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Productivity improvement in Robot welding through experimentation by varying process parameters

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Abstract—

This paper deals with an experimental investigation through industrial engineering tools was carried to study the effect of various welding parameters suchas, welding current, voltage, feed rate, number of welding passes, coil diameter, welding path etc., to increase the productivity of transfer case cover welding. Detailed methodology provides the number of iterations done to achieve the optimized parameter reading for maximum productivity. The cycle time calculation reports the present capacity of the robotic welding, which needs to be improved more than thrice of the existing production rate. This paper also provides details analysis report on the cost aspect on varying productivity affecting factors such as; welding parameters, robot special features, coil diameter, layout arrangement and allocation of man power. Results observed in this paper are useful for setting welding parameterand guides how to plan cost effective production.

I. INTRODUCTION

Robot welding machine taken for experimentation is KUKA robot with Fronius [6] welding setup (Fig 1.1). Experiments are carried out by analyzing the factors influencing robotic welding by varying welding parameters, utilizing special features and advancements in robot welding to monitor the welding capacity of the machine.

The productivity improvements are carried out by analyzing the cycle time, utilization of special fixtures and material handling time.

This paper discusses on various welding techniques used and welding defects found during the fabrication of transfer case cover. Welding plays very important role in fabrication industry and to ensure the quality of fabrication, all the welding shall be defects free. As welding defects can reatly affect weld performance and longevity, early detection and correction is important to ensure that welds can carry out their designed purpose [7]. For ensuring the quality of welding joints and finally the integrity of the equipment, various inspection and testing methods are available in today's modern industries.

A. About Robotic welding

Actual market conditions are only compatible with Small/medium batch manufacturing, due to strong competition and dynamical behaviour of the market.

Fig 1.1 Robotic welding setup

In those conditions, robotic production setups exhibit the best "cost per unit" performance if compared with manual work and with hard automated setups (Fig 1.2).

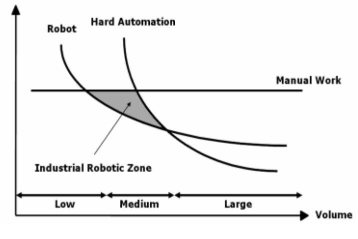

Fig 1.2 Industrial robot zone [1]

Industrial Robotic Welding is by far the most popular application of robotics worldwide [8].

B. About Transfer case housing

The transfer case housing (Fig 1.3), located underneath the vehicle, is constantly exposed to the elements. It can become corroded or develop cracks and leaks, causing it to lose lubrication. Leaking fluid around the transfer case should be a warning sign that the transfer case is in trouble and may need to be resealed or replaced.

Fig 1.3 Transfer case cover

C. About the process

Robotic welding is by far the most popular application of industrial robots. Very good research works, achieving very interesting results, were done since the early 1980s [5], focusing issues like the welding process itself. Robot automation systems are rapidly taking the place of the human work force. One of the benefits is that this change provides the human work force with the time to spend on more creative tasks. The number of arc welding automation robot stations is growing very rapidly. The two most common stations are the GMAW (Gas Metal Arc Welding) station and the GTAW (Gas Tungsten Arc Welding) station [1]. This work presents the robotization of the welding process with covered electrodes, combining the flexibility of the process and the repeatability and safety of the automation [2].

The metal inert gas welding process [12] consists of heating, melting and solidification of parent metal and a filler material in localized fusion zone by transient heat source to form a joint. MIG welding parameters are the most important factors affecting the quality, productivity and cost of welded joint. The input variables directly affectthe shape factor. The input variables consider for investigation are as follows [3].

Welding current

It is the most important variable for welding, because it controls the burn off rate of electrode, fusion depth and weld geometry.

Welding voltage

It determines the shape of fusion zone and weld reinforcement height.

Welding speed

It is defined as the rate of travel work piece under electrode.

Heat Input

Speed of welding(s) = Travel of electrode/ arc time mm/min.

Heat input rate = (V×A×60) /S joules per mm

Where, V is arc voltage in volts,

A is welding current in ampere,

S is speed of welding in mm/min

Shape Factor

It is the ratio of Penetration Depth to Weld Width.

Shape factor = Penetration Depth/Weld Width

The above factor i.e. arc current, arc voltage and welding speed and their interactions play a significant role in determining the weld bead shape characteristics.

Welding technology needs constant upgrading and with the widespread applications of welding [4].

II. LITERATURE REVIEW

Table 1.1 Literature survey and its usefulness for this paper

Literature Name	Author	Inference	Co-relation to this project
Optimal pass planning for robotic welding of large-dimension joints with deep grooves	S.J. Yan, S.K. Ong, A.Y.C. Nee	For the pass planning of deep groove welding, this paper proposes an optimization method with the objective to maximize the section area of the weld bead, so that the number of passes can be minimized.	Relationship between bead dimensions and welding parameters
Effect of Welding Parameters on Tensile & Yield Strength of IS 2062 grade Steel Using Design of Experiment Approach	K. R. Jagtapa, M. S. Rojekara, S. V. Dravidb, A. R. Deshpande	1. Effect of input parameters on mechanical properties. 2. Analysis of variance (ANOVA) was used to predict the impact of welding parameters on the response.	1. DOE on welding parameters 2. Helps to find out optimum welding parameters.
Automated planning of robotic MAG welding based on adaptive gap model	Alexander Kussa, Thomas Dietza, Felix Spenratha, Alexander Verlb	A gap model has been developed that represents the relation between welding parameters and a changing gap geometry due to assembly variations resulting i.e. from errors in manual tack welding.	How to plan for and experimental validation
Welding Seam Tracking in Robotic Gas Metal Arc Welding	Yanling Xu, Na Lv, Gu Fang, Shaofeng Du, Wenjun Zhao, Zhen Ye, Shanben Chen	Vision based robotic GMAW welding seam tracking system	Related to welding quality improvements

III. OBJECTIVE

The following is the problem case on productivity.

- ❑ Component Name : Transfer case cover
- ❑ Current, Robot welding production rate (8hrs.) : 24 nos. per shift
- ❑ Component requirement : 150 nos. per day
- ❑ Operating shifts : 2
- ❑ Production allotted days : 10

The following objectives are framed to fulfil the requirement of this report.

- ❑ To analyse and improve the productivity of robot welding by reducing welding cycle time
- ❑ To simplify welding processes
- ❑ To reduce welding rejections

IV. METHODOLOGY

The objective of the work is to increase the productivity of robotic welding. The methodology followed to achieve is depicted in the Fig. 1.4.

Fig. 1.4 Flowchart for methodology

The above methodology gives fair idea on how this project flows. The factors to be considered for improving the productivity of robotic welding are as follows [11];

- ❑ Welding parameters : Sheet thickness, Voltage, Current and Travel speed
- ❑ No. of passes during welding
- ❑ Welding path
- ❑ Thickness of the welding coil : 0.8mm,1.2mm, 1.6mm
- ❑ Fail to use automatic accessories : Positioner motion and auto cleaner

- Operator fatigue

By modifying the above factors results are obtained. The obtained results are tabulated and monitored to achieve the required productivity

V. EXPERIMENTAL SETUP

Below is the experimental setup area to weld transfer case cover. There are two such positioners on both sides ofthe robotic welding machine (Fig 1.5). First set of six transfer case covers are placed in one of the positioner for top side welding. Once the operation is completed, these are taken to the operator side table (Fig 1.6) for deburring and fettling. On completion of the manual activities, these transfer case covers are loaded to the second positioner forbottom side welding.

Fig. 1.5 Robot welding side

Once bottom side welding is under process, another six sets of transfer case covers are loaded in first positioner for top side welding. Meanwhile bottom side welding gets completed in the second positioner, the completed jobs are taken to the rear side table for fettling and deburring. These six numbers of components are called for inspection. On getting inspection cleared, finally number punch ismade on every transfer case cover and loaded in the specially done transporting pallet for moving to next operation.

Fig. 1.6 Robot welding operator side

VI. EXISTING PRODUCTION RATE AND DISCUSSIONS

A. Current production output cycle time

Table 1.2 Current cycle time

TC Cover - Robo welding - Time study									
Starting time		8:00:00	am	1 hr capacity		End Time		9:00:00	am
Topside welding		Bottom side welding		Others		Total cycle time		Time	No of components produced
Min	Sec	Min	Sec	Min	Sec	Min	Sec		
9	34	7	54	0	20	17	48	8:17:48	1
9	34	7	54	0	20	17	48	8:35:36	2
9	34	7	54	0	20	17	48	8:53:24	3

Above Table 1.2 gives the details cycle time analysis report on an hour production rate. As per this table it is clearly visible that an hour production rate is three components. Objective of this project is to improve this cycle time by analyzing the factors influencing this welding cycle time. On improving this cycle time andachieving the required component of 150 numbers per day will gives a cost saving of Rs.6,80,000 per month only on robotic welding as per Table 1.3.

Table 1.3 Robotic welding cost

Robot welding cost saving details / month	
Hour rate	₹2,000.00
Current production qty. / day	48
Process cost per component	₹666.67
On achieving production qty. /day	150

Process cost per component	₹213.33
Cost saving / component	₹453.33
Total order qty. / month	1500
Total cost saving / month	□ **6,80,000.00**

Detailed analysis on the process cost of each and every process is listed in Table 1.4. Other costs such as material, man power and overheads are also included in process cost calculation of per component.

Table 1.4 Process flow and cost

Process flow and Process cost					
Sl. No.	Process	Process done at	Resource used		Process cost/unit
			Machine	Man power	
1	Gas cutting	Equipment division	1	1+1	₹ 119.00
2	Sub parts machining	Machine shop	1	1	₹ 215.00
3	Manual setting welding	Equipment division	1	1	₹ 45.00
4	**Robo welding**	**Equipment division**	**1**	**1**	**₹ 666.67**
5	Stress relieving	OSP	-	-	₹ 65.70
6	Shot blasting	Equipment division	1	1	₹ 43.80
7	Painting	Equipment division	-	1	₹ 43.80
8	Final machining	Machine shop	1	1	₹ 1,850.00
9	Oiling, Packing & Dispatch	Machine shop	-	2	₹ 180.00
			Raw material cost		₹ 2,856.00
			Overheads		₹ 304.25
	Customer PO Price / unit	₹ 11,650.00	Total expenses/ unit:		₹ 6,270.22
	Current profit / unit	₹ 5,379.79			
	Monthly order Qty.	1500	Total Billing Value		₹ 1,74,75,000.00

VII. AMPLIFIED PRODUCTION RATE AND DISCUSSIONS

A. Range of welding parameters range

- ❑ Travel speed : 0.20 - 0.32 m/min
- ❑ Voltage : 18.9 - 39 volts
- ❑ Welding Gas : 100% CO_2 (or) 75%Ar & 25%CO_2
- ❑ Flow rate : 15 - 18 CFH (7.05 – 8.46 L/min)
- ❑ Coil dia. : 0.8, 1.2 & 1.6mm

Physical trails [10] are taken with multiple combinations for travel speed and voltage [9], finally ended with optimized parameters shown in Table 1.6. Table 1.5 gives the existing welding parameter reading with current production output of 24 nos. per shift. Whereas, iteration 18 parameter gives maximum production output without and defects of about 84 nos. per shift.

Table 1.5 Current welding parameter reading

Existing Robotic welding machine parameter readings	
Welding Parameter	**Existing Reading**
Travel speed	0.21 m/min
Voltage	39 volts
Welding Gas	100% CO_2
Coil dia.	1.2mm

Table 1.6 Optimized welding parameter

Physical trials: Iteration 18	
Welding Parameter	**Trial Reading - optimized**
Travel speed	0.25m/min
Voltage	28 volts
Welding Gas	75%Ar & 25%CO_2
Coil dia.	1.6mm

VIII. CONCLUSION

Thus transfer case housing robotic welding productivity was improved by taking physical trials by varying welding parameters. Although, productivity was increased, cost of welding increased by 20% since 75%Ar & 25%CO_2 mixed gases was used instead of CO_2 alone as shielding gas, which produces more spatter. Also, welding coil diameter was changed from 1.2mm to 1.6mm.

Software analysis involves representing key characteristics or behaviors of a physical or abstract system. Simulation can be *used to* show the eventual real effects of alternative conditions and courses of action. This was planned by using software's such as Flexsim and Arena to find out the idle time, idle material and man movement, manual work cycle time to reduce overall cost of the component.

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