Analysis of Plasma ARC Cutting for Mild Steel and Stainless Steel Plates

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Abstract: This work is about the study and analysis of the plasma ARC machine for its applicability and adaptability for cutting of mild steel and stainless steel plates of various thicknesses. For making of this work plasma ARC machine of prescribed features have been selected and in addition mild steel pieces of size 150mm x150mm x 5mm and 150mm x150mm x10mm and 150mm x 150mm x 15mm were taken and stainless steel of 50mm x 150mm x 5mm taken. At first the machine is conditioned for cutting process by suitable means of fluids and parts. For this work Distilled water and acetone were chosen by 50:50 (v/v) and fed to the cutting torch. Actually methanol has to be used for this purpose however because of non availability and non affordability a similar kind of liquid acetone is used. Next the M.S. and S.S. plates are cleaned enough to making cutting. As the power input and output must be same based on this the voltage, current and resistance within the system are calculated after the initiation of cutting. In addition to this the angle of torch, direction of cutting, shielding gas flow rate, time for setting, holding, cutting, length of cut against time all these are recorded. By applying suitable means of formulae analysis is done. At the end the material removal rate, time took for cut, angle of torch, voltage used, current consumed, resistance and hardness at various locations, roughness of cut were calculated for the purpose of further investigation and optimization of parameters. At the same time the variations that observed in the work piece were found such its change in hardness. As plasma ARC is mainly intended for making intricate holes but the present work is emphasized on cutting using the plasma ARC process. So by default is adaptability has to be justified. This work has made an arena by plotting control charts. At the end the results and further scope discussed.

Key-Words: - Plasma ARC cutting, Control chart, Material removal rate

1 Introduction

Plasma ARC cutting [1] is a cutting process that is made by the application of plasma ARC heat on the material surface being cut [2]. There are many number of types of cuttings of materials are available but accuracy of cut, precision in the process of cutting are the key elements upon which the research was made [3]. Mild steel plates are been set for the operation of cutting. In this work the power characteristics, material removal rates are been analysed for further scope and application [4].

2 Experimental Procedure

Mild steel plates of length l = 150 mm and width = 150 mm and thickness = 5 mm, 10m and 15mm is cut on plasma ARC cutting machine. And in addition to this stainless steel of 150mm x 150mm x 5mm is cut. The argon gas is used as shielding gas and a trailing gas right after cutting to prevent absorption of oxygen and nitrogen from the atmosphere. The following observations are made while cutting the above said pieces [5].

3 Process Parameters in PAW

3.1 Case-1: Mild steel plate of 150mm x 150mm x 5mm

The entire cutting took almost 120 seconds. But the total time took for cutting is different from the cutting time. Because of setting of machine, loading and reloading of the distilled water and acetone mixture and loading such tasks were not included in the cutting time calculations. All these were described in Fig 1 [6].

Figure 1: 5mm Mild steel plate

Setting up of machine = 5min = 5*60 = 300 seconds. Mixing of distilled water with acetone on 50:50 (v/v) basis = 2 min = 2*60 = 120 seconds. Filling the torch = 1 min = 60 seconds. Cutting time first spell= 60 seconds. Miscellaneous disturbances = 2 min = 2*60 = 120 seconds. Cutting time second spell = 60 seconds. Removing the setup and cooling the torch = 5min = 5*60=300 seconds. Now the total time for cutting = 300+120+60+60+120+60=720 seconds. Cutting time alone = Total time – (cutting time spell 1 + cutting time spell 2 – Mixing time – filling time - Misc disturbances – Removing set up) = 720 – (60+60-120-60-120-300) = 120 seconds.

After the cutting of the plate of mild steel the two MS plates were formed those two are taken aside and left for cooling for some time. Mean while the input parameters were analyzed for the understanding are shown in Fig 2 & Fig 3.

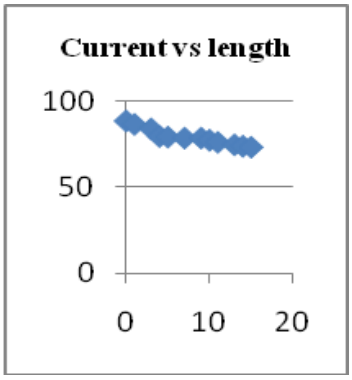

Figure 2: Current vs. Length of 5mm ms plate

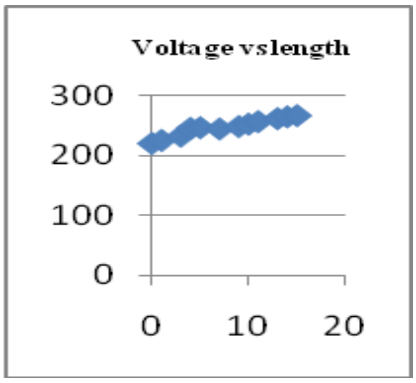

Figure 3: Current vs. Voltage of 5mm ms plate

The maximum consumption of current is 88.6 Amps, minimum consumption of current is 73.3 Amps and the mean consumption of current is 79.23 Amps. And the consumption is gradually reduced. The maximum consumption of Voltage is 266 Volts, minimum consumption of Voltage is 220 Volts and the mean consumption of Voltage is 246.58 Volts. And the consumption is gradually increased shown in Fig 4 & Fig 5.

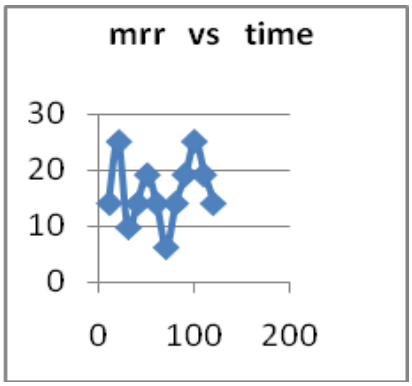

Figure 4: Material removal rate vs. time

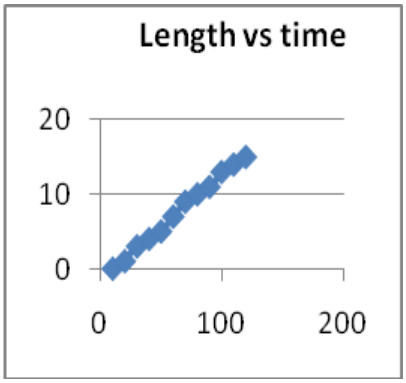

Figure 5: Length vs. time

The maximum material removal rate (mrr) is observed at 20th second and 100th second and its value is 25.13 mm^3/s, minimum material removal rate (mrr) is observed at 70th second and its value is 6.28 mm^3/s. And the mrr is zig-zag. And the cutting is took place linearly. Started from 0th second to 120 seconds.

3.2 Case-2: Mild steel plate of 150mm x 150mm x 10mm

The entire cutting took almost 300 seconds. But the total time took for cutting is different from the cutting time [7]. Because of setting of machine, loading and reloading of the distilled water and acetone mixture and loading such tasks were not included in the cutting time calculations. All these were described below.

Setting up of machine = 5min = 5*60 = 300 seconds. Mixing of distilled water with acetone on 50:50 (v/v) basis = 2 min = 2*60 = 120 seconds. Filling the torch = 1 min = 60 seconds. Cutting time first spell= 150 seconds. Mixing of distilled water

with acetone on 50:50 (v/v) basis = 2 min = 2*60 = 120 seconds. Filling the torch = 1 min = 60 seconds. Miscellaneous disturbances = 2 min = 2*60 = 120 seconds. Cutting time second spell = 150 seconds. Removing the setup and cooling the torch = 5min = 5*60=300 seconds. Now the total time for cutting = 300+120+60+150+120+60+120+150+300= 1380 seconds. Cutting time alone = Total time – (cutting time spell 1 + cutting time spell 2 – Mixing time – filling time - Mixing time – filling time - Misc disturbances – Removing set up) = 1380 - (150+150-300-120-60-120-60-120-300) = 300 seconds.

After the cutting of the plate the two plates of ms were formed those two were taken aside and left for cooling for some time. Mean while the input parameters were analyzed for the understanding shown in Fig 6 & Fig 7.

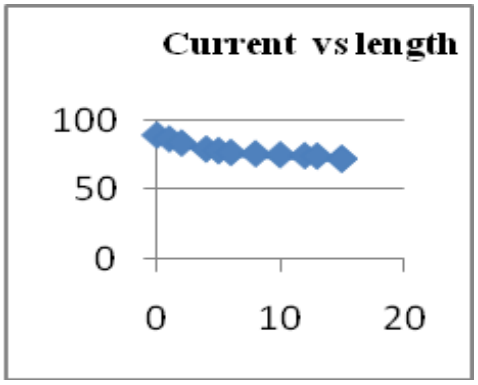

Figure 6: Current vs. Length of 10mm ms plate

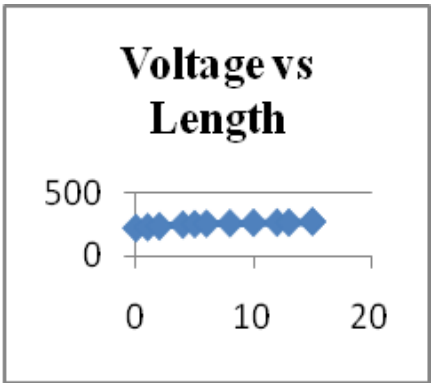

Figure 7: Current vs. Voltage of 10mm ms plate

The maximum consumption of current is 88.6 Amps, minimum consumption of current is 71.2 Amps and the mean consumption of current is 77.49 Amps. And the consumption is gradually reduced. The maximum consumption of Voltage is 274 Volts, minimum consumption of Voltage is 220 Volts and the mean consumption of Voltage is 252.75 Volts. And the consumption is increased rapidly up to half the way and later gradually increased shown in Fig 8 & Fig 9.

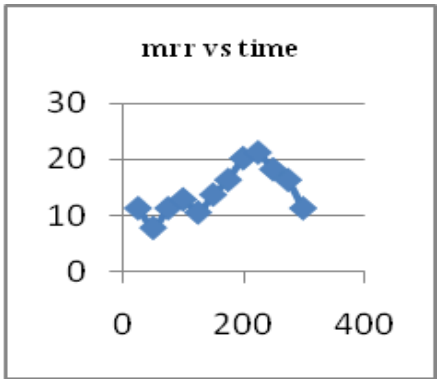

Figure 8: Material removal rate vs. time

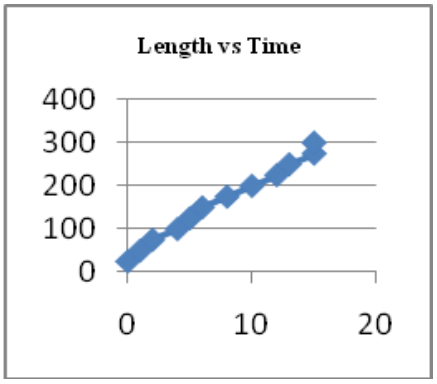

Figure 9: Length vs. time

The maximum material removal rate (mrr) is observed at 225th second and its value is 21.13 mm^3/s, minimum material removal rate (mrr) is observed at 50th second and its value is 7.85 mm^3/s. And the mrr is zig-zag in the starting and later it followed normal distribution. And the cutting is took place linearly with time. Started from 0th second to 360 seconds.

3.3 Case-3: Mild steel plate of 150mm x 150mm x 15mm

The entire cutting took almost 420 seconds. But the total time took for cutting is different from the cutting time. Because of setting of machine, loading and reloading of the distilled water and acetone mixture and loading such tasks were not included in the cutting time calculations. All these were described in Fig 10.

Figure 10: 15mm Mild steel plate

Setting up of machine = 5min = 5*60 = 300 seconds. Mixing of distilled water with acetone on 50:50 (v/v) basis = 2 min = 2*60 = 120 seconds. Filling the torch = 1 min = 60 seconds. Cutting time first spell= 210 seconds. Mixing of distilled water with acetone on 50:50 (v/v) basis = 2 min = 2*60 = 120 seconds. Filling the torch = 1 min = 60 seconds. Miscellaneous disturbances = 2 min = 2*60 = 120 seconds. Cutting time second spell = 210 seconds. Removing the setup and cooling the torch = 5min = 5*60=300 seconds. Now the total time for cutting = 300+120+60+210+120+60+120+210+300= 1500 seconds. Cutting time alone = Total time – (cutting time spell 1 + cutting time spell 2 – Mixing time – filling time - Mixing time – filling time - Misc disturbances – Removing set up) = 1500 – (300-120-60-120-60-120-300) = 420 seconds.

After the cutting of the plate the two ms plates were formed those two were taken aside and left for cooling for some time. Mean while the input parameters were analyzed for the understanding shown in Fig 11 & Fig 12.

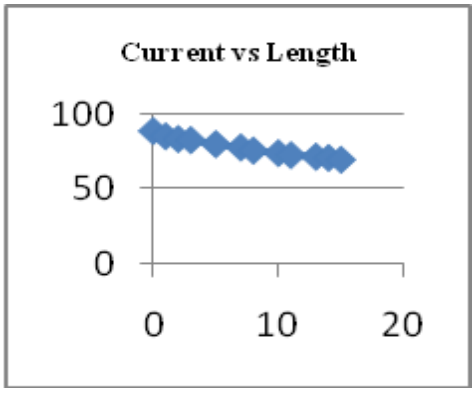

Figure 11: Current vs. Length of 10mm ms plate

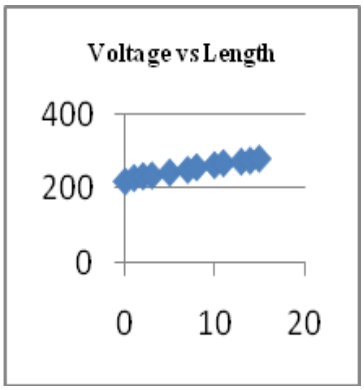

Figure 12: Current vs. Voltage of 10mm ms plate

The maximum consumption of current is 88.6 Amps, minimum consumption of current is 69.4 Amps and the mean consumption of current is 77.55 Amps. And the consumption is gradually reduced. The maximum consumption of Voltage is 281 Volts, minimum consumption of Voltage is 220 Volts and the mean consumption of Voltage is 252.91 Volts. And the consumption is increased gradually shown in Fig 13 & Fig 14.

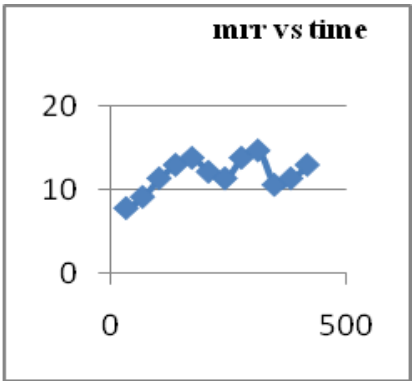

Figure 13: Material removal rate vs. time

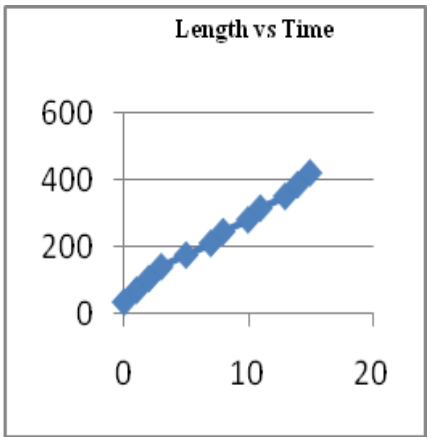

Figure 14: Length vs. time

The maximum material removal rate (mrr) is observed at 315th second and its value is 14.71

mm^3/s, minimum material removal rate (mrr) is observed at 35^{th} second and its value is 7.76 mm^3/s. And the mrr is zig-zag through out the operation. And the cutting is took place linearly with time. Started from 0^{th} second to 420 seconds.

3.4 Case-4: Stainless steel plate of 150mm x 150mm x 5mm

The entire cutting took almost 130 seconds. But the total time took for cutting is different from the cutting time. Because of setting of machine, loading and reloading of the distilled water and acetone mixture and loading such tasks were not included in the cutting time calculations. All these were described below.

Setting up of machine = 5min = 5*60 = 300 seconds. Mixing of distilled water with acetone on 50:50 (v/v) basis = 2 min = 2*60 = 120 seconds. Filling the torch = 1 min = 60 seconds. Cutting time first spell= 64 seconds. Miscellaneous disturbances = 2 min = 2*60 = 120 seconds. Cutting time second spell = 66 seconds. Removing the setup and cooling the torch = 5min = 5*60=300 seconds. Now the total time for cutting = 300+120+64+66+120+60=720 seconds. Cutting time alone = Total time – (cutting time spell 1 + cutting time spell 2 – Mixing time – filling time - Misc disturbances – Removing set up) = 730 – (64+66-120-60-120-300) = 130 seconds.

After the cutting of the plate the two plates were formed those two were kept aside and left for cooling for some time. Mean while the input parameters were analyzed for the understanding shown in Fig 15 & Fig 16.

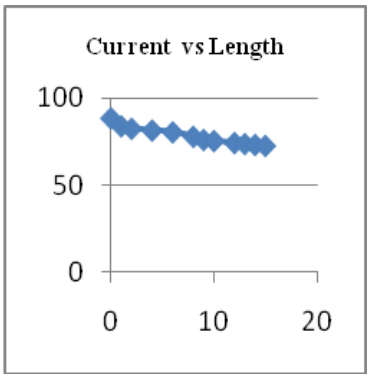

Figure 15: Current vs. Length of 10mm ms plate

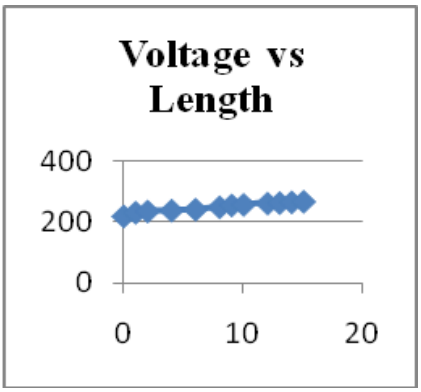

Figure 16: Current vs. Voltage of 10mm ms plate

The maximum consumption of current is 88.6 Amps, minimum consumption of current is 72.8 Amps and the mean consumption of current is 78.46 Amps. And the consumption is gradually reduced. The maximum consumption of Voltage is 268 Volts, minimum consumption of Voltage is 220 Volts and the mean consumption of Voltage is 249.41 Volts. And the consumption is increased gradually shown in Fig 17 & Fig 18.

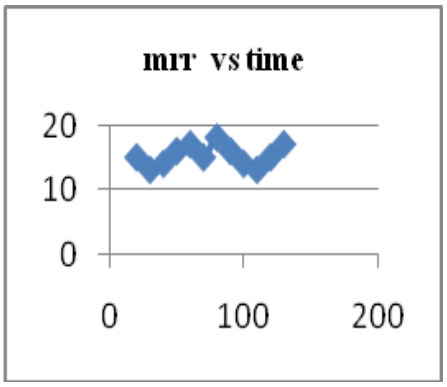

Fig 17: Material removal rate vs. time

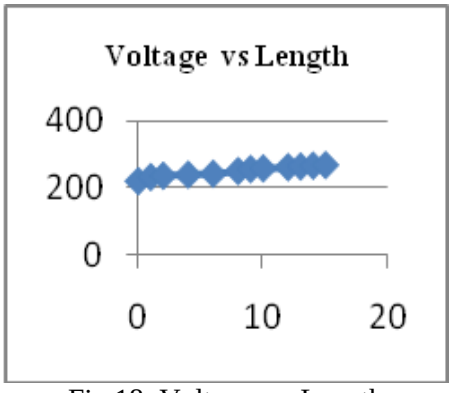

Fig 18: Voltage vs. Length

The maximum material removal rate (mrr) is observed at 80^{th} second and its value is 18.10 mm^3/s, minimum material removal rate (mrr) is observed at 30^{th} and 110^{th} second and its value is 13.20 mm^3/s.

And the mrr is zig-zag throughout the operation. And the cutting is took place linearly with time. Started from 0^{th} second to 130 seconds.

3.5 Finding the Hardness

Various hardness's are shown in Table 1.

TABLE 1
HARDNESS

Sl No	Plate	Location	Hardness Brinnell's
1	5mm MS	On cut	102
2	5mm MS	5mm away from cut	105
3	5mm MS	10mm away from cut	107
4	5mm MS	20mm away from cut	110
5	5mm MS	30mm away from cut	112
6	10mm MS	On cut	102
7	10mm MS	5mm away from cut	104
8	10mm MS	10mm away from cut	106
9	10mm MS	20mm away from cut	109
10	10mm MS	30mm away from cut	114
11	15mm MS	On cut	104
12	15mm MS	5mm away from cut	106
13	15mm MS	10mm away from cut	109
14	15mm MS	20mm away from cut	111
15	15mm MS	30mm away from cut	113
16	5mm SS	On cut	188
17	5mm SS	5mm away from cut	191
18	5mm SS	10mm away from cut	195
19	5mm SS	20mm away from cut	198
20	5mm SS	30mm away from cut	200

3.6 Surface Roughness Calculations

i. Root Mean Square Value Method
ii. Centre Line Average Method

The above said methods are in use for the measurements of the surface roughness and it is an indication for the process to check whether it is in the permissible limits or not. Based on the mean value that is calculated from the above said methods, complete roughness of the system can be computed.

$H_{r.m.s.}$ = sqrt ((h_1^2+ h_2^2+h_3^2+h_4^2+.....h_n^2)/n)

For 5mm ms plate:
The observations were made as follows: h1 = 1mm, h2=3mm, h3=2mm, h4=3mm, h5=3.5mm, h6=4mm, h5= 3.5mm, h6= 4mm, h7 3.5mm, h8=2mm, h9 = 3mm, h10= 2mm, h11=1.5mm, h12=2mm, h13=1.2mm, h14=2mm, h15=1mm and number of observations made= 15. By substituting these values in the above equation the hardness found is = 2.48mm

For 10mm ms plate:
The observations were made as follows: h1 = 2mm, h2=4mm, h3=1mm, h4=3mm, h5=2.5mm, h6=2mm, h5= 2.5mm, h6= 4mm, h7 2.5mm, h8=2mm, h9 = 3mm, h10= 3mm, h11=2.5mm, h12=2mm, h13=1.2mm, h14=2.5mm, h15=1.5mm and number of observations made= 15. By substituting these values in the above equation the hardness found is = 3.57mm

For 15mm ms plate:
The observations were made as follows: h1 = 2mm, h2=2.5mm, h3=3mm, h4=4mm, h5=2.5mm, h6=2.2mm, h5= 2.5mm, h6= 4mm, h7 3.5mm, h8=2mm, h9 = 3mm, h10= 3mm, h11=3.5mm, h12=3mm, h13=1.2mm, h14=1.5mm, h15=2.5mm and number of observations made= 15. By substituting these values in the above equation the hardness found is = 2.97mm

For 5mm ss plate:
The observations were made as follows: h1 = 3mm, h2=2.5mm, h3=2.5mm, h4=4mm, h5=3.5mm, h6=2.2mm, h5= 3.5mm, h6= 4mm, h7 3mm , h8=2mm, h9 = 2.5mm,h10= 3mm, h11=2.5mm, h12=3mm, h13=1.2mm, h14=1.5mm, h15=2.5mm and number of observations made= 15. By substituting these values in the above equation the hardness found is = 3.12mm

C.L.A =((h_1+h_2+h_3+h_4+h_5+.....h_n)/n)

For 5mm ms plate:
The observations were made as follows: h_1= 2.5mm, h_2=3mm, h_3=3mm, h_4=4mm, h_5=2.5mm, h_6=2.2mm, h_5= 2.5mm, h_6= 4mm, h_7=3.5mm , h8=2mm, h9 = 3.2mm,h10= 3mm, h11=3.5mm, h12=3mm, h13=1.2mm, h14=1.5mm, h15=2.5mm and number of observations made= 15. By substituting these values in the above equation the hardness found is = 2.41mm

For 10mm ms plate:
The observations were made as follows: h_1= 3.5mm, h_2=3.5mm, h_3=3mm, h_4=3.5mm, h_5=2.5mm, h_6=3.2mm, h_5= 3.5mm, h_6= 4mm, h_7=2.5mm , h8=2mm, h9 = 3.2mm,h10= 2mm, h11=3mm,

h12=3mm, h13=1.2mm, h14=1.5mm, h15=2.5mm and number of observations made= 15. By substituting these values in the above equation the hardness found is = 3.12mm

For 15mm ms plate:
The observations were made as follows: h_1= 3.5mm, h_2=3.5mm, h_3=3.2mm, h_4=4.5mm, h_5=2.5mm, h_6=2.2mm, h_5=4.5mm, h_6= 4mm, h_7=3.5mm , h8=2mm, h9 = 2.2mm,h10= 2mm, h11=3mm, h12=2.5mm, h13=1.2mm, h14=1.5mm, h15=2.5mm and number of observations made= 15. By substituting these values in the above equation the hardness found is = 3.22mm

For 5mm ss plate:
The observations were made as follows: h_1= 2.5mm, h_2=4.5mm, h_3=3mm, h_4=4mm, h_5=3.5mm, h_6=3.2mm, h_5=4mm, h_6= 3mm, h_7=3.5mm , h_8=2mm, h_9 = 2.2mm,h_{10}= 2.5mm, h11=3.5mm, h12=3.5mm, h13=1.2mm, h14=3.5mm, h15=3.5mm and number of observations made= 15. By substituting these values in the above equatAion the hardness found is = 3.35mm

3.7 Control Charts

Control charts were made for knowing the process weather it is in control or not. In this upper, lower and central lines were calculated. By comparing current data to these lines, one can draw conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation).

Control charts for variable data are used in pairs. The top chart monitors the average, or the centering of the distribution of data from the process. The bottom chart monitors the range, or the width of the distribution. If your data were shots in target practice, the average is where the shots are clustering, and the range is how tightly they are clustered. Control charts for attribute data are used singly.

3.7.1 Control charts for 5mm ms plate

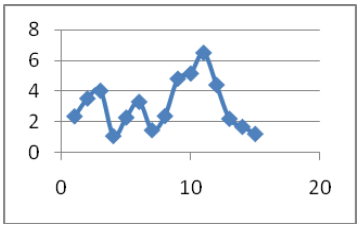

Figure 19: Control chart for 5mm MS plate

The process of making cut of this plate is went out of permissible roughness value and is slightly beyond the limits. For the above chart as the sample size taken is 15. The constants are A_2= 0.789, B_3=0.428, B_4=1.572.

10 mm ms plate
The process of making cut of this plate is went out of acceptable roughness value and is slightly beyond the limits. And compare with the 5mm ms rod this has a control over the process as the control limits have expanded.

15mm ms plate: slightly out of control limits

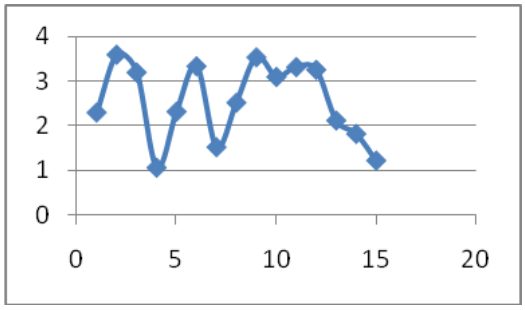

Figure 20: 15mm MS plate for control chart

The process of making cut of this plate is within the acceptable roughness value but to some places the values have gone below the lower control limit. Hence the process can to be improved further.

5mm ss plate: out of control limits

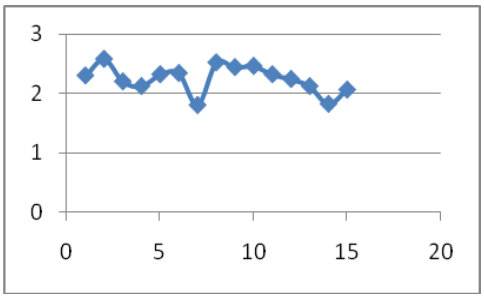

Figure 21: 5mm SS plate Control chart

The process is completely within the operational limits and yielded a good surface finish. This is a good sign for the further process to be carried out.

3.8 Material Removal Rate Calculations

The MRR calculations were made by the following assumptions:

The cutting is done in the form of cylindrical shape. That means the cutting torch is imposing its plasma in the cylindrical form, actually the shape is cone type but as the slant height and axis height for the penetration is same the cut part is taken as cylinder. Hence the volume of MRR is taken as the volume of cylinder. And for each step taken the MRR is calculated by measuring the radius of cut. And the height of the shape of cylinder is taken as the thickness of the plate. This is done for all the plates. The following table indicates the list of results that are came out from the work carried out.

And it also indicates the extreme values of the parameters that are observed. It can be observed from the table that voltage, current, resistance were changing based on the thickness of the work piece used.

In addition to that the roughness, hardness, material removal ate =, were tested at various locations and that values are also tabulated below.

4 Conclusion

Even though cutting process took place successfully, this process can be further improved in terms of following.

- Roughness reduction
- Reduction in Power Consumption
- Improvement of surface finish
- Improvement of Material Removal rate

All these are achievable if the process parameters are optimized; hence there is a lot of scope in this regard for further development and enrichment.

References

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