Manual Arc Welding Productivity and Recent Development in Stick Electrodes

By V R SUBRAMANIAN*

Introduction

The use of welding in India has caught on at a rapid rate in the last decade and to-day it is accepted as a fully dependable and an indispensable tool for fabrication. The basic reason for this has been the rapid industrialisation and expansion of economy in general. In particular, the growth of wagon and coach building, structural fabrication and automobile industries has contributed largely to this increased adoption of welding.

Among the various arc welding processes, manual metal arc welding process which uses flux coated stick electrodes, is predominant in India. It accounts for more than 95% of the total weld metal deposited. In industrially advanced countries, like U. S. A., U. S. S. R., W. Germany, Japan and Italy also manual metal arc welding process continues to be the dominating arc welding process, though other major welding processes such as submerged arc welding, automatic welding with covered continuous electrodes, semi-automatic welding with continuous wires and gas shielding, semi-automatic welding with flux cored gas shielded wire, gasless or self-shielding flux cored semi-automatic welding process and electroslag welding account for a considerably larger percentage of weld metal deposited than in India. Though these automatic and semi-automatic processes have the advantage of higher productivity and faster and larger production capacity because of their higher deposition rates (fig. 1 shows the deposition rates for some of the important welding processes) these processes have not gained much ground in India as rapidly as should have been accepted. The reasons for these are not far to seek. They are, the economic conditions prevailing in the country especially the comparatively low labour rates prevailing, availability of labour, paucity of capital and high cost of automatic and semi-automatic welding equipment. Further the non-availability readily of welding equipment and consumables from indigenous manufacture of consistently reliable quality has also been responsible to an extent for this. In fact there is still an apathy to increased adoption of methods and processes for improving productivity levels. Even in the manual metal arc welding, the use of electrodes incorporating iron powder in their coatings for obtaining higher productivity is far below 5 p.c. of the total electrode consumption in the country. Considerable advances expected in nuclear, fertiliser, chemical, petro-chemical, automobile and shipbuilding industries in the coming years would certainly lead to increasing adoption of automatic and semi-automatic processes as these processes have their specific fields of applications, which cannot be satisfactorily substituted by manual metal arc processes. Manual metal arc welding because of its versatility, low capital cost, economy on small jobs and suitability for site fabrication will continue to be the major process of welding and the consumption of stick electrodes is expected to maintain steady growth rate, though percentage of weld metal deposited of the total will decrease.

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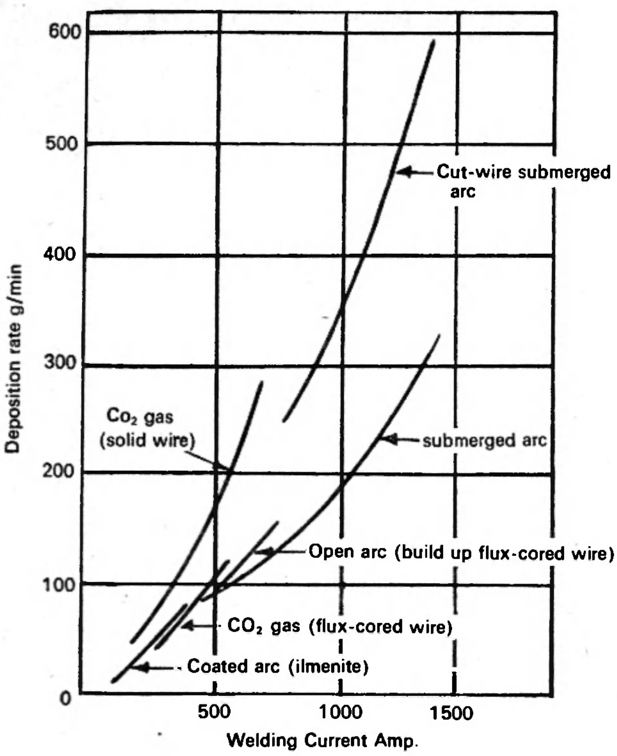


Fig. 1. Deposition rates in different welding processes.

American Example

In the context of our country's economy therefore it would be worthwhile and beneficial to study how welding production has been speeded up elsewhere in the world in manual arc welding and how best these methods and systems can be used in India. It is appreciated that modifications to these methods and systems will be necessary for their adoption in our country because of the difference in the wage-material cost ratio prevailing in our country compared to elsewhere in advanced countries. I quote below from a report on welding techniques and uses in the U. S. A. published by the Organisation for European Economic Co-operation :—

"As an example we might take work time studies for manual arc welding with coated electrodes. Most American factories have their own time studies based on rate-fixing methods corresponding to the type of production.

These systems are different for single objects, line and series production. For one single object, the exact work time is determined by labour studies from which standard working times are established. Times for certain parts of the work are listed in tables. In this way, the whole work is analysed and different operating factors for the work are determined. United States factories use these tables more than do European factories, which for the most part still estimate work time for a certain object.

The study of work time is carried out by stop-watch and varies with the method of production. Much of this is described in 'Design for Welding' by the James F Lincoln Arc Welding Foundation, Cleveland, Ohio (1948).

Nevertheless, time study and analysis is not the only factor on which rate fixing is based, as the work time is modified by many factors which can only be estimated. Among these are the influence of fatigue on the welder, his skill and his production capacity. Though there are scientific methods for determining these factors, they are mostly fixed by agreement, estimated man-production capacity being neglected and skill being fixed at 100 per cent.

As the method of work in almost every factory is a type of mass production, the skill of the worker soon reaches a certain degree of perfection, as his work is limited to small routine movements.

As an example, the production of small gasoline tanks for field welders seen at the Lincoln factory, Cleveland, might be mentioned. The fabrication of one tank consisted of many separate but very simple short processes, the tanks being built up out of stamped and rolled plates and fabricated by a combination of hand welding, spot welding and seam welding. Even the various hand welding operations on different parts were done separately. In Europe, such a tank would normally be handled by one welder who would have to perform all the operations, including tacking.

It was noticed incidentally that in America a production welder never caried out tack welding. This is an example of the way in which work is subdivided and classified to the greatest possible extent and the more difficult jobs are performed only by the highest class of welders. This specialisation speeds up production. America uses the individual as well as the group method of rate-fixing.

An example of group rate-fixing was seen at Budd Railway Manufacturing, Philadelphia. It was based on piece work ; but as one group could not usefully produce more right wing side panels of a railway car than the other group left wing side panels, the whole rate-fixing was actually based on fixed daily groups. The number of cars produced per day was laid down in an agreement with the Labour Union.

Welding Rate-fixing

The calculation is based on the number of electrodes to be used for a certain welding job, the welding current and weld preparation. From these factors a time is worked out to which a certain amount is added. These necessary welding times are increased, for instance by 25 per cent, so that an average rate-fixed bonus of 25 per cent can be obtained by the welder over his base wage.

American welding shops have developed clamping devices, jigs, turntables and manipulators to a remarkable extent in order to facilitate the real welding work and so obtain a high arc time or actual welding time. Arc times of as much as 60 per cent for manual welding are no exception in American industry due to excellent preparation, extensive work differentiation, elaborate equipment and the use of the highest possible electrode diameters and welding currents.

'Cut down times the arc is not burning' ; it is worth while to study all circumstances which influence these times and production will speed up.

Fig 2 and 3 show charts of a welding operation and give an idea of the intensive study that has been made. The times given are those for the following actions of the welder :—

1. Taking the electrode holder in the hand
2. Placing the electrode in the electrode holder
3. The welding operation (arc time)
4. Taking away the electrode stub-end
5. Cleaning the weld with a small pneumatic hammer
6. 'Chiselling off' the welding crater
7. Turning up and down the welding helmet.

These times are measured in connection with the actual arc time and the following percentages are added :

25 per cent for contingencies

20 per cent preparation, personal recreation and unavoidable waiting times

12 per cent for changing the elec rode

15 per cent or 0.05 x arc time for cleaning the crater

5 per cent for every layer of the weld per inch welded.

These figures were given by the Graver Tank Co. which also gave the following interesting data for welding jobs in general. Beginning and end of work-time : five minutes for getting tools and garments from and to central magazine. For each welding job every welder has an allowance of four minutes for the following additional work :—

1. Receiving the job instructions and studying the welding sequence

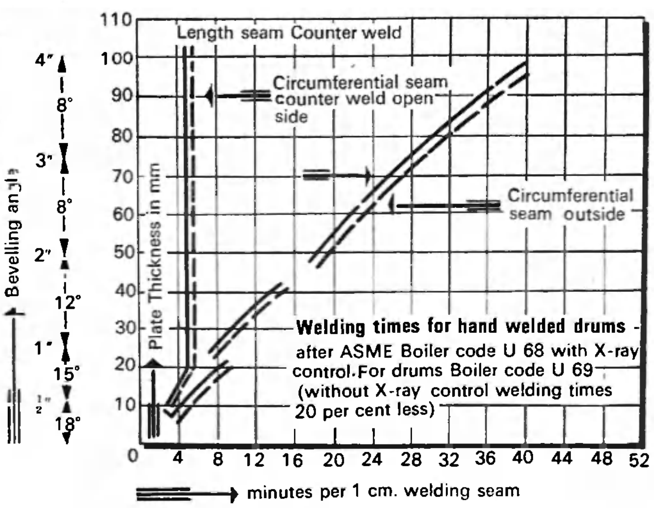


Fig. 2.

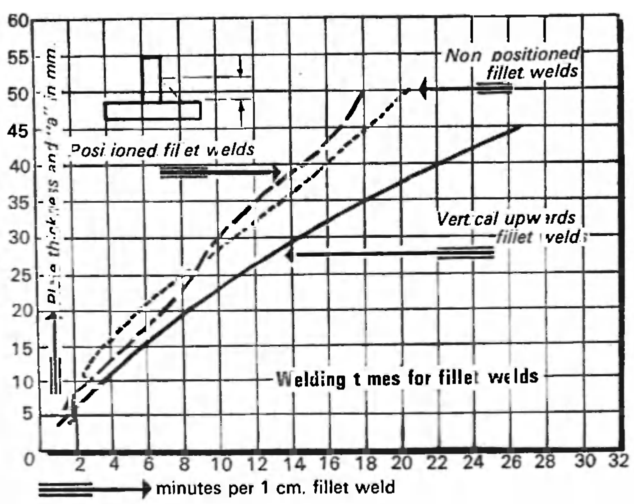


Fig. 3.

2. Bringing up the necessary electrodes from stock
3. Walking to the work piece
4. Starting the welding machine
5. Positioning the welding cable, electrode holder and return cable
6. Regulating the welding current
7. Positioning the welding machine and tools
8. Inspecting the indicator marks on the work-piece.

This analysis gives an idea of the fundamental study American industry makes of welding work and welding time. Electrodes have to be taken from and after work delivered to electrode boxes, which contain separate sections for each diameter and type of electrodes, clearly indicated. The whole box is placed in a heater during the night. A general impression of welding speed and production may be obtained from Table 1 (Caterpillar Peoria) for Trailbuilders.

Conclusion from Table 1

High electrode diameters result in high arc voltage and hence high power and heat output in the arc. The average electrode diameter is higher in relation to the plate thickness in American industry than in most European welding shops ; welding with 3/8" or 5/16" electrodes was observed but it seems that 3/16" is the most popular size. No attention is paid to details of the appearance of the weld, such as smooth surface and undercutting.

Special attention is paid to the main welds in welded construction. Welds which are exposed to stresses and whose strength is calculated are executed with the greatest skill an care. However welds of secondary importance are done with the utmost speed and without any attention to penetration, appearance or quality.

Although the training and instruction of welders is dealt with in the report of Group A, it may be mentioned here that the European visitor is struck by the great attention paid by American workshop management to exhibiting perfectly welded samples with etched cross sections which give the welder a better idea of

TABLE—1

Type Joint	*Plate Thickness*	*Electrode Diameter*	*Welding Current*	*Arc Voltage*	*Welding Speed*	*Electrode Consumption*
	mm	*mm*	*A*	*V*	*cm/min*	*kg/m. seam*
Square butt	6	6	325	33	23	0.33
	8	8	375	38	23	0.46
	10	8	450	40	23	0.53
V-joint	6	5	220	30	14	0.37
	8	5	220	30	13	0.55
	10	6	325	33	13	0.71
	12.5	6	350	35	10	1.22
	16	8	350	39	7	1.85
Fillet weld	6	6	275	31	30	0.22
	8	6	300	32	27	0.30
	10	6	325	33	27	0.32
	12.5	8	400	40	25	0.64
Single lap-joint (fillet)	6	6	325	33	58	0.18
	8	8	375	38	48	0.24
	10	8	425	40	36	0.42
	19	8	450	40	7	1.65

what is wanted from his work than written instructions and handbooks. This idea of the representative sample as required might be profitably adopted."

To sum up, European countries would be well advised to pay particular attention to increasing welding arc-time. In Europe, generally 40 per cent arc-time is considered very good, though there are shops which exceed this figure. In American welding shops however, the standard is 40-50 per cent and up to 60 per cent. These higher figures are secured by :—

1. Strict observance of the prescribed welding procedure.
2. High welding current and large electrode diameters relatively to plate thickness.
3. Emphasis on high welding speeds at the expense of appearance.
4. Intensive use of handling devices, tool-holders and clamps.
5. Use of welding helmets.
6. The distinction made between high quality welds, which are subjected to full non-destructive tests and low-quality welds for which visual checking accepted.
7. The splitting up of welding work into a number of separate, specialised jobs.

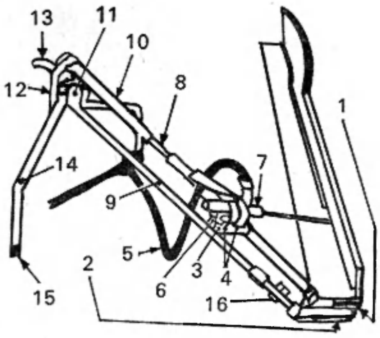
There have been some recent developments that have taken place elsewhere in the world in the use of coated stick electrodes and their design primarily aimed at high efficiencies and productivity. The manual metal arc welding electrodes are normally restricted in their lengths to 450 mm or below and in this length the current carrying capacities for satisfactory transfer of metal are determined by the coating characteristics and the size of the core wire. The size of the core wire normally ranges from 1 mm to 8 mm. The length cannot be increased because manoeuvreability of electrode will decrease. The diameter cannot be increased because of higher current and therefore higher heat will make the operator less comfortable. The efficiency of recovery of metals is determined by the core wire covering characteristics, the nature of transfer (spray or globular) the spatter loss, etc. Great advantage the manual metal arc welding process enjoys i.e. its versatility, low initial capital cost and economy in small jobs has drawn the attention of welding engineers to developing new designs and processes for using coated stick electrodes aiming at higher efficiencies and recovery and higher productivity. The very well known development in this direction is obtaining higher efficiencies of recovery by introducing increasing amounts of iron powder in the flux covering. Today there are electrodes designed elsewhere in the world which can deposit as high as 200 p.c. of the weight of the core wire. Another developement is in the direction of increasing the length of stick electrodes (upto 1000 mm) and use of mechanical device to deposit the metal replacing manual. Two such mechanical devices in increasing use in shipbuilding, structural welding and bridge fabrication industry are described below :—

Gravity Arc Welding

As welding became easier and more efficient with advancement in automation and semi-automation, many dependable welding processes have been developed. These automatic and semi-automatic processes however need increased initial capital investment and have certain limitations in their applications. As against this, the semi-automatic welding with coated electrodes which naturally will have the advantage of initial small capital investment, has been studied by shipbuilders and electrode-makers for a long time and the result is that gravity arc welding (gravity type) followed by inclination welding with electrode set for low angle (spring type) has made its appearance. These processes are regarded as valuable processes particularly in shipbuilding and bridge constructions as a means of obtaining higher efficiency.

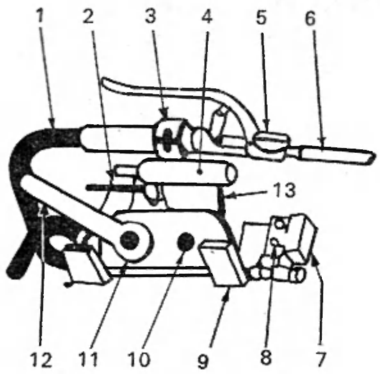
Gravity arc welding employs a simple device the principle of which is as follows :—

With the progressive consumption of electrode the electrode holder automatically slides down under its own weight along the inclined support thereby feeding the electrode for welding. In this device you have only to set the device and start the arc manually and the rest of the operation i.e. welding and the arc extinction is achieved automatically. An additional variation in this device also provides for an arrangement i.e. with finishing of one electrode starting of another electrode to continue the job without interruption. This device is simple in operation, calls for no special skill, provides the additional advantage of one operator being able to attend at the same time several such devices with high efficiency. A schematic sketch of the gravity arc welding is shown in Fig. 4.



1 Stopper
2 Base plate
3 Operating plate
4 Adjust roller
5 Insulating bake
6 Slider
7 Holder
8 Shaft
9 Auxiliary stay
10 Slide bar
11 Leg-fixing metal
12 Bracket
13 Handle
14 Leg
15 Rubber cup
16 Operation stopper

Fig. 4—Example of gravity arc welding set up.



1 Cabtyre
2 Angle change cam
3 Holder-fitting ring
4 Cam slide cylinder
5 Holder
6 Electrode
7 Magnet
8 Magnet holder
9 Guide base
10 Angle change supporting point bolt
11 Spring Casing and built-in spring
12 Start lever
13 Angle change plates

Fig. 5—Example of inclination welding device (available for right and left horizontal fillet),

Gravity arc welding process is essentially for straightline and horizontal fillet welding with good bead appearance, deep penetration and equal leg lengths. Depending upon the set up used, it permits variation in the length of weld deposit per electrode from 1.5 to 2 times the length of electrode. For Gravity arc welding process, 5 to 8 mm dia electrodes in the length range of 450 to 1000 mm are used. The coatings are iron powder iron oxide type and iron powder low hydrogen type. The former coating contains about 40/50 p.c. iron powder and assures high efficiency of work and possesses excellent usability characteristics. The latter type of covering which ensures a high resistance to crack and high ductili.y is applicable to important structures.

Inclination welding with electrode set for low angle

Inclination welding with electrode set for low angle compared to the gravity welding process needs an extermely small holding angle to the weld line and it uses a small light device. This is therefore useful for application in cramped or restricted space. In contrast to gravity welding, where the method of feeding the electrode is by the weight of the holder the principle of inclination welding is the actuation by spring pressure. The electrode is pressed to the weld line by spring pressure. As the electrode is consumed, it is fed with an increased angle of its holding. The device is usually fixed magnetically. Flat butt, flat fillet welding can be done by this process. There are two variations in the equipment, one which can be used for universal application for all the above welding positions and another exclusive for respective positions. A schematic illustration of the equipment for welding with the electrode set for low angle is shown in Fig. 5. Electrodes for this process are usually 4 mm to 8 mm diameter and 450 to 900 mm in length. The coatings are iron powder-ilmenite, iron oxide and iron powder low hydrogen types. The electrodes are so designed as to be able to produce uniform bead appearance and equal leg length in different holding angles. The electrode manipulation ratio i.e. the ratio of deposited length of the weld per-length of electrode is restricted to approx. 1 : 1 as against 1 : 1. 5/2 in the case of gravity welding. The device being light, simple and small, one operator can handle more equipment than in the case of gravity welding. It is therefore used in greater scale for application in shipbuilding, machine building and bridge constructions. It is reported that work is in progress on designing a small equipment for welding vertical downward and a suitable electrode for use in this equipment.

Vertical down welding electrode

The problem of increasing the efficiency of deposition and in turn productivity has been tackled also by designing electrodes suitable for use in vertical downward welding as against the conventional vertical upward. Electrodes suitable for welding in the vertical downward direction in the past have been either of cellulosic type or titania type coating. The application of these electrodes was confined to light structures and thin sheets.

Recently electrodes suitable for welding downward with hydrogen controlled type coating have been developed and because of excellent mechanical properties of deposited metal, the usability of the electrodes and the economic advantage, it has found increased use in ship, bridge and building construction industries mostly replacing the vertical up welding. In countries like Japan, the vertical downward welding with hydrogen controlled electrode is found to be on steady increase. The advantages of hydrogen controlled

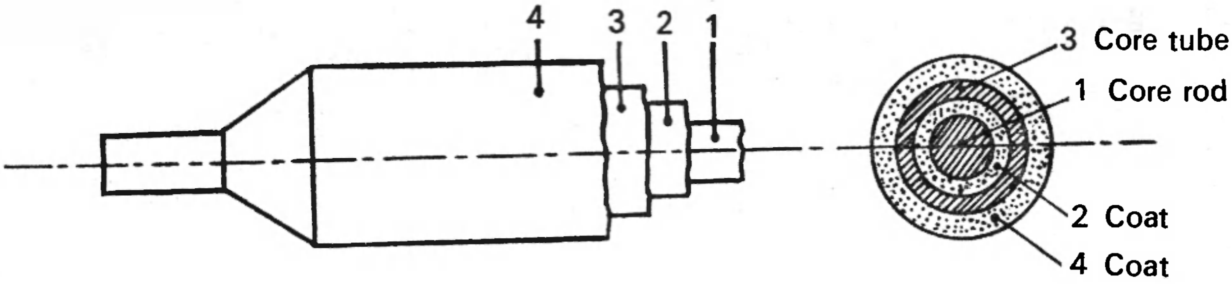


Fig. 5—Multiple Electrode.

electrodes designed for vertical downward welding as compared with hydrogen controlled electrodes suitable for vertical up welding are as follows :—

(i) Unlike the common hydrogen controlled type of electrodes, it is so designed as to form a slag with high viscosity and surface tension which is fit for downhand welding. The deposit metal mechanical properties and resistance to cracking are as good as that from conventional hydrogen controlled electrodes.

(ii) It gives a bead appearance which is almost free from defects such as undercut or overlap unlike in vertical up welding and resembles a bead appearance obtained from flat position welding.

(iii) Unlike upward welding downward welding permits use of high currents and therefore a fast melting rate with high efficiency.

(iv) Unlike vertical upward welding, vertical downward welding needs no special skill and can be used with relative ease.

In view of the above, vertical downward welding with hydrogen controlled electrodes has a great future in the vertical down welding of structures with less than 10 mm size fillets.

High work efficiency electrodes

In addition to the above methods of improving electrode deposition efficiencies i.e by increasing the diameter, increasing the length, incorporating iron powder in the flux coating and designing electrodes for specialised easy welding position, efforts have also been directed toward achieving the same by structural change in the design of the electrodes. An example of this is so called filled core wire electrode i.e. an electrode with a core wire filled with powder. The coating is high titania oxide. The arc is spray type. The melting rate and the deposition rates are high with increased work efficiency and beautiful bead with shallow penetration which is the specific characteristic of high titania type.

Besides the above, the multiple type of electrode has also been introduced. It is illustrated in Fig. 6. It is composed of core wire (1) the core tube (3) and coating 2 and 4 respectively covering the core wire and core tube. In this electrode, the core tube diameter can be 10/15 mm and the length upto 1000 mm. When used with gravity type or low angle type inclination welding equipment, high efficiency is realized. Because of spray type of transfer the arc is smooth and there is little spatter. The deposit metal is claimed to have good mechanical properties. The electrode is useful for welding fillets with long leg lengths and for welding thick plates.

Conclusion

The time study based on rate fixing methods described from American bulletin and the recent developments in the use of stick electrodes for obtaining high efficiencies and high productivity deserve a close study by welding fabrication industry in the country. The adoption of gravity welding process and increased use of vertical downward hydrogen controlled electrodes will help achieving higher efficiencies and productivity with lower initial investment and reasonably assured supplies of coated electrodes from industrial production.