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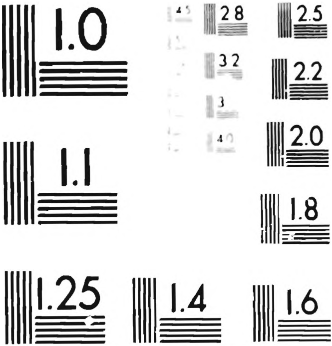
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PRODUCTIVITY AND QUALITY THROUGH MECHANIZATION AND USE OF HIGH PRODUCTIVE PROCESSES AND TECHNIQUES IN WELDING*

by

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1.0 INTRODUCTION

An Engineering industry can be profitable only when it continuously strives to increase the productivity and improve the quality of its products. It is more so, at times of economic recession and when there is growing awareness and demand for best quality product at the lowest cost. In fact it is the key to success amidst a competitive market situation. This philosophy is particularly true in the case of welding industry where the process and technology developments have been advancing by leaps and bounds over the past two decades. The outstanding success that the Japanese Welding Industries have achieved over the last decade has proved this unequivocally. They have also demonstrated that productivity and quality are two inseparably linked aspects.

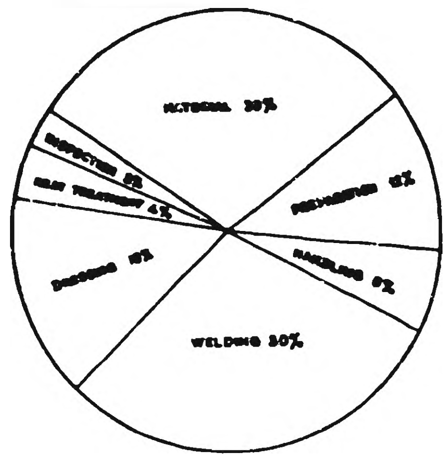
Though there are number of ways of achieving this, developed countries like USA and Japan have conclusively proved that mechanisation and use of high productive processes and techniques are the most effective ways to accomplish this goal with sizable returns on investments. However, the extent of mechanisation adaptable in a developing country should be thoroughly analysed as the industrial environment and economic conditions prevailing are different from that of industrially developed countries. Further, certain infrastructure and supporting facilities are also called for to achieve tangible benefits. In this paper an analysis has been projected on the merits of employing high productive techniques and mechanisation towards increasing productivity and improvement of quality in certain typical welding applications through a few specific case studies. Suggestions regarding how mechanisation can be attempted in a developing country have also been made.

2.0 PRODUCTIVITY AND QUALITY

Welding productivity can be defined as the optimum use of available resources to make the best quality product. These resources can include labour, material, capital, technology, etc. In otherwords, the company that can sell a product for the least cost has the best productivity.

In a typical welding industry, welding is the most predominant function with all the other functions playing allied or supporting role to it. This is more so when the cost of the product itself is large or when it represents a significant proportion of the total cost. The Pie chart shown in Fig.1 gives an idea about the percentage costs that each operation is associated with in a typical medium scale welding industry. Hence, welding productivity or manufacturing productivity automatically becomes the focus of any such industry.

Fig.1 PIE CHART



Before analysing how welding productivity can be improved let us discuss how we measure this productivity. Most productivity uses 'labour productivity' - i.e, the output per unit of labour as the measuring unit since this is very simple and easily measurable unit. The output may be expressed either in Tonnes or number of units manufactured over a period of time, usually per annum. However, another more useful way of measuring and expressing it is in terms of so many standard hours or minutes required per unit or per Kg. of metal deposited. As this will be convenient for our discussions this will be used in our analysis.

Further considering the welding operation alone there are several other activities that are required to be performed to accomplish welding. In general, the following activities are associated with any welding operation.

01) Picking the job
02) Handling the job
03) Locating the job on to the fixture

04) Clamping it on to the fixture
05) Positioning the job
06) Manipulation of the welding head
07) Tacking and welding
08) Cleaning the weld
09) Positioning
10) Unclamping
11) Picking the welded job
12) Dispose

As each of these individual activities consumes a considerable amount of time the productivity not only depends on welding but also on the time spent for other activities. In certain cases the overall handling time can be as high as 5 to 6 times the welding time. In terms of standard time the productivity can be expressed as the ratio between net arc time and the total time which is a combination of arc time and handling time. This ratio indicates that handling time must be reduced in order to have a substantial increase in productivity. This can be improved further if the arc time required for a specific job can be reduced by using mechanised processes with higher deposition rates. In fusion welding area alone there are 4 or 5 mechanised processes capable of giving different deposition rates.

By mechanisation both the handling time and the arcing time can be reduced giving an overall increase in productivity.

TABLE-1

PRODUCTIVITY RESULTS OBTAINED DURING MECHANISATION OF GAS WELDING

Sl. No.	Job	No.of Layer	Type of Surfacing	Surfacing time in mts.	Surfacing speed mm/min	Deposit rate Kg/Hr
1.	Ø 300mm plate	2	Manual	120	15	1
			Machine	60	30	2
2.	Ø 100mm plate	1	Manual	14	21	0.5
			Machine	8	40	1

2.1 Quality means different things to different people. However, in simple words it describes the extent and degree to which the product or structure satisfies the specifications laid out either as per codes or drawn by customer. It can be defined as the fitness for purpose. It indirectly assures efficiency and reliability of the product to the customer. Hence, it is but natural for any industry to aim for the improvement of quality of its products. Though a myth and not real many production managers and personnel involved with production generally carry a feeling that a higher productivity cannot be achieved without a compromise on quality. This is not true and in fact it is the other way and mechanisation is one option that offers both.

3.0 MECHANISATION

Mechanisation is the method of using machines to perform the various activities that are associated with welding. In practice, depending upon the investment potential, the infrastructure and the demand, mechanisation can be attempted either partly or fully. Generally mechanisation is attempted in any one of the following ways.

3.1 By employing a low cost mechanisation technique where simple machines are used for a few of the selected activities such as positioning the job, manipulation of the welding head etc. In this case all the other handling activities are done manually supplemented with suitable fixtures. This is a very popular and versatile technique well suited for a flexible type of operation at the same time keeping the investment part low.

3.2 By employing a higher level of mechanisation where machines are used for most of the activities controlled by integrated control modules with the help of sensing devices such as timers, transducers, etc. This is more sophisticated and mostly custom built or tailor made with larger investments.

3.3 By employing robots instead of simple machines either for each or combination of activities controlled by integrated microprocessor or computer systems. Robots are machines having articulated arms at the end of which any specialised toolings can be mounted. Though it offers good flexibility and higher productivity facilities like good maintenance crew availability of trained personnel etc, are required which makes it more expensive.

4.0 MERITS OF MECHANISATION

01) As mechanisation enables higher deposition rates the arc time required becomes less compared to manual operation;

02) It minimises the handling time keeping the total time less;

03) Since the human element is almost eliminated it enables even semi skilled or less skilled workers to perform satisfactory good quality welding;

04) It enables, consistently better quality welds to be obtained compared to manual operation;

05) As the overall quality is improved the cost of welding is less;

06) Contributes to better quality welding as fatigue on the welder's part is considerably reduced and safety is ensured.

To get a quantitative idea on the benefits that one can obtain let us analyse a few case studies which highlights the advantages of mechanisation.

5.0 CASE STUDIES

In this part a few case studies have been discussed to highlight the merits of mechanisation in Gas, Plasma and CO_2 welding processes.

5.1 Case Study 1 describes mechanisation of a simple gas welding process for a valve industry. Often valve manufacturing industries employ stellite, a cobalt based alloy surfacing, for valve wedges and seat rings to obtain antiwear resistance by manual oxy-acetylene gas welding process. As surfacing is to be done on preheated components manual operation is laborious and offers a very low productivity as well as poor quality weld due to operator fatigue.

In order to increase the productivity this stelliting operation was mechanised by mounting the welding torches on a custom built manipulator with oscillation set up and a positioner to hold and to rotate the job. Photograph 1 shows the set up. In this mechanised set up the rod feeding was done manually as stellite wires are not available. Fig.2 shows the actual job that was carried out and the Table-1 highlights the saving in time and cost along with the production rate which was achieved using this equipment. In summary the following results were achieved by this mechanisation.

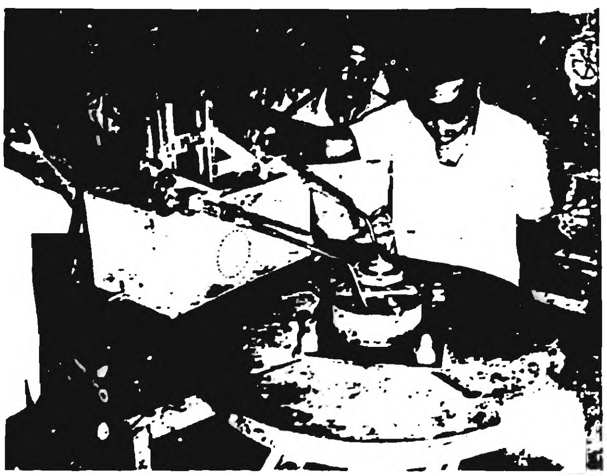


Photo-1 - GAS STELLITING SET-UP

01) A 200 to 300 % increase in production rate was achieved comparing the output of manual welding using the same operator per shift.

02) It was possible to employ even semi-skilled operators;

03) Very smooth and uniform beads could be obtained with reduced machining time and tool loss yields very good reduction in cost upto 30% per piece;

04) Since operator fatigue is considerably reduced the welding operation was involving less fatigue and safer, resulting in further increase of production.

5.2 Case Study 2 highlights how mechanisation was employed to obtain dimensional control during surfacing of a turbine spindle using plasma arc welding process.

The requirement was to set up the stellite surfacing procedure on a slender steam turbine spindle made of X22Cr MoV 121 steel as shown in Fig.3 with very close control on dimensions (a distortion level of ± 1.5 mm over 420 MM length). As other processes like gas and manual metal arc did not give satisfactory results plasma surfacing process was selected so that deposition can be done at fairly faster rates in order to minimise distortion. In that context mechanisation was resorted to using a manipulator to move the welding head along with smaller sized tailstock-headstock positioner to hold and rotate the spindle. As the technique requires mechanised feeding of stellite wire a special 2.4 dia flux cored wire was used. A special deposition technique was also employed to achieve deposition with minimised

FIG.2 PLATE

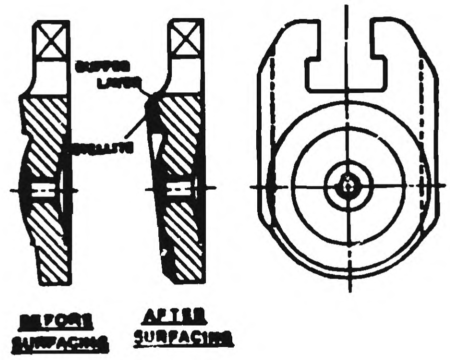


FIG.3 SCHEMATIC REPRESENTATION OF SPINDLE

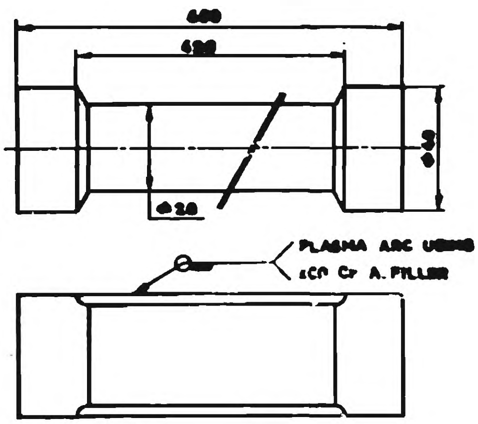


FIG.4 TRANSFORMER CASING PART

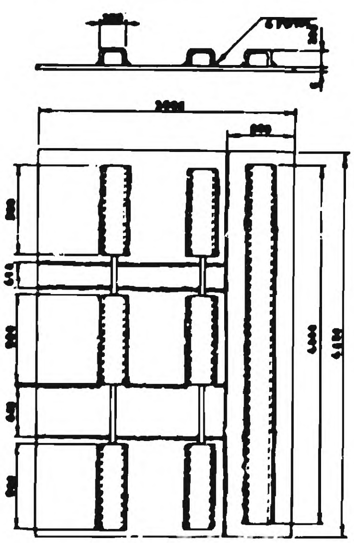


Photo-2 PLASMA STELLITING

distortion. Mechanisation suited the job very well as the job had to be surfaced under preheated condition continuously without break. Photograph-2 shows the stelliting of the spindle along with the equipment set up. Elaborate trials were conducted over 40 spindles whose results can be summarised as follows:

01) As the deposition was mechanised the distortion level was well within the specified limits meeting the quality level set;

02) As very high deposition rates were possible the dilution levels were low, yielding good quality deposites;

03) The quality obtained was consistent and uniform resulting is lesser damage to tool life thereby resulting in improved economy;

04) It was possible through this mechanisation to achieve the required quality level at an increased production rate and productivity.

5.3 Case Study 3 illustrates how the use of a semi-automatic process like CO_2 welding process can improve productivity compared to manual metal arc welding. It deals with a techno-economic study that was conducted at our Institute to compare the economics of the usage of CO_2 welding versus manual metal arc welding of a transformer casing shown in Photograph-3, Table-2 along with Fig.4 gives the details of the process parameters, the time details and the overall saving achieved. The analysis of

TABLE 2

CASE STUDY - 3

Product Analysis : Side wall of a MS tank (4650 x 3000 — 6 mm thick) Fig 1.
Objective : Substitution of CO2 welding process over MMAW for improving productivity

Procedure details	Existing method		Proposed method
1 Process	Manual metal arc		MAG (CO_2)
2 Parameters	110 Amps 20 V DC		265 Amps 24 V DC
3 Welding speed	0.15 m/min		0.35 m/min
4 Welding size	6 mm fillet-23 m 6 mm butt — 13 m		6 mm fillet — 23 m 6 mm butt — 13 m
5 Number of passes	One		One
6 Weight of weld metal to be deposited	7.143 Kg.		7.143 Kg
7 Weight of consumables required	11.421 Kg.		7.68 Kg.
8 Consumable specification	E60 class ϕ 5 — 450 1		E60 class ϕ 1.2 wire
9 Wire feed	—		3 m/min
TIME DETAILS			
10 Net arc time	364		110.4
11 Handling time	1052		414.24
12 Total time	1416		524.64
13 Equipment cost Maintenance @ 2% Total	Rs. 6.30 Rs. 0.126 Rs. 6.426		Rs. 5.4 Rs. 0.108 Rs. 5.508
14 Field cost Electrode cost @ Rs. 5/Kg.	Rs. 57.10	Wire Gas	Rs. 76.80 Rs. 6.60
Power Total	Rs. 2.70 Rs. 59.80	Power	Rs. 1.15 Rs. 84.55
15 Labour cost	Rs. 94.40		Rs. 35.00
TOTAL COST	Rs. 160.00		Rs. 120.00

INFERENCES

Process	Deposition rate (Kg/hr)	Arc time required (mins)	Total welding time (mins)	Total cost (Rs.)	Cost/Kg of weld metal deposited (Rs.)
MMAW	1.2	364	1416	160/-	22.4
CO2	4.0	110.4	524.64	120/-	16.8

Photo-3 - **TRANSFORMER CASING**

the data reveals the following:-

01) The net arc time required while applying CO_2 welding is only one third that of manual metal arc welding;

02) The number of units to be manufactured on the weight of the metal deposited per hour can be increased by 200% using CO_2 welding process;

03) The cost of weld metal deposited is 25% less by using CO_2 welding;

04) The total cycle time required to manufacture one tank was only 60% while using CO_2 process compared to use of MMAW. The productivity may be increased if further mechanisation is applied.

6.0 EMPLOYMENT OF HIGH PRODUCTIVE PROCESS AND TECHNIQUES

Achieving improved productivity through the application of high productive welding processes and techniques is another popular way that appears to be a basic necessity to survive in the present competitive world. In fact today almost every customer looks for better quality products at a cheaper price with a shorter lead time for supply. To meet this situation the fabricators are forced to review their existing technology in order to achieve shorter construction cycle times involving lesser expenditure for their products in order to maximise returns. This fact is clearly evident from the way even smaller companies in Japan invest on Research and Development activities in welding.

Hence the need for improvements in process and technology has become a necessity rather than a luxury especially in industries involved with welded fabrications. In fact yet another interesting observation is that the Japanese are going in for making special steels and consumables suitable to be welded by such high productive and high heat input processes and techniques.

Table-3 illustrates the conventional manual semi-automatic and automatic processes used today along with their capabilities. Apart from these there are many newer developments in each of these processes to improve their capabilities. For instance in Manual Metal Arc Welding, besides Fuse Arc process two other interesting recent developments are -

01) The gravity/auto contact welding process;

02) The one-side welding process.

Table 3

CHARACTERISTICS OF CERTAIN WELDING PROCESSES

Process		Range of current (Amps)	Arc Shielding method	Deposition Rate (Kg Hr)	Thickness Weldable (mm)	Operating Consideration	Welding Position
Manual Metal Arc	Class 2, 3 rutile electrodes	Upto 500	—	Upto 5	3mm to any thickness	Labour intensive	All positions
	Class 6 Basic Electrodes	-do-	—	-do-	-do-	Flexible in operation	-do-
	High yield Electrodes (Iron powder)	-do-	—	Upto 6.5	-do-	-do-	Downhand and Horizontal — Vertical
Fusarc		200 to 1200	—	1.5 — 10	10mm to any thickness	Long weld runs recommended	-do-
Gas Metal Arc	Spray-transfer type	200 — 900	CO_2 or Argon	3 — 7.5	5mm to any thickness	Good qlty. labour required Equipment	Downhand Horizontal — Vertical
	Dip transfer type	50 — 200	CO_2	0.5 — 5	2 — 15mm	Requires maintenance	All positions
	Pulsed Arc Welding	50 — 300	Argon or $Ar+CO_2$	0.5 — 7	1.5 — 40	-do-	-do-
Gas Tungsten Arc		40 — 250	Argon or Helium	Slow completion rate	0.5 — 4	-do-	-do-
Submerged Arc	Single wire	200 — 1200	—	1.5 — 15	3mm to any thickness	Long weld runs recommended	Downhand Horizontal — Vertical
	3 cms in Tandem	-do-	—	Upto 35	15 — 25mm in a single pass	-do-	-do-
Electroslag		200 — 700	—	5 — 22.5 per elec. wire	12mm to any thickness	Restarts are difficult if the eqpt. breaks down during welding.	Vertically up.

6.1 In the gravity welding process electrodes of higher length than the conventional ones are held by means of a special fixture which feeds the electrode by means of gravity once the arc is struck enabling to deposit fillet welds faster than the conventional manual arc process. Another variation in the same category is the auto contact welding where the electrode is held in a spring loaded fixture clamped on to the stiffeners themselves. As the setting of this unit is easy and simple one welder can operate with 3 or 4 units simultaneously thereby increasing the deposition rates to about 100% more than the conventional MMAW process per welder. This process finds extensive use in Shipbuilding for welding of stiffener plates or sections to side panels.

6.2 One-side Welding technique is yet another interesting and innovative tool extensively used in shipbuilding where butt welds are performed from one-side with conventional electrodes with a metallic or non-metallic backing underneath the joint edges. This is especially useful in the butt welding of double bottom deck plates at the dry docks from top side itself eliminating the need for back gouging and welding from reverse side which occupies a considerable time. One of the other advantages is that this technique can tolerate larger variations of root gaps. Extensive studies conducted at our Institute with various kinds of metallic backings showed that by employing this technique the production cycle time can be decreased by more than 30% while also achieving very smooth beads improving the overall quality as well. In fact these results have also spurred the application of this one-side welding technique to other processes.

6.3 In GMAW welding processes there have been a few recent developments which are -

01) Narrow gap technique
02) Twin torch - CO_2 welding technique
03) Flux cored arc process

6.3.1 In the narrow gap welding technique the gap between the square edges of fairly medium thick plates are kept around 10 to 15 mm welded with special welding torches with 0.8 mm CO_2 solid wires. Due to the decreased gap the weldmetal to be deposited is less by around 30%, reducing the welding time as well as improving the deposit quality. This also results in minimised distortion. Another interesting variation in this category is the Twist Arc process where instead of a straight solid wire, two wires that are in a twisted form are fed to increase the deposition rate further.

6.3.2 In the twin torch CO_2 welding technique two GMAW torches are used to weld at two locations simultaneously which are connected to a single power source as shown in Photo-4. This technique when applied over different thin sheet application showed that the weld time and cost could be reduced by over 35% and 10% respectively with minimised distortion levels.

Photo-4

TWINTORCH CO_2 TECHNIQUE

6.3.3 Flux cored welding is another development of GMAW process where a flux cored wire is used instead of solid wire with or without CO_2 gas shield. This process has already proved itself for yielding deposition rates twice as much as CO_2 process with improved mechanical properties. In shipbuilding a development of this process known as electrogas welding technique is a widely used for butt welding of side panels of ships.

6.4 In recent years many developments have taken place in submerged arc welding mainly directed towards increasing the deposition rates and the productivity that are achieved in the conventional SAW process. Out of those, a few of the prominent and recent developments are -

01) Quasi-narrow gap SAW process
02) One-side SAW process
03) Hot Wire SAW process

6.4.1 Quasi Narrow Gap SAW is a conventional process using a different joint design. The gap for the QNG SAW process is between 16 and 20 mm compared to 8 and 10 mm in NG MIG welding. As the gas is reduced the volume of weld metal deposited for a particular thickness is less resulting in lesser weld metal cost and better quality deposits. However, this technique uses a special water cooled nozzle to accomplish welding in thicker plates. Photo-5 showsa the typical nozzle developed at WRI

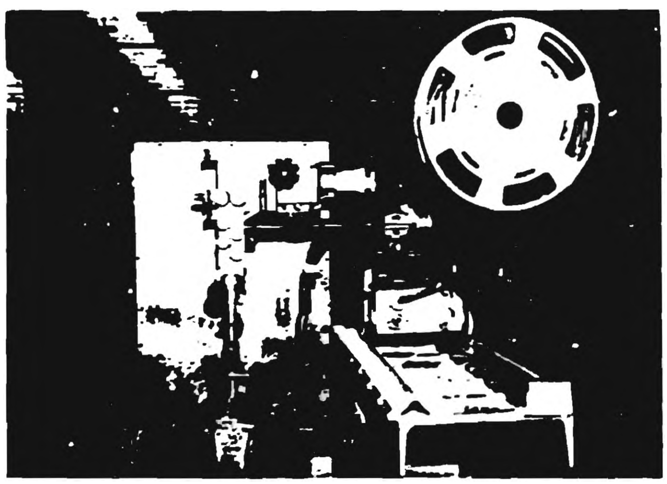


Photo-5

QNG SAW - NOZZLE

being used for welding of QNGSAW for a 135mm plate butt welding application.

6.4.2 This one-side welding using submerged arc welding process uses a special flux and copper backing with well controlled gaps between the plate edges. The welding is accomplished in a single pass with two wires one behind the other capable of welding thickness upto 40 mm. This is a very highly productive technique which can reduce the cycle time upto 60 %. For instance plate panels of dimension 32 x 2000 x 6000 mm each can be welded in over 10 minutes with this technique without the need for turning the plates.

6.4.3 Hot wire sub-arc process is yet another productive welding technique where an additional preheated wire is fed into the arc between the main wire and the plate. The preheated ancillary wire absorbs the additional heat for melting and gets deposited, thereby increasing the deposite rate. Extensive trials done on pipe welding applications conducted at our WRI revealed that productivity can be increased by 70 to 100 % with an additional 30 % investment towards the hot wire system attachment. Photo-6 shows such a typical system in use.

Other than these a few other processes like multi-wire subarc process and long stickout SAW also can be thought of which can improve productivity to a considerable extent.

6.5 Another high productive process is the electroslag welding used extensively for welding of large thickness plates. A development worth of mention in this process is the consumable guide electroslag

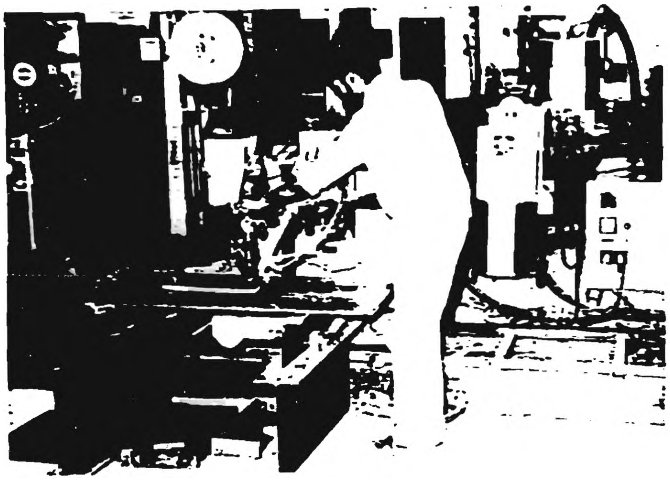


Photo-6

HOT WIRE SUB-ARC

welding process which is flexible and applicable for medium thick plates. This is another process which finds extensive usage in shipbuilding industries.

6.6 In the Gas Tungsten Arc process area the hot wire TIG welding technique is a useful technique for achieving higher deposition rates as well as better quality deposits in TIG welding. The following study highlights the advantages that can be obtained using this technique.

The conventional TIG welding process when used for overlaying applications suffers from lower deposition rates inspite of yielding very good quality deposits.

This process is also used for surfacing of needle valves, low and medium pressure valve components requiring antiwear resistance characteristics.

To improve the deposition rates and to increase the productivity Hot Wire technique was attempted using a specially developed hot wire attachment along with a specially built column and boom type of manipulator with oscillation facilities and a standard 1 Ton Positioner to rotate and position the job.

Both this positioner, welding head along with manipulator were integrated using a central control console to sequentially control the functions. Photo-7 shows the equipment with details. Trials conducted on number of jobs during surfacing including surfacing of straight chrome steel compressor components yielded the following results.

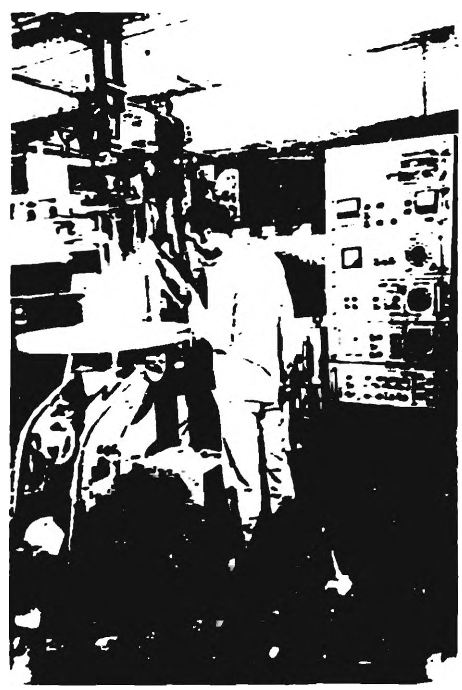


Photo-7 HOT WIRE TIG

1) By proper choice of parameters the deposition rate that could be achieved was as high as 300% compared to conventional cold wire feed system. This gives a direct increase on the production rate upto

300%. The above result is quite substantial compared to the extra investment which costs about 25% of the original system;

2) As the heat input is low deposits was as low as 3 to 5% resulting in good quality deposits;

3) Smoother and rippleless beads were obtained.

7.0 INFRASTRUCTURE REQUIRED FOR MECHANISATION

As we have seen through the above discussed case studies mechanisation is beneficial. However, the results cannot be sustained unless the following infrastructure is built in the production set up.

1) Basically, for mechanisation to ensure tangible results, the component parts to be welded must be strictly maintained within specified tolerances. This may sometimes call for a tighter control of dimensions during the previous stages of manufacture or may require specialised equipment.

In this context I would like to refer to one of the productivity studies which we conducted at a LPG cylinder manufacturing unit as per customer's request. In spite of having a fully mechanised set up the rework and rejection rates were as high as 35 to 40 % impairing the overall productivity to quite a considerable extent. A thorough investigation study right from the raw material preparation stage till welding conducted revealed the following facts:-

1) During the forming and trimming operations previous to welding, dimensions were not

controlled within specified limits;

b) The backing strip assembly which is another operation prior to welding was not satisfactory giving rise to lot of defects during welding;

c) Frequent malfunctioning of the machines due to continuous work and lack of proper maintenance and supply of spares.

When dimensions were controlled by adopting a different procedure and better quality control checks the rework level was considerably reduced indicating the influence of these factors.

Thus this case study only brings out the point that a closer control of dimensions and proper maintenance are two basic needs of any mechanised set up.

2) It may also require mechanisation of other associated activities like handling etc, so that it is fully exploited;

3) To get the best out of mechanisation better and faster quality control equipments, larger inventory and such other supporting facilities are needed, backed up by a Research and Development team to constantly monitors the quality and to make improvements to maintain higher level of productivity.

8.0 CONCLUSION

The case studies discussed here clearly show that mechanisation is a sure way of achieving higher productivity without a compromise on quality. However, the extent of mechanisation is to be decided based on the investment potential, the labour rates, and conditions prevailing locally and the type of demand envicaged. As far as developing countries are concerned it will be most appropriate if mechanisation is attempted in a phased manner going in for low cost automation and subsequently towards higher levels of mechanisation including use of robots. By this way, many finer aspects of mecnanisation and associated needs would be getting established resulting in higher and higher levels of productivity in the longer run.

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