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Sustainable Energy Efficiency for MIG Welding Process

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Abstract: Sustainable manufacturing emphasizes on the needs of an energy efficient process that optimise energy consumptions. Reduction in electrical energy consumption will diminish the carbon emission in generating electricity at the power plant. Welding is one of the most important joining technologies in manufacturing. Metal Inert Gas Welding (MIG) / Metal Active Gas (MAG) is one of the popular welding processes. In welding, the process parameters were not set to optimise electrical energy consumption for overall procedure. In this research, an optimized electrical energy consumption in welding process was determined. This was based on the optimised welding parameter model. The electrical energy consumed were summarised in a single energy map. This model produces good quality and energy efficient welding process. With reference to the design of experiments by Taguchi technique, three parameters which include the current, voltage and wire feed rate were varied to obtain an optimum energy efficient process and good quality of welding. The electrical energy consumed during the process were calculated and recorded. The data were used to obtain an optimised electrical energy consumption based on different welding parameters. The optimized welding parameters were used to develop a suitable welding parameters model which optimised the electrical energy consumption for the welding process. The reduction of electrical energy consumption benefits the industries in having to reduce the overall cost of welding process.

Keywords: Sustainable manufacturing, MIG, Electrical energy.

I. INTRODUCTION

Welding is one of the most significant manufacturing process. It is widely being used by the manufacturing industries. Unfortunately the amount of electrical energy used in welding seldom being taken into consideration towards sustainable manufacturing. This industry cannot run away from the sustainable manufacturing. One of the main factor of implementing the sustainable manufacturing is optimization of electrical energy consumption. Optimization of electrical energy consumption is being highlighted by (Erdil, Aktas, &Arani, 2018; Rajemi, Mativenga, &Aramcharoen, 2010).Reduction in electrical energy consumption will reduce the carbon emission in generating the electricity at the power plant.

Welding is the most important joining technology in manufacturing. Metal Inert Gas Welding (MIG) / Metal Active Gas (MAG) is one of the popular welding processes. In welding, the process parameters were not set to optimize electrical energy consumption for overall procedure.

However, optimization of MIG process is important (Jogi, Awale, Nirantar, & Bhusare, 2018). Hence, real time data for the welding process is important in finding the optimised welding parameter for this particular traditional manufacturing processes. In this research, an optimized electrical energy consumption in welding process were determined. This was based on the optimised welding parameter model. The electrical energy consumed were summarised in a single energy map.This model produces good quality product and also an energy efficient welding process.

In order to determine the optimum electrical energy consumption, the design of experiments by Taguchi technique were implemented. Taguchi technique is important in finding important and optimised parameters in manufacturing (Lokesh, Niresh, Neelakrishnan, & Rahul, 2018). In MIG, there are four (4) parameters that can be control which is current (I), voltage (V), wire feed rate (S) and gas flow rate (F). The parameters were varied to obtain an optimum energy efficient process and good quality of welding. The electrical energy consumed during the process were calculated and recorded. The data were used to obtain an optimised electrical energy consumption based on different welding parameters. The optimized welding parameters were used develop a suitable welding parameters model which optimised the electrical energy consumption for the welding process.

The reduction of electrical energy consumption benefits the industries in having to reduce the overall cost of welding process. Besides that, this model reflects an optimum energy efficient of MIG/MAG welding process. In turn, this will reduce electrical energy consumption to support sustainable manufacturing for the welding processes.

II. METHODOLOGY

Sustainable manufacturing emphasizes on optimizing electrical energy consumption. In this research, the optimum electrical energy consumption is being determined using Taguchi method design of experiment. In this experiment, Figure 1a and 1b shows the MIG welding setup. The Miller In vision 354MP were used in this research. This MIG welding machine uses DC current in welding

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Fig. 1a MIG setup

Fig. 1b Miller Invision 354MP

The welding process for this research involve joining two mild steel plate using butt join. The plates were machined into 150mm x 50mm x 3mm as base metal. The surface of the plates was grinded to remove the dust and other foreign particles. The diameter of the welding wire depends upon the base metal thickness. As the thickness of the base metal was 3mm, welding wire with a diameter of 0.8mm was selected. There 4 factors that can be control for the MIG process which is welding current (A), voltage (V), wire speed (f) and gas flow rate (g). The welding input parameters that can affect the output response were identified andtheir range of operation was selected as shown in Table 1.

Table. 1 Welding parameters

Parameter	Welding Current, I [A]	Welding Voltage,V [V]	Wire Speed, S [m/min]	Gas Flow Rate, F [l/min]
Values	214-235	21-23	2.4-3.3	12-16

The parameters were used to optimize process parameter settings. Hence, through utilizing of Taguchi method, best set of specific process parameter level combinations were determined to run the experiment. The specified welding parameters were shown in Table 2. Taguchi's parameter design method is used to arrange the orthogonal array experiments and to reduce number of experiments. In this research, L9(3^4) table were used to run the 9 multiple experiments (Table 2).

Table. 2 Welding parameters based on Taguchi DOE method

Experiment	Current, *I* [A]	Voltage, *V*[V]	Welding Wire speed, S [m/min]	Gas Flow Rate, F [l/min]
1	I1 (214)	V1 (21)	S1 (2.4)	F1 (12)
2	I1 (214)	V2 (22)	S2 (3.0)	F2 (14)
3	I1 (214)	V3 (23)	S3 (3.3)	F3 (16)
4	I2 (224)	V1 (21)	S2 (3.0)	F3 (16)
5	I2 (224)	V2 (22)	S3 (3.3)	F1 (12)
6	I2 (224)	V3 (23)	S1 (2.4)	F2 (14)
7	I3 (235)	V1 (21)	S3 (3.3)	F2 (14)
8	I3 (235)	V2 (22)	S1 (2.4)	F3 (16)
9	I3 (235)	V3 (23)	S2 (3.0)	F1 (12)

Miller Invision 324MP welding machine uses DC current. However, the electric supply came from the power grid is an AC current with a voltage of 415V. Miller Invision 324MP converts the alternating current (AC) to the direct current (DC) to starts the welding process.

Kyoritsu KEW5020 current logger was used to monitor the current of the welding machine. It is important to highlight that this equipment is used to measure the current consumption in machining by using different cutting arameters. The measurement can be used to determine the effectiveness of different cutting parameters in reducing energy consumption in machining.

Figure 2 showed the current logger being clamp to main supply to monitor the current consumption for the process. Results of the current consumption was recorded in suitable table and discussed further in the next section.

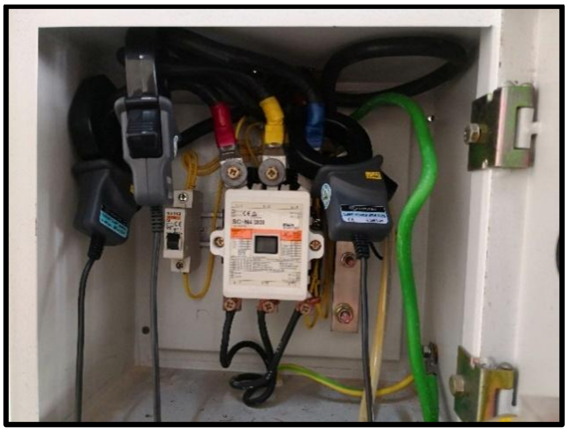

Fig. 2 Kyoritsu current logger clamp onto the main power supply

The current consumption of the welding process were recorded. Current (I) reading were used to calculate the Power (P) for the whole process. It is calculate using equation (1). The Energy (E) that is needed by the process to create the weld pool and to melt the wire were calculated using equation (2).

$P = \sqrt{3}\ x\, V\, x\, I\ [W]$; (1)

where V = Voltage [V] ; I = Current [A]

$E\ \ = P\ x\ t\ [Ws]$ -(2)

Where: E = Energy [Ws] ; P = Power [W] ; t = time [s]

The workpiece is being welded using the butt welding joining process. The welding process parameters were set according to the specified values in Table 2. After the welding process, the workpiece is being tested for their yield strength. Figure 3a and 3b showed the tensile strength test machine and the workpiece respectively. The results of the tensile strength test has been tabulated in suitable table and discussed further in the next section.

Fig. 3a Tensile strength machine

Fig. 3b Workpiece after tensile strength test

Based from the results, an optimised electrical energy consumption were determined. Hence, model of optimised electrical energy consumption using a specific welding parameters were developed. The results were used to design an electrical energy map for future reference.

III. RESULTS AND DISCUSSIONS

The metal workpieces has been successfully joint using the parameter sets in Table 2. Figure 4 showed the mild steel plate that has been welded using MIG.

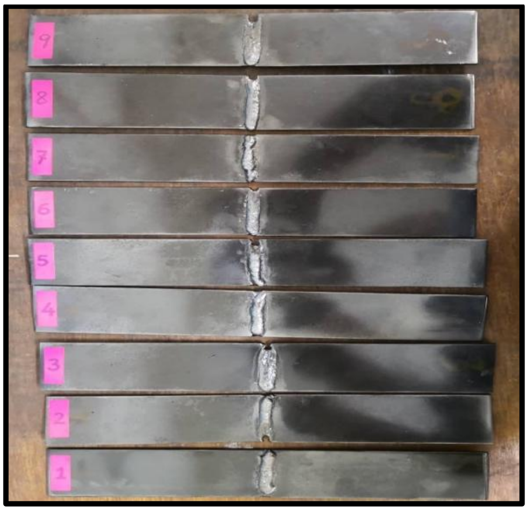

Fig. 4 The welded sheet metal

The 150 x 50 x 3 mm showed that is has been welded successfully. After being welded, the sheet metal is brought to the tensile test machine. All of the workpiece are being tested according. Results of the tensile strength test is shown in Table 3.

By using formula 1, the energy for welding was calculated. Table 3 showed the energy consumed for the welding. The energy for welding varies from a minimum of 50979 Ws and a maximum of 74387 Ws. The time taken for welding also varies. The minimum time taken for welding is 14.02 s and the maximum is 19.09 s.

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Table. 3 Results of the welding process

Parameter	Time [s]	Current [A]	Power [W]	Energy [Ws]	Tensile strength x 10^3 [N/m^2]
1	15.21	4.67	3354.41	51021	36.68
2	16.18	6.10	4384.69	70944	36.87
3	15.91	6.10	4384.69	69760	36.97
4	19.04	4.73	3402.33	64780	36.58
5	15.09	4.73	3402.33	51341	36.74
6	14.02	5.07	3641.93	51060	37.17
7	17.3	5.20	3737.77	64663	37.36
8	15.39	5.17	3713.81	57155	37.56
9	15.68	6.60	4744.09	74387	38.05
Optimum	14.27	4.97	3572.44	50979	38.64

Parameter 6 has the shortest time taken for welding. Paramater 4 has the longest time for welding process as shown in Table 3. On the other hand, parameter 9 has the highest energy consumption reaching almost to 75 kWs. The optimum parameter has the lowest energy consumptions compared to the other 9 parameters setting.

Having to weld the all the 9 workpiece according to the welding parameters, the optimize parameter were determined by ploting the mean (Figure 5a) and signal noise (S/N) ratio (Figure 5b).

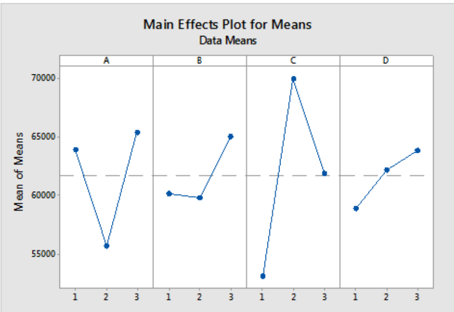

Fig. 5a The energy mean for the welding process

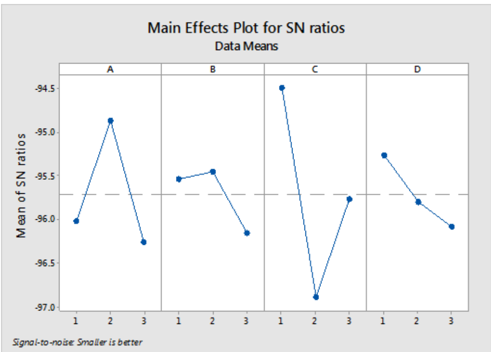

Fig. 5b The Signal-Noise ratio

The S/N ratio graph were plotted using a minimum is better conditions. Referring to Figure 5b, the optimized welding parameter are current (I3), voltage (V3), welding wire speed (S2) and gas flow rate (F3). Having to determine the optimised parameter, another welding process was done according to the optimised welding parameter. The current and time taken for welding were recorded. The results were also shown in Table 3 under the optimise parameter.

Besides having to determine the optimum welding parameter, the electrical energy consumption for the whole parameters were ploted in an energy map graph. The energy map is shown in Figure 6.

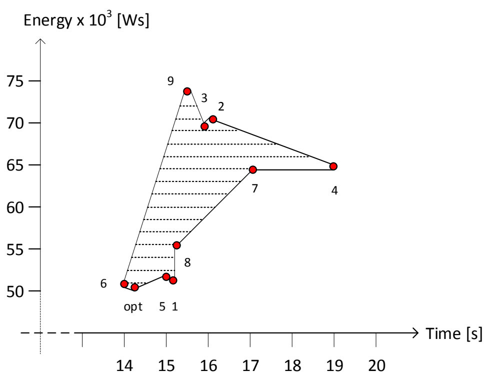

Fig. 6 The energy map

The energy map in shown Figure 6 clearly showed that the optimum parameter consume the least energy consumption in the welding process. It proves that optimising the welding parameters do lead to a reduction of electrical energy consumptions in MIG welding process. Reduction of electrical energy consumption minimise the operational cost of welding process. Besides that it also supports the sustainable manufacturing process which will lead to the reduction of carbon emission at the power plant in generating the electrical power in the power grid.

IV. CONCLUSION

Optimising the electrical energy consumed is one of the methods in reducing energy consumption in welding process and supports sustainable manufacturing process. In this research the total energy used in MIG welding process were recorded and calculated. Having to determine the welding parameters varies the electrical energy consumptions for each of the process. The optimised welding parameter did minimise electrical energy consumption in welding process. The reduction of electrical energy consumption leads to a lower carbon emission at power plant in generating the electrical energy. As for the manufacturing industries, reduction of electrical energy will save the cost of welding their products. Both of the benefits in electrical energy consumption support the sustainable manufacturing especially in industries that involve heavily in the welding process using MIG machine.

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