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Surface Roughness and MRR Effect on Manual Plasma Arc Cutting Machining

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***Abstract*—**Industrial surveys shows that manufacturing companies define the qualities of thermal removing process based on the dimension and physical appearance of the cutting material surface. Therefore, the roughness of the surface area of the material cut by the plasma arc cutting process and the rate of the removed material by the manual plasma arc cutting machine was importantly considered. Plasma arc cutter Selco Genesis 90 was used to cut Standard AISI 1017 Steel of 200 mm x100 mm x 6 mm manually based on the selected parameters setting. The material removal rate (MRR) was measured by determining the weight of the specimens before and after the cutting process. The surface roughness (SR) analysis was conducted using Mitutoyo CS-3100 to determine the average roughness value (Ra). Taguchi method was utilized to achieve optimum condition for both outputs studied. The microstructure analysis in the region of the cutting surface is performed using SEM. The results reveal that the SR values are inversely proportional to the MRR values. The quality of the surface roughness depends on the dross peak that occurred after the cutting process.

***Keywords*—**Material removal rate, plasma arc cutting, surface roughness, Taguchi method

I. Introduction

PLASMA arc cutting is one of thermal removing process which operates on the principle of passing an electric arc through a quantity of gas through a restricted outlet [1]. This process has been used in cutting applications of stainless steel, hardened and high melting-point metal and hardened alloys [2]-[5]. The interest of modern industries in plasma arc cutting applications have increased due to the capability of this process to compete with Laser cutting (higher quality but also more expensive) and Oxygen-fuel cutting which is less expensive but lower cutting quality. Most of plasma arc cutting process was supported by the CNC attachment which benefits wide industries. There is several numbers of researches on the plasma arc cutting machining. Abdulkadir Gullu [6] concludes that the different cutting speed produces the same effects on microstructure at the deformation of the structure that occurred at the area of the cutting process. Whilst, according to L.J Yang [7] the maximize depth of the hardened zone in steel specimens is significant with the optimization of plasma arc cutting process.

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Higher quality of plasma arc cutting can be achieved by manipulating the speed and the cutting current [8]-[11]. However in this work, the cutting process was performed manually which could benefit to small manufacturing industries. Therefore, plasma outputs and parameters of the study which is suited for manual and capability of plasma arc cutting machine are not entirely similar to the conventional automated plasma arc cutting machine.

Qualities of thermal cutting processing can be evaluated based on many aspects. In this work, the surface area of the materials cut by plasma arc cutting process and the rate of removed material were considered. SR is the measurement of the surface texture based on the vertical deviation (Ra) of a real surface from its ideal form. The surface roughness test is conducted to determine the irregularities of the cutting surface after the cutting process. These irregularities in which manufacturing industries considered could lead part to easily being crack when used as mechanical components [12]. MRR is the capability measurement of plasma arc cutting process to remove the specific volume of material in a specific time (mm^3/min). The weight of the specimens were measured before and after the cutting process to determine the material removal rate of the plasma arc cutting based on the chosen parameters. There were several methods available for the design of experiments to optimize the plasma cutting parameters. The Taguchi method approach was utilized since it requires a fewer number of tests and the information extracted more efficiently compare to full factorial and fractional factorial design of experiments method [7].

II. Material Properties and Experimental Parameters

A. Material Properties

AISI 1017 mild steel which are widely used in industries were chosen as a material for cutting. Elements composition of the specimen obtained from the spectral analysis is listed in Table I.

B. Parameters

Based on the condition and capability of the manual plasma cutting process, four parameters which affected the outcome results were considered and listed below, whilst the intervals of each parameter were shown as in Table II.

1. Air pressure [bar].
2. Cutting current [A].
3. Cutting speed [mm/min].
4. Arc gap [mm].

TABLE I
ELEMENT COMPOSITION OF AISI 1017 MILD STEEL

Element	Atomic Number	Wt. %
Carbon	6	17.72
Manganese	25	32.04
Phosphorus	15	1.96
Sulfur	16	1.64
Silicon	14	0.29
Iron	26	46.35
	Total :	100.00

TABLE II
PARAMETERS AND INTERVAL

Parameters	Intervals		
	1	2	3
Air pressure (bar)	5.5	6.0	6.5
Current (A)	70	75	80
Speed (mm/min)	600	700	800
Gap (mm)	3.0	4.0	5.0

TABLE III
MATERIAL REMOVAL RATE RESULTS

Exp. No	Parameters				Reading				S/N
	Air	Current	Speed	Gap	1	2	3	Avg.	
1	1	1	1	1	3971.525	3297.115	3521.918	3596.853	71.042
2	1	2	2	2	3830.564	3296.067	3474.233	3533.621	70.914
3	1	3	3	3	4687.898	4484.076	4585.987	4585.987	73.224
4	2	1	2	3	3117.901	3741.481	3296.067	3385.150	70.517
5	2	2	3	1	3566.879	3974.522	3566.879	3702.760	71.337
6	2	3	1	2	6369.427	6594.230	6369.427	6444.361	76.180
7	3	1	3	2	3261.146	4178.344	3566.879	3668.790	71.156
8	3	2	1	3	5695.017	5919.820	5695.017	5769.951	75.219
9	3	3	2	1	4097.813	4008.730	4186.896	4097.813	72.247

TABLE IV
SURFACE ROUGHNESS RESULTS

Exp. No	Parameters				Reading				S/N
	Air	Current	Speed	Gap	1	2	3	Avg.	
1	1	1	1	1	61.201	64.235	62.090	62.509	-35.921
2	1	2	2	2	67.811	69.799	67.811	69.038	-36.782
3	1	3	3	3	35.056	38.320	37.045	36.807	-31.324
4	2	1	2	3	77.308	73.434	73.973	74.905	-37.492
5	2	2	3	1	39.338	39.185	39.867	39.463	-31.924
6	2	3	1	2	23.780	23.090	36.580	27.817	-29.097
7	3	1	3	2	45.690	41.223	43.908	43.607	-32.799
8	3	2	1	3	26.329	25.506	33.614	28.483	-29.162
9	3	3	2	1	38.380	39.084	38.237	38.567	-31.725

III. METHODOLOGY

A. Material Removal Rate Measurements

Weight measurement of the AISI 1017 mild steel specimens were carried out before and after the cutting process. The material removal rate (mm^3/min) of the plasma arc cutting process was calculated by using (1).

$$MRR = \frac{(Weight\ diff./\ density)}{cutting\ time} \tag{1}$$

The density equal to 0.00785 g/mm^3 was used in the calculation.

B. Surface Roughness (SR) Analysis

The SR analysis was carried out using Mitutoyo CS-3100 machine in the area of the cutting surface to observe the irregularities of the surface based on the applied parameters. The surface is assumed rough when the deviations of a real surface from its ideal form are large and vice versa. However the values of roughness analysis might vary with the MRR in some cases because the Mitutoyo CS-3100 machine was not designed to cover the whole surface area.

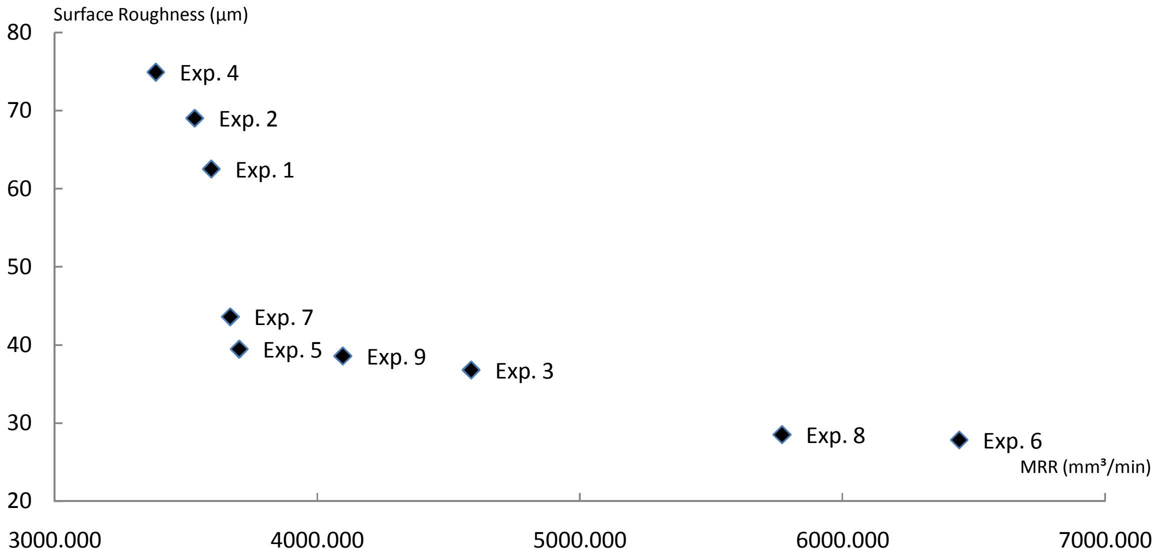
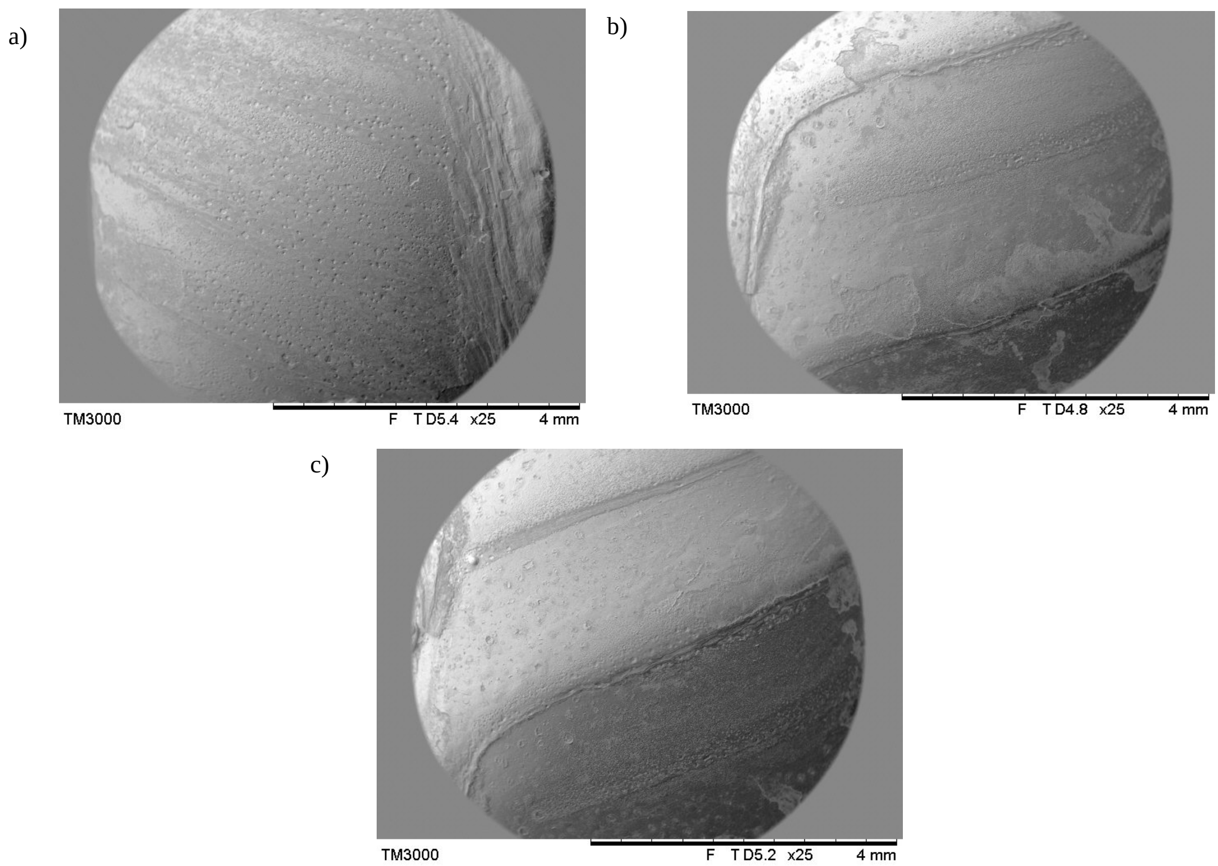


Fig. 1 Results of SR and MRR for all experiments



a) MRR = 5500-6400 mm³/min, SR = 20-30 µm b) MRR = 3600-4800 mm³/min, SR = 30-50 µm
c) MRR = 3000-3500 mm³/min, SR = 65-80 µm

Fig. 2 Structural cutting surface with different parameter settings

C. Taguchi Method Orthogonal Array

Four factors with three level intervals were used, thus Taguchi orthogonal Array of L9 was selected as experimental layout (Table III and Table IV).

IV. Results and Discussion

Fig. 1 shows the results of surface roughness (SR) versus MRR for all experiments. The value of SR is based on the Ra value. In general it can be observed that the relation between average material removal rate and average surface roughness is inversely proportional. Higher MRR will have lower SR and vice versa.

The relations between the experimental results were based directly on the dross occurred after the cutting phase; higher material removal rate produced small dimension of dross thus resulted better surface roughness. Fig 2 shows the results of SEM analysis for all experiment. Constant dross that occurred at the area of the cutting surface was due to the manual plasma arc cutting removal process. As shown in the graph in Fig 1, experiment 4, 2 and 1 produce the highest SR value with the lowest MRR value thus indicates rougher surface roughness whilst experiment 8 and 6 produce the lowest SR and the highest MRR values. The dross formed for experiment 4, 2 and 1 as in Fig 2c, and the peak of the dross can be visually seen and estimated between 1mm and 1.5mm. The same type but higher dross length occurred within the range of 30 to 50 µm (experiment 7, 5, 9 and 3) as in Fig 2b which indicates that the surface irregularities were low therefore produced slightly better surface roughness. Smaller dross that occurred (experiment 8 and 6) within the range of 15 to 30 µm as in Fig 2a is difficult to be detected, however it can be observed using the roughness analysis.

V. Conclusion

Based on the experiment results several conclusions for manual plasma arc cutting machine can be highlighted as below:

1) Generally the SR values are inversely proportional to the MRR values.
2) The dimensions of the dross determine the quality of plasma arc cutting in terms of surface roughness.

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