Present Status of and Future Direction for Welding Technology in India

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INTRODUCTION

Welding, as one of the most important fabrication and maintenance processes, has been playing an important role in the industrial and infrastructural development of any nation in the world since the industrial revolution that took place around 1850 when technological and economic progress gained momentum with the development of steam-powered ships, railways, and later with the internal combustion engine and electrical power generation in some parts of the world. India has an illustrious history and glorious past in the use of welding. Indians knew how to join two pieces of 'metals' since long - at least about five thousand years from the present time. The remains of Mohanjodado and Hadappa and the Buddhist sculptures spread all over India bear testimony to this fact. The construction of Iron Pillar of Delhi weighing 5.4 metric tons in 310 AD is a classic example of welded fabrication.

Majority of the material joining processes, which are in practice at the present time, are new but forge welding is several hundred years old. Joining a thin strip of steel to the edge of a sword or tips of bolts shot from the crossbows, production of fabricated cannons, etc. are examples of Middle Age use of welding. Soldering and brazing, which were known essentially as a Goldsmith's Art to produce comparatively 'weak joints', were in vogue several thousand years ago. However, documentary evidence of application of welding dates back to the last quarter of the nineteenth century.

During the last one-and-a-quarter century, in general and since about middle of the last century in particular, welding has made progress in leaps and bounds and India has been contributing in this spectacular progress through research and developmental activities being carried out in various research laboratories, industrial houses and educational institutions.

In this article, an attempt has been made to present the developmental imperatives that led to the present status of welding being practiced in India together the welding process capabilities and the future direction which India should be aiming at.

IMPERATIVES FOR DEVELOPMENTS

Modern welding techniques are employed for the fabrication of numerous products such as ships, bridges, buildings, pipes lines and so on. Over the years there has been a phenomenal development in the field of welding technology which has been necessitated by a number of imperatives. The developments from the early stages of welding are in the broad areas of: (i) welding processes, (ii) welding equipments, (iii) welding consumables, (iv) welding metallurgy, (v) welding automation, and (vi) testing, prediction and control of weld properties. Some of the imperatives leading to developments and subsequent adoption by the Indian industries are the following:

1. **Faster speed of welding** - Speed of production had always been an important factor for consideration for the designers and manufacturers. With the developments in shielded electrodes since 1930s, speed of welding could be increased by ten times as com-pared to oxyacetylene gas welding. Demand for still faster speed of welding led to the developments of MIG, FCAW and EBW processes. For example, a joint made by the electron beam welding process can be ten times faster than the one made by the manual metal-arc welding process (Table-1). Robot assisted resistance spot welding applied in the automobile and other industries since about 1980s can make much faster joints.
2. **Better quality, consistency and reliability of welded joints** - The infamous catastrophic failure of the Titanic in April 1912 should not be allowed to happen again. The

mechanics of materials and welded joints have got to be better understood. Electron beam weld-ing (EBW) (which is performed in a vacuum) developed in the world during 1960s has the capability to produce welds of very high quality. Though EBW including laser beam process has high capability, but has not found much commercial use because of high cost of equipment. TIG welding done under an inert gas atmos-phere can produce good quality welds on all weldable metals and alloys. Similarly, fluxes and covered electrodes developed since 1960s are capable of ensuring consistency in the weld quality.

3. **Improved process capability and flexibility** - With the development of the metal-arc inert gas (MIG) welding process, any metal over a wide range of thicknesses varying from very thin to thick plates could be welded; it also has positional weldability unlike SAW process which can mostly be used only in 'flat position'. FCAW process of the 1970s has the capability to give much faster rate of deposition as compared to all other arc welding processes. Fast rate of deposition is called for while joining boilers, pressure vessels, ships and the like. MIG, FCAW, TIG and SAW processes are widely used in Indian industries though they account for not more than about 15 to 16% of the total fusion welds done.

4. **On-line and off-line control** - Such controls were considered essential to minimize rework since about 1970s. Modern TIG or MIG welding using vision-based sensors of the 1990s can provide on-line controls. Some welding machines are now provided with programmable controls. Soft computing modeling tools along with parametric sensors, that are available since about 1980s, can be adopted to provide off-line controls.

5. **Health and environment-friendliness** - This has been one of the prime considerations during the last three to four decades in developing newer processes, equipments and accessories. Traditionally health has been one of the neglected areas but with general awareness in the society on the likely hazards associated with welding, welders and welding industries take good amount of precautionary measures during welding. Manual welding head gears and accessories are locally being manufactured to aid in this respect.

6. **Cost reduction** - It is no exaggeration to say that a nation's economy is dependent on the successful application of welding. Continued advances in the field of welding as well as ability to make judicious selection of the right process are necessary to improve productivity. The productivity of FCAW process is high. Metal arc inert gas (MIG) process with consumable electrode fed at a predetermined rate is economical as compared to say, SAW process, which needs costly equipment. Robotized automated welding developed during 1980s is expensive as like electron beam or laser beam welding equipments. So cost reduction has been one of the important factors in the developments.

PRESENT STATUS

The developmental activities in welding leading to the present status can be broadly divided into the following four sectors. Indian industries and R&D organizations had been working in tandem in each sector contributing to the development of science and technology of welding and its applications:

(a) **Processes :** Carbon-arc and Thermit welding came into practice more than a century ago. Then came in quick succession shielded metal-arc, gas metal-arc, gas tungsten-arc, submerged-arc, friction and resistance welding. The end of the World War II saw a fresh impetus in the development of welding processes such as plasma arc, electron beam, laser beam, explosive, ultrasonic and flux-cored arc welding which are capable of ensuring improved quality, faster speed, better repeatability and consistency together with on-line control (Table-1). For example, during seventies of the last century robotic and sensor-based programmable welding techniques were introduced in the Indian fabrication industries. In spite of several semi-automatic or automatic welding processes being available, SMAW continues to account for almost 80% applications (Fig.1) with fusion welding being practiced for more than 98% applications in India (Fig.2). To reap the benefits of solid phase welding processes, large scale research is going on in research laboratories and educational institutions on industrial scale applications of variants of friction (friction stir and friction plunge) welding and diffusion bonding processes.

(b) **Consumables:** During the last two decades a large number of Indian manufacturers entered into the market of manufacturing various types of welding consumables. There are at least 78 and 73 manufacturers engaged in the production of shielded electrodes and MIG / MAG / FCAW filler wires respectively (Table-2). One important feature of these products is that they confirm to various national and international quality standards and specifications. Shielded electrodes of various types are suitable for a wide range of applications and they are characterized as normal and high efficiency, radiographic quality with high metal recovery, low hydrogen, medium and high tensile strength, ferritic stainless steel, cast iron (machinable and non-machinable welds), low-heat input, hard-facing and overlaying, and so on. There are also more than 60 flux-core wire manufacturers in India producing almost 21 varieties of such products. High quality inert gases like helium and argon are also produced in India. India also has a share of exporting welding machines and consumables almost throughout the globe.

(c) **Welding Power Sources:** This is another area which has got a big boost during the last two to three decades, thanks to the technological advancements including availability of inverter technology. There are 39 manufacturers in India which are producing various types of power sources for arc welding (Table-2). India has the capability of producing synergic MIG power sources as well as programmable robotic welding machines indigenously.

(d) **Welding Metallurgy:** Along with the developments in the above mentioned three sectors, India has been contributing in creating a knowledge base on metallurgical and physical changes that occur during welding. Substantial amount of research work is being carried out throughout the country on welding and weldability of metals and non-metals. Research publications and patents bear testimony to work being done in the country.

FUTURE DIRECTION

1. **Enhanced Welding Requirement** - Virtually every manufacturing or construction industry uses some type of welding, whether during manufacturing of welded products or repair of defective parts, or construction or maintenance of equipment and machinery. The major share of welding is found in construction of ships, bridges,

Table 1 : Comparison of Characteristics of Welding Processes

Process	Speed, cm^2/min	Heat intensity, W/cm	Heat consumption, Wh/cm	Penetration, mm/joule
SMAW	10	10^4	6.5	1.1
TIG	12	10^4	4.0	1.0
MIG	20	10^4	3.5	1.4
SAW	40	10^4	3.0	2.5
FCAW	30	10^6	3.0	2.0
EB	100	10^{10}	0.4	15.0
LM	100	10^{11}	0.12	12.0

Table 2 : Number of Welding Equipment and Consumable Manufacturers in India

Sl. No.	Item	Number
1	Arc Welding Machinery & Equipment	92
2	Arc Welding Power Source	39
3	Welding Electrode	78
4	MIG/MAG Welding Wire	73
5	Argon Gas	25
6	Helium Gas	5

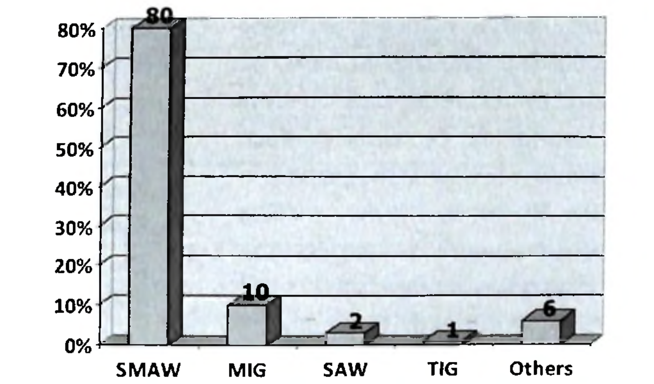

Fig. 1 : Share of Fusion Welding Processes in Indian Industries

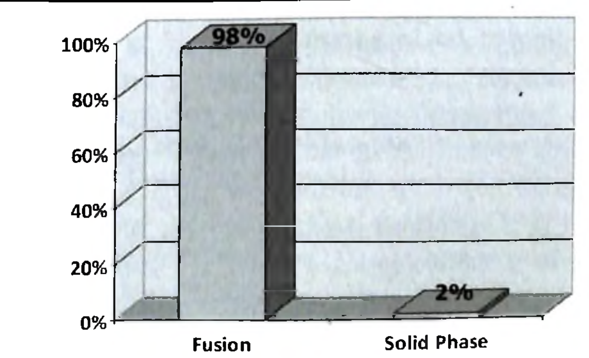

Fig. 2 : Share between Fusion and Solid Phase Welding in Indian Industries

railway coaches and wagons, agricultural implements, auto-mobiles, flyovers, boilers, pressure vessels, gas pipelines, industrial sheds, high rise buildings, etc. There are four major industry segments based on the intensity of use of welding:

a) Heavy industries like ships, bridges and flyovers, steel plants, and railways.

b) Petroleum and energy like pipelines, tanks, cylinders, offshore structures.

c) Automotive, and

d) Aerospace such as aircraft, missiles, rockets.

India as a developing nation has been advancing at a rapid pace in all these fields. It is engaged in massive infrastructure building in all metros. There are 20 automotive industrial establishments and almost equal number of major fabrication enterprises, and 8 numbers of major shipbuilding industries in India. All such activities are dependent heavily on fabrication by welding. Such activities would be on the increase in years to come. Newer welding processes, welding consumables, welding power sources, sensors and controls would need to be developed. It is estimated that welding work would increase by 40 to 50% by the next decade.

2. **Welding to be Integrated into Manufacturing Process** - High-tech methods of joining hitherto difficult-to-join combinations of materials are to be developed to make products of innovative shapes and sizes. Development of newer materials for space and other exotic applications got to be done keeping in mind the question of weldability. In fact, welding has to be integrated into the production-cycle to remove the possible bottlenecks in manufacturing the products.

3. **Welding of Dissimilar Materials** - Dissimilar metal joints are finding many new applications. For example, in chemical reactor vessels a thin layer of expensive corrosion resistant material is welded on to a thick cheap material like mild steel. In boilers, super-heater joints constitute a combination of 2.25Cr-1Mo steel tube joined with an austenitic stainless tube. In cryogenic applications, aluminium components are joined with stainless steel pipe work. Due to the possibility of formation of intermetallics at the fusion zone, the joint becomes poor in strength while adopting a fusion welding process. Further refinement of the solid phase welding processes such as explosive and friction welding (including friction stir), and diffusion bonding for dissimilar material joints would have to be taken up.

4. **Welding of Exotic Materials** - Super alloys like Monel 400, Inconel 600, Nimonic 90, Zircaloy, etc. would find increasing applications in nuclear and similar other industries. To be able to weld such materials a highly controlled atmosphere is needed, which can be obtained in the electron beam welding or resistance welding. Though presently electron beam welding involves very high capital investment but because of the superior quality, this process is likely to be used more extensively in future with equipment cost going down. The research work being done in the country and elsewhere on TIG and MIG welding using such super alloys may also be able to provide alternative cheaper options.

5. **Economy in Welding** - Cost reduction by a reasonable amount, say by 20 to 30 %, would have to be yet another strategic requirement for the welding industry in the years to come. This can be achieved by resorting to high-tech automated welding processes and by lowering the incidence of defects and thus reworks and eliminating rejections by aiming at 'zero defects'. The welding cost constitutes various cost components like: (i) labor, (ii) consumables such as electrodes, filler wires, gases and fluxes, (iii) energy, (iv) equipment, (v) research and education and (vi) waste disposal. Normally a major share of the welding cost goes to 'labor' - roughly 65 to 75% of the total expenditure. This would necessarily mean that the fabrication industries would have to go for automation including use of robots. Metal arc inert gas (MIG) process with consumable electrode fed at a predetermined rate is economical as compared to say, SAW process, which needs costly equipment. Robotized automated welding developed during 1980s is still expensive as like electron beam or laser beam welding equipments. Future research is likely to lead to reduction of equipment cost.

6. **Energy and Environment** - Though cost of energy in welding is only about 3 to 4% of the total cost, any effort made to make the system more energy efficient has social relevance. The welding industries in future have also to think of using renewable sources of energy. A good

amount of attention has to be paid to research and education and there must be appropriate budget to take care of such needs. Waste disposal including recycling has to be accounted for. Every kg of shielded electrode consumed produces about 70 gm of 'butts'. Future research and developmental efforts have to be directed towards cutting costs to retain the competitive edge.

7. **Welding Quality** - Quality technology would take centre place in any decision making exercise. Along with automation, there would be more wide spread use of simulation techniques to help select the welding parameters. Sensors would play a decisive role in providing off-line control in all future applications.

8. **Human Resource Development** - Education and training of human resources would have to receive high priority. There are about 500,000 personnel directly or indirectly involved in the execution of welding work in India. Their education level varies from engineering degree (4-year duration) to diploma (3-year) and certificate (Industrial Training of one year duration). At the present time students pursuing degrees in Mechanical, Production and Metallurgical branches receive some amount of knowledge training in welding technology. But in future 'knowledge in welding' has to encompass almost every field of science and technology. It has to be a fusion of knowledge derived from all disciplines of science and engineering. Training of welders and welding technologists have to be more comprehensive and scientific. The Professional Societies like the Indian Institute of Welding should own the responsibility of training and retraining the personnel engaged in welding and should act as the authorized competence certification agency. Welding industries have to realize the change in the offing and take appropriate measures to face the challenges by adopting new technologies and attracting talented people to the profession.

CONCLUDING REMARKS

Welding is one of the driving forces of economy. The world has made tremendous amount of progress in the field of science and technology of welding over the years. India has been a partner in this developmental process and has been carrying out successful welding works. Today welding is carried out in India in air and under water, and India has the capability to take up fabrication work in space as well. The future holds out a bright prospect for the welding industry in India. The imperatives for the developments would continue to be in place, may be with some variations. It would be the responsibility of all concerned connected with welding to play their roles well and make welded fabrications more reliable, cost-effective and eco-friendly.

ABOUT THE AUTHOR

Dr. Gouranga Lal Datta had received B. Tech., M. Tech. and Ph. D. degrees from IIT Kharagpur. He had served the alma mater for close to four decades as a distinguished teacher, a renowned researcher and an able administrator. Presently he is with the KLEF University, Vaddeswaram, Guntur, Andhra Pradesh as the Vice-Chancellor.

He had handled 23 projects in the fields of welding and foundry. About 220 of his research contributions have appeared in several peer reviewed journals and proceedings. He has guided many Ph. D. and Master Degree theses. In recognition of his contributions, he has been honored with a number of awards from different organizations such as: **"The Corps of Engineers Prize:1994-95"** by the Institution of Engineers (India), the **"Anna University National Award for Outstanding Academic of the Year 1998"** by the Indian Society for Technical Education, **"Sir L P Misra Memorial Award for the year 1999"** by the Indian Institute of Welding, **"Professor B. Karunesh Memorial Lecture Award"** delivered at the 44th Congress of ISTAM, **'IIF Honorary Fellowship'.**

On four occasions, he was selected by the Institute of Indian Foundrymen to present **Official Exchange Papers** from India at different World Foundry Congresses such as Prague, Geyongju and Istanbul. He was a Member of a World Bank funded Foundry Status Study visit to Bangladesh.

He had held several administrative positions at IIT Kharagpur including Dean, Chairman of a Dept, etc, and responsible positions in many Professional Societies including IIW, IIF, IEI, ICS, ISTE. He has made a significant contribution as the Chairman of NBA-AICTE Expert Teams.