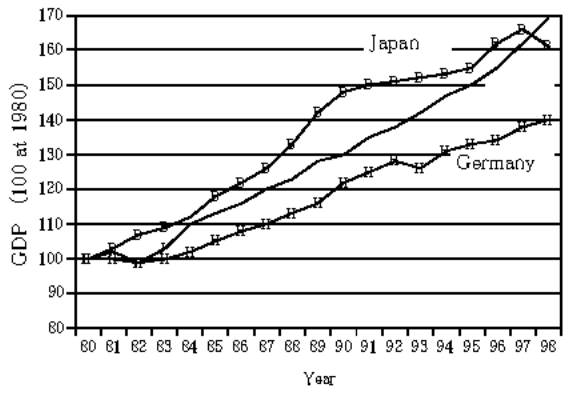


Fig. 3 Recent trend of GNP

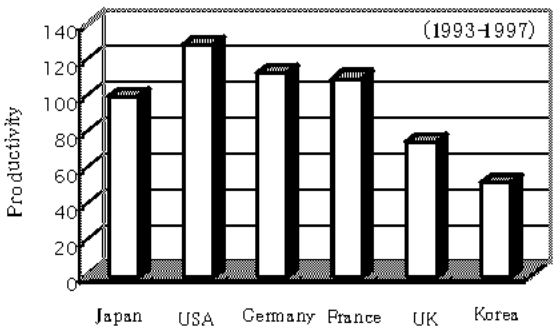


Fig. 5 Comparison of productivity in various big countries

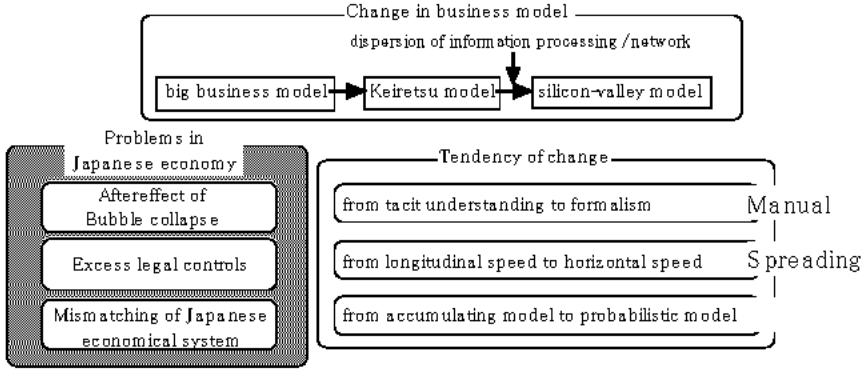


Fig. 4 Change of business model and problems in Japanese economy

3. Welding: Now and Future

Table 1 shows the development of the welding engineering in Japan in the last 100 years. As shown in Table 1, at 1920s', the application of the welding technology in Japan started to the steel structures of the fields of shipbuilding as well as bridges and buildings.

After 1950s', the remarkable development of the welding engineering in Japan could be seen owing to the great exertion by the Japanese welding engineers, though the delegates from USA pointed out that the welding engineering of Japan was behind 30 years from USA. After all, it is universally recognized that the Japanese welding technologies has been the greatest in the world. The welding technology also had been played an important role in the development of industrial economies in Japan. In particular, it brought about the considerably high productivity in Japanese manufacturing industries.

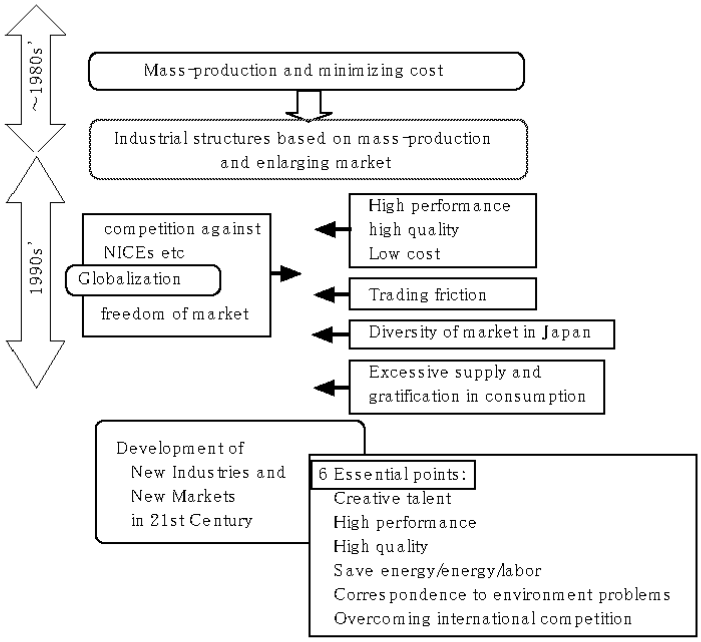


Fig. 6 Essential points in Japanese industries for future

Nevertheless, in the recent years, the conditions surrounding Japanese industries have varied. For example, the typical changes are given as:

Table 1 Progress of welding engineering in Japan

Year	History of welding in Japan	Year	Progress in Main Welding Method
1890s	invention of arc welding		
1914	First import of electrode from Sweden		SMAW
1920	First all welded ship "Suwa-maru"	1920	
1923	Home- produced arc welder	Early stage of welding	
1930s	Failure examples in warships	Point to progress of quality	
1942	Development of rutile-type electrode	1940	
1950	Import of Union-melt welder (9 welders)	Postwar rehabilitation	SAW
1953	Gravity welding	Great advance of welding engineering	
1955	Introduction of Technique on MIG & TIG	1960	MIG/MAG
1960	Introduction of Technique on CO_2 welding	High rate of economic growth	
1964	One-side welding	Change of industrial structure	
		Low rate of economic growth	
1980	Start of application of robot of arc welding	1980	EBW
	Development of fine flux-cored wire	Bubble period and collapse of bubble	
1988	Laser welding		LBW
		Reform of technology	FSW
1955	Low fumed electrode	New economy period	
		2000	

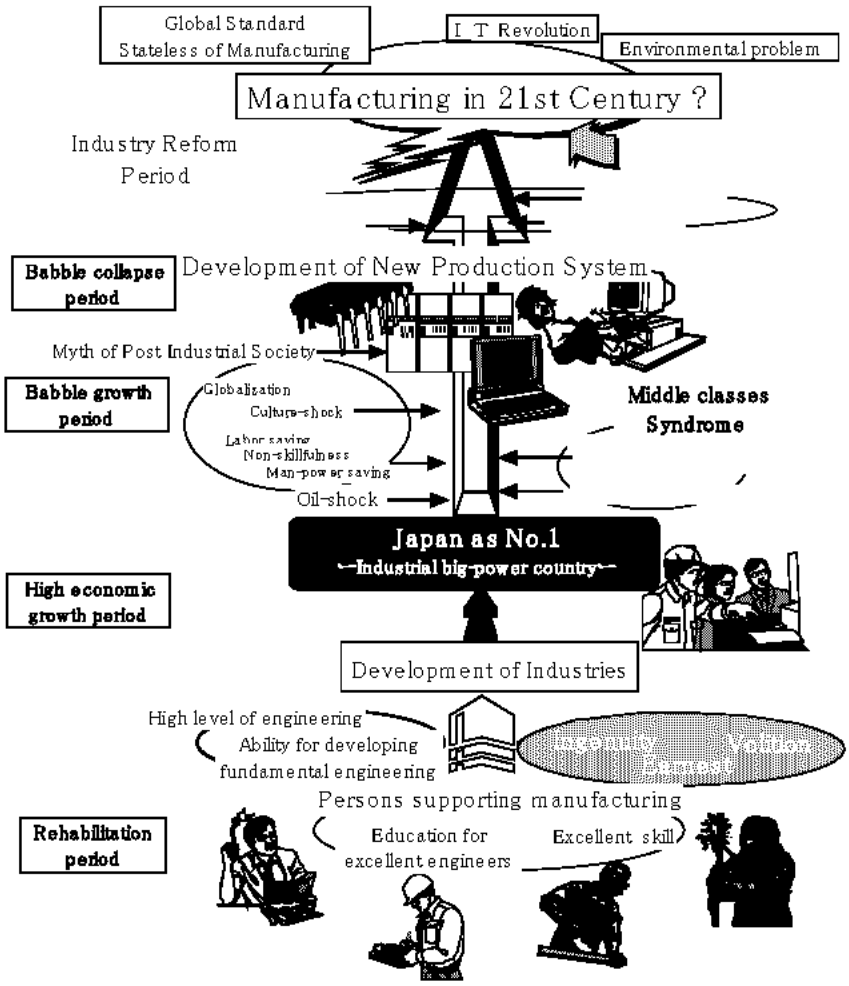


Fig. 7 Trend of surroundings in Japanese industries in the last 50 years

1) Dispersion and integration/intension of manufacturing factories,
2) Remarkable advance and enlargement of information technology (IT),
3) A great deal of attention in environmental problems,
4) Globalization and global-standard.

In the recent years, the most assignment of Japanese manufacturing industries is to improve/progress the productivity and cost-performance of products. The strict situation in a certain field of industries may be figuratively called to be terminal symptoms. The reasons of those conditions can be believed as followings:

- Loss of volition and ingenuity due to the conditions by the affluent society.
- Lack of transition of skillfulness due to the retirement of the superior specialists.
- Removal into overseas of manufacturing due to despair to Japanese skillfulness.
- Myth for IT revolution.

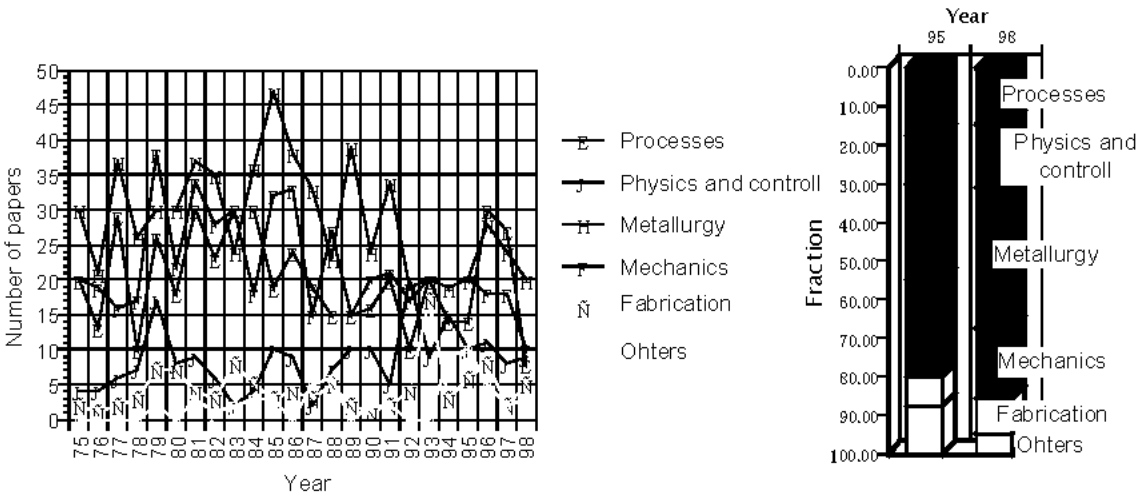
Figure 7 shows the trend of Japanese industries in the last 50 years from viewpoints of conditions surrounding manufacturing industries. For establishing new industries in the 21st century, the excellent and enthusiastic engineers have to crowd, that is, the professional/pure talent is a great asset to the future industries.

4. Activity of Welding Research and Technology in Japan

At the present stage, it is accepted as being beyond doubt that the activities on welding engineering fields, in both research and industrial development, in Japan are superlative level in the world. Table 2 gives examples within restrict extent of the typically leading areas by Japanese R&D groups. This table does not give all of the fields, because there is a limit of the author's knowledge. Japan also breaks new ground in the new fields such as micro-joining. For example, the number of papers published in Quarterly Journal of Japan Welding Society (JWS) is more than 80-100 papers and the number of presentation in the Annual Assembly exceeded 220. Figure 8 shows the number of papers by the typical research area and their fraction with regard to the papers published in Journal of JWS. The recent tendency of the research activities is that the fraction of researches on

Table 2 Typical activities of R&D of welding in Japan

Fields			Circumstance and level of R&D related to welding engineering in Japan
Technical papers			80-100 papers/ year in JI of JWS, double of other countries'
Development	Materials	Development of high weldable steels	Ultra-high strength steels (weldable HT800, 1100MPa class steels)
			Steels for high heat input (for max.100MJ/mm)
			Plated thin plate with high weldability for automobiles
		Electrodes/wires	Seamless wire within flux
			Consumption of wire for CO_2 welding: top in the world
	Welding processes	Development of welding processes	Diffusion of inverter welders: No.1 in the world
			One-side welding in shipbuilding
			Narrow-gap welders (MAG, TIG)
			Control technology of power output of welder
		Automation/ Robotics	welding robots: top of production in the world
			Development of robot systems
			Full-automation welding system based on light sensor
			Arc sensing system
		Micro joining	High-density technology, New soldering materials
Research	Welding metallurgy	Hot cracking	Critical deformation rate theory
		Weldability	Pioneering works on hardenability and sustainability of cold cracking (Pcm, SEN, 빈)
		Modelling of solidification	Modelling and analysis method
	Welding mechanics	Strength and Fracture	Mismatching mechanics (Heterogeneous mechnanics)
		Welding mechnaics	Systematize of welding mechnaics



systemization, LBW, and modeling on welding metallurgy. Although the new-type processes in welding, such as A-TIG, Friction Stir Welding (FSW), Laser-are hybrid welding, Two-wire GMA welding, etc, were developed, all of them, unfortunately, are not the proposition from Japan. However, in the practical and industrial development, a lot of useful and proud/valuable activities could be indicated in the various fields.

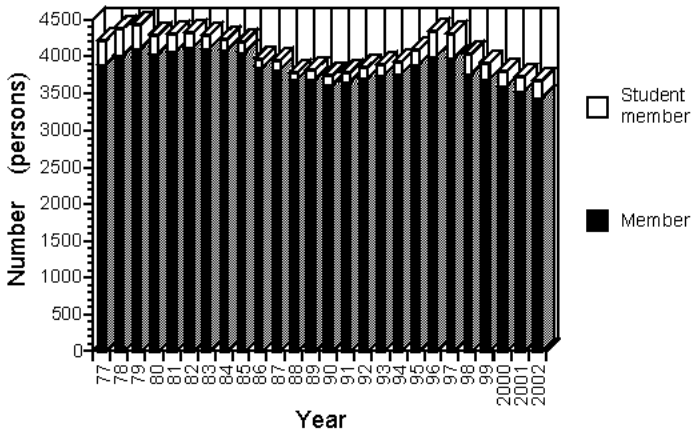


Fig. 9 Trend of number of member of JWS

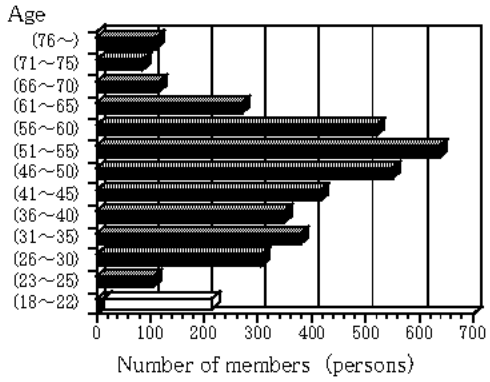


Fig. 10 Distribution of generation of members of JWS

The activity of the society of welding is much dependent upon the number of the member of the society. However, according to the statistics as given in Fig. 9, the number of members in Japan Welding Society gradually decrease in this some years. And the distribution of the generation of the members of JWS gives into a little question as shown in Fig. 10.

The great achievement in the welding science and technology made so far by the former engineers/researchers with a great energy. In order to continue the active action on the research and development in welding engineering, we have to get a sufficient number of members to the welding society.

5. Direction of Welding Engineering: Role of Welding on Creation of New Manufacturing

In the present century, the following fundamental approach concerning welding engineering should be necessary in order to play an important role on the manufacturing and production system in succession even in future:

1) Scientific Approach for clarifying physical phenomena related to welding behavior and interface physics in joining processes.
2) Approach for creating the new structural and intelligent materials based on welding/joining science.
3) Approach for innovating the new welding production technology based on the new matching philosophy with design.
4) Development of innovative manufacturing technique by the closer connection with the other scientific and technological fields starting from welding.
5) Systemization of production including welding process
6) Establishment of fundamental philosophy for merging welding technology to production information.

Figure 11 gives the direction of future welding science and engineering based on the four axes: design, material, production and manufacturing. As shown in this figure, in the future engineering, the merging and integrating the plural matters, such as the factors given by two or three axes, should be accomplished. In particular, for satisfying the requirements in the future manufacturing society, following two directions must be essential:

(a) To make high quality and reliable products with high productivity.
(b) To establish the innovative future production system using information technology and fundamental joining science.

There is no knowing what will happen in the future. Nevertheless, the welding technology should be

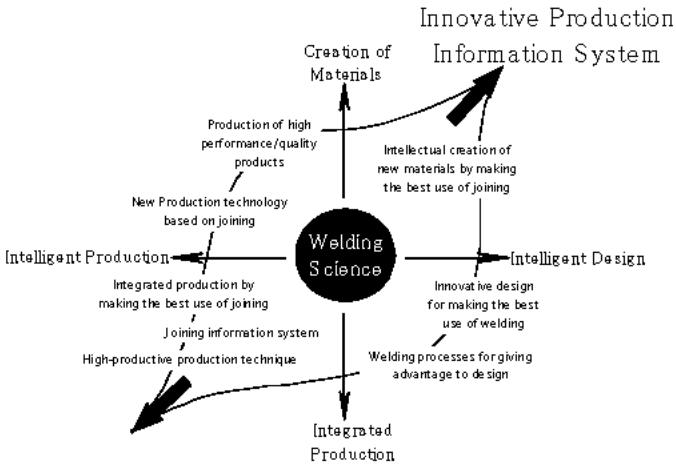


Fig. 11 Role of welding science for four axes matters

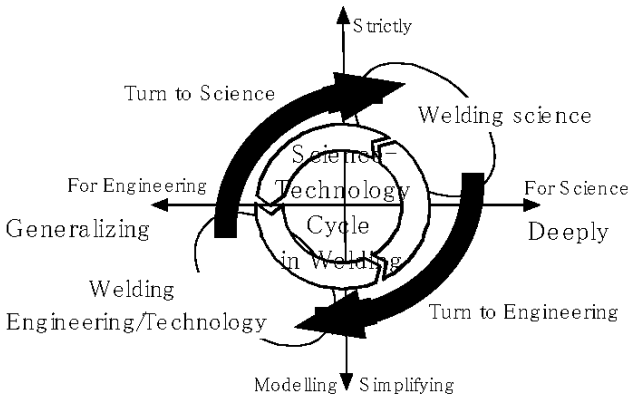


Fig. 12 "Synergistic" cycle of science and technology in welding

and another is a further practical (serviceable) approach. Figure 12 shows the concept that is need in future welding engineering, that is, the construction of the "synergistic" cycle of science and technology.

During the merging period in the beginning of this century, the followings are pursued fundamentally:

a) Merging of welding research and welding engineering
b) Synergistic merge of both welding and structural/production design
c) Applying welding to industrial production

internalized in the new paradigm of the future manufacturing technology system. It, at present, is a difficult question what is the new paradigm? The prospective form must be the new system in which the production technology and information technology are merged based on intelligence and information. In that new paradigm, the global development can be made taking the human, nature, and environment into consideration. The most important in that paradigm must be the "creation" of knowledge/information.

In the above paradigm, there are two directions in the welding engineering: "deepening" and "generalizing". That is, one is a deeply scientific approach in welding

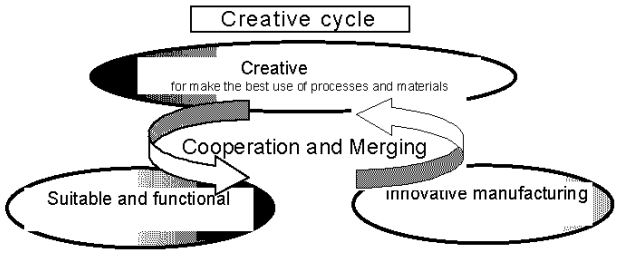


Fig. 13 Creative Cycle for integrated manufacturing

Moreover, in the practical manufacturing (welding) engineering field in the present age, the effort in only one field is not instrumental in developing the innovative technology. In particular, in the welding technology for the manufacture of welded structures, the "creative cycle" for the innovative manufacturing as given in Fig. 13. The merging of the different fields is key issue in the future engineering.

6. Welding in Intelligent and Information Technology Age

It is no easy matter what technology is dominant in the welding engineering in the next generation. In all case, the fundamentally important matters are research ability for production itself and a person of ability for welding engineering. That is, both research and education are two basic principles.

According to Prof. Kaya, the research of engineering is:

"Process for discovering the knowledge for the human being."

On the one hand, the engineering education is:

"To give the knowledge and intellectual powers suitable for engineers."

If the above concept is applied to "welding", the principles of the education for welding engineering must be as follows:

- Education is not signified to give only skill of welding.
- To give the intellectual powers of welding required for all over the manufacturing.
- To give the ability for integrating the various expert knowledge on welding for materializing the most proper production by using the intelligent skill.

The education based on the above concepts might bring about the important role of welding engineering in the future manufacturing process, from the both technology and practical ethics standpoints.

In that case, it becomes questions what are the distinguishing characteristics. The tendency of the development required in the future welding technology is close related to a concept as

"Free from the skill itself."

The examples on the individual subjects required in future welding engineering are given as follows:

(1) Development of welding engineering accommodated for the new information technology age.
(2) Development of merged processes from the common fundamental welding process.
(3)Development of welding process with considering the process of dismantling - Welding and Diswelding.
(4) Breakthrough for high-value added processes matched in the new type production system.

The objective welding processes to be developed in future are:

- Totally low-energy welding process
- Applicable high energy density welding process
- One-shot welding and large area joining process
- Process for dissimilar materials
- Value added joining processes

and,

- Joining process possible to unfasten: diswelding.

The most critical problem at the present stage is the lack of "true" professional welding engineers. The various developments so far brought about that the skill/technology became to be black box. In the years ahead, it is high possibility that the welding engineering sinks into oblivion in the manufacturing system. In the welding engineering in future, it is question how to keep the self - identification in the new engineering fields (Fig. 11).

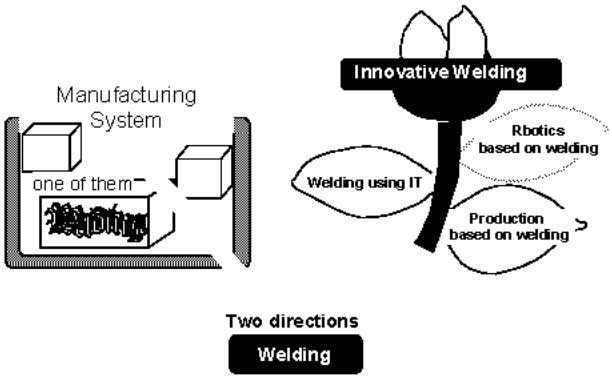


Fig. 14 Direction of welding engineering in future