Parametric analysis of material removal rate(MRR) and surface roughness(Ra) on plasma cutting machine

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Project Background

- In last forty years there is tremendous research in machining and development in technology. With increase in competition in market and to attain high accuracy now a days the nonconventional machining are become lifeline of any industry.
- One of the most important non conventional machining methods is **Plasma Arc Machining**. Its high accuracy, finishing, ability of machining any hard materials and to produce intricate shape increases its demand in market.

Project objective

- “To study about the best combination of solution for maximizing the Material Removal Rate (MRR) and for minimizing the Surface Roughness (Ra)”

Definition of plasma

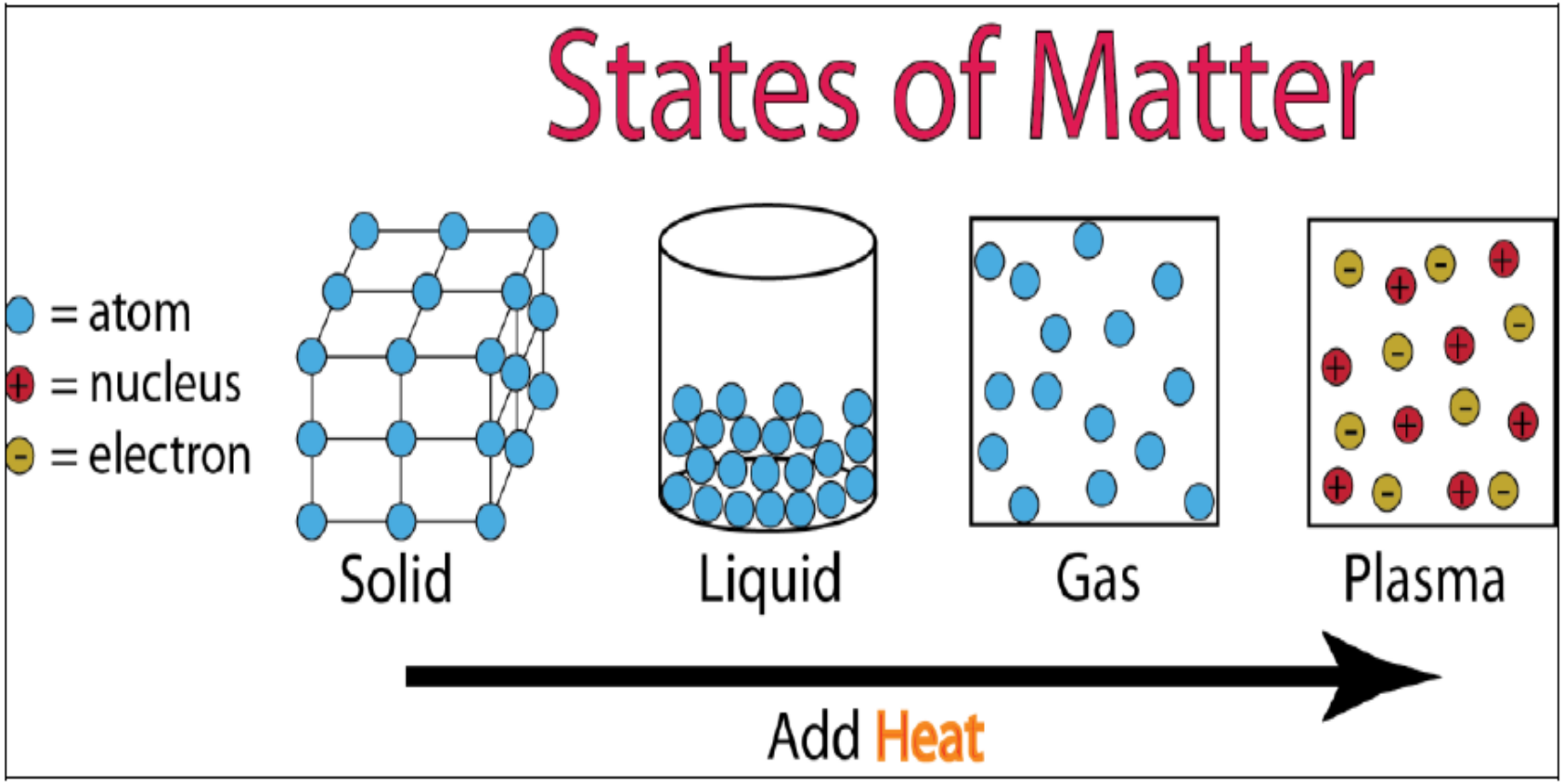
There are four states of matter

- solid
- liquid
- gas

and fourth is

- plasma

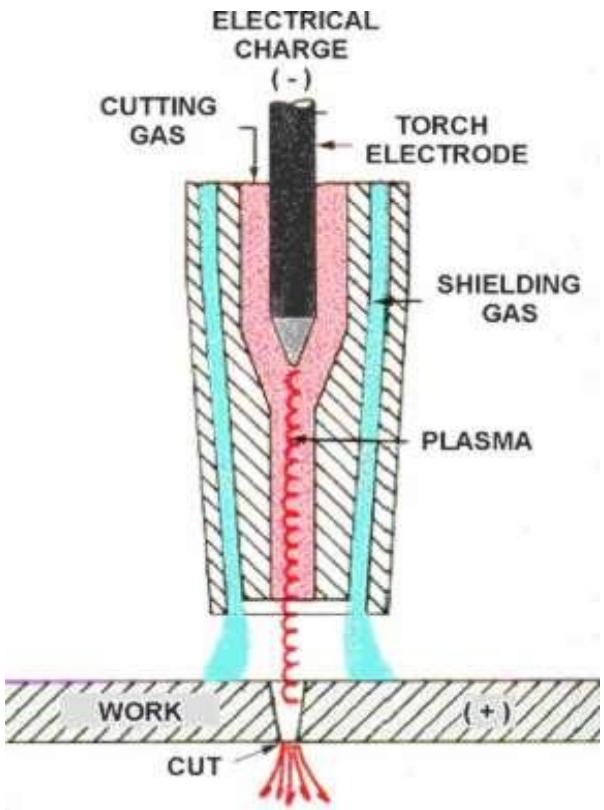
Definition of plasma



Definition of plasma

- Plasma is a high-temperature, electrically conductive gas, comprised of positively and negatively charged particles as well as excited and neutral atoms and molecules.

How plasma works?



- Plasma cutting is a process that is used to cut steel and other metals (or sometimes other materials) using a plasma torch.
- In this process, an inert gas (in some units, compressed air) is blown at high speed out of a nozzle, at the same time an electrical arc is formed through that gas from the nozzle to the surface being cut, turning some of that gas to plasma.

- The plasma is sufficiently hot to melt the metal being cut and moves sufficiently fast to blow molten metal away from the cut.
- Plasma can also be used for plasma arc welding and other applications.

Gases used in plasma

- **Primary Gases:**
  Gases that are used to create the plasma arc.

  Examples are nitrogen, argon, hydrogen, or mixture of them.

- **Secondary Gases or Water**:
  Surrounds the electric arc to aid in confining it and removing the molten material.

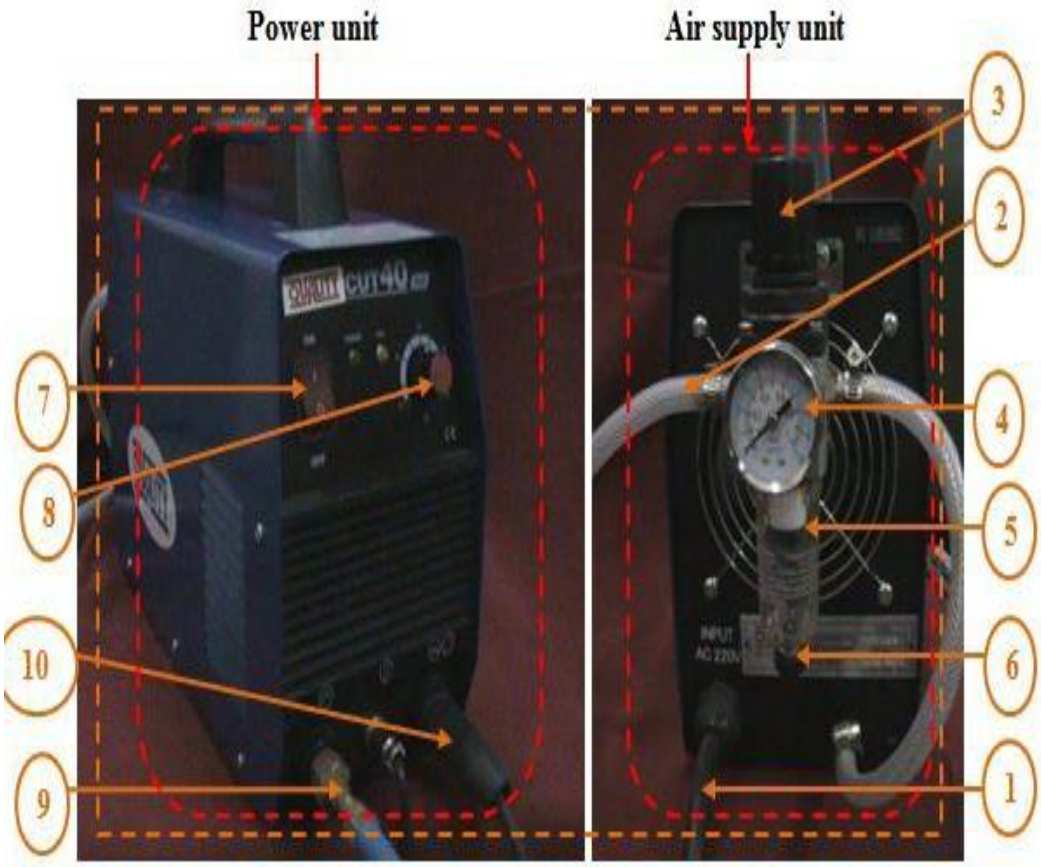
- We could carried out our experimental works on Quality CUT 40 air plasma cutting machine in M. S. University of Baroda under the guidance of Prof. A. B. Panday.

Technical specification

CUT 40 Air Plasma Machine	
Parameter	**Range**
Power voltage (v)	Single phase 220v ±15%
Rated input power (kva)	6.6
No load voltage (v)	230
Rated input current (A)	30
Rated output voltage (v)	96
Duty cycle	60%
Pilot arc model	HF oscillating
Burner inter diameter (mm)	1
Pressure of air (bar)	4-5
Thickness	1-12
Weight (kg)	9
Size (mm)	371 x 153 x 232

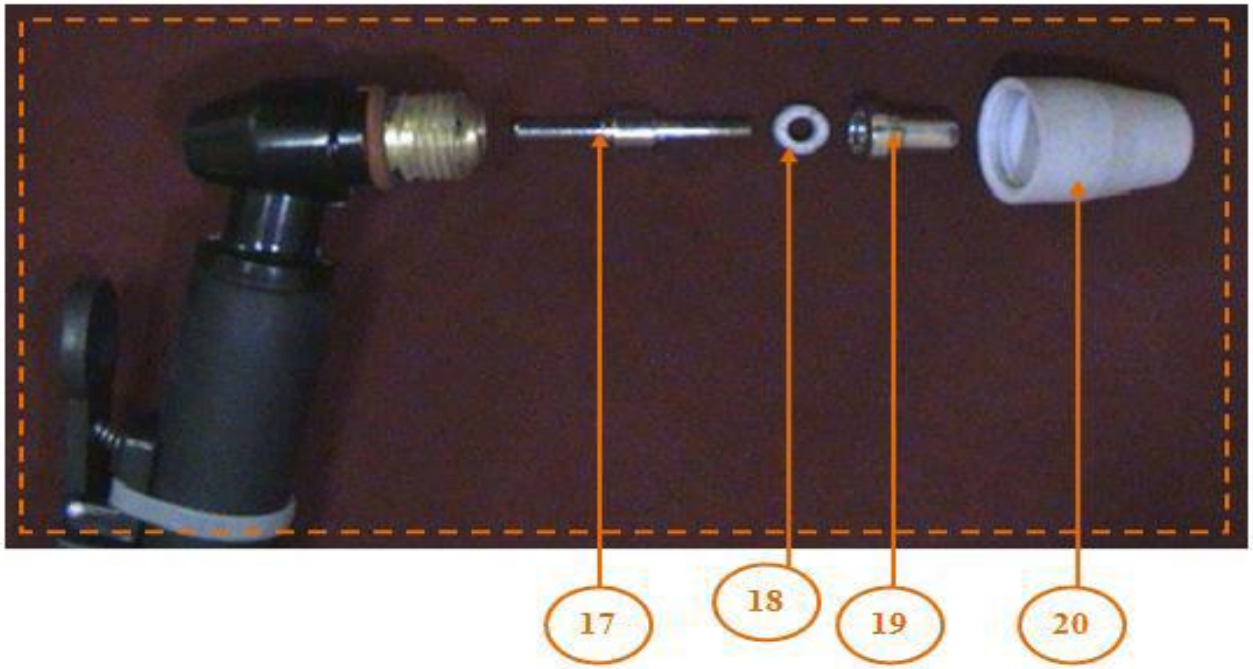
System Components

A. Power supply unit



1.Power cord
2.Compressed air inlet
3. Pressure control knob
4. Pressure gauge
5. Air dryer
6. Water drain
7. Main power switch
8. Current regulator knob
9. Torch cord
10. Ground cord

- **B. Tourch**



17. Electrode **18. Swirl ring**
19. Nozzle **20. Shield cap**

Experimental Setup

A. Ground Clamp
B. Work Stage
C. Torch head assembly
D. Work Piece

Literature Review

- It provides the scope for the present study. It works as guide to run this analysis.
- Literature review section works as reference, to give information and guidance based on journal and other source in the media.

Investigation of the effects of plasma arc parameters on the structure variation of AISI 304 and St 52 steels (Abdulkadir Gullu el.)(2005)	
Material used	AISI 304 stainless steel , St 52 carbon steel
Various Input parameters	Material thickness, voltage, cutting Speed, and current
Various output parameters	Improve hardness
Machine used	Plasma cutting machine
Cutting fluid	O_2, N_2
Analysis	Work by microstructure
Mathematical model	No

Experimental study of the features of the kerf generated by a 200A high tolerance plasma arc cutting system (R. Bini, B.M. Colosimo el.)(2007)

Material used	Mild Steel
Various Input parameters	Arc voltage , cutting speed, plasma gas flow rate, shield gas flow rate
Various output parameters	To reducing the cutting speed
Machine used	Plasma cutting machine
Cutting fluid	O_2, N_2
Analysis	ANOVA
Mathematical model	No

The influence of the laser and plasma traverse cutting speed process parameter (Daniel J. Thomas)(2011)

Material used	hot rolled steel
Various Input parameters	power, cutting speed, current
Various output parameters	Improving cutting speed
Machine used	PAC
Cutting fluid	O_2 and Air
Analysis	-
Mathematical model	No

Analysis of process parameters of plasma arc cutting using design of experiment(Vivek singh)(2011)

Material used	Stainless Steel
Various Input parameters	Gas pressure, Current flow rate, Cutting speed, Arc gap
Various output parameters	Material Removal Rate (MRR) Surface Roughness (Ra)
Machine used	Plasma cutting machine
Cutting fluid	02, N2
Analysis	ANOVA
Mathematical model	Yes

Material specification

- We can use the material of EN 31 Steel of size 150 mm x 80 mm x 6 mm in our experimental work. The material has medium- high carbon alloy steel which achieves a high degree of hardness with compressive strength and abrasion resistance.

- Chemical composition of EN 31 steel is shown in table below:

Element	Atomic Number	Wt.%
Carbon	6	1.07
Silicon	14	0.32
Manganese	25	0.58
Phosphorus	15	0.04
Sulfur	16	0.03
Cromium	24	1.12

Exploratory Result

(A) Dross formation at low speed

(B) Dross formation at high speed

Selection of orthogonal array and parameter assignment

- Base on exploratory results we find out three levels of different input parameters.

Factor	Level		
	Level 1	Level 2	Level 3
Air pressure(bar)	4	4.5	5
Current(A)	30	35	40
Speed(m/min)	0.26	0.34	0.43
SOD(mm)	3	3.7	4.5

Design of experiment

DOE helps in:

- Identifying relationships between cause and effect.
- Determining the levels at which to set the controllable factors (product dimension, alternative material, alternative designs, etc.) in order to optimize reliability.
- Minimizing experimental error (noise).
- Improving the robustness of the design or process to variation.

Designed experiments are usually carried out in five stages

- planning,
- screening,
- optimization,
- robustness testing and
- verification

Taguchi design of experiment

- Taguchi method provides a systemic and efficient approach for conducting experimentation to determine near optimum setting of design parameter for performance and cost.
- The present research, an L'27 Taguchi standard orthogonal array was selected for the design of experiments.
- Since the numbers of factors are four with three levels, therefore the most suitable Taguchi orthogonal array for the experiment was L'27 array.

Experimental Result

- In our experimental work for study of MRR and Surface roughness, the following results are summarized

Sr NO.	Air press.	Current	Speed	SOD	MRR	Ra
1	4	30	0.26	3	43.4782	1.9
2	4	30	0.26	3	23.8095	1.82
3	4	30	0.26	3	35.7142	4.07
4	4	35	0.34	3.7	53.5714	1.73
5	4	35	0.34	3.7	71.4285	2.96
6	4	35	0.34	3.7	51.7241	5.27
7	4	40	0.43	4.5	65.2173	2.18
8	4	40	0.43	4.5	41.6667	2.41
9	4	40	0.43	4.5	86.9565	2.11
10	4.5	30	0.34	4.5	51.7241	2.28
11	4.5	30	0.34	4.5	53.5714	1.98
12	4.5	30	0.34	4.5	71.4285	2.58
13	4.5	35	0.43	3	45.4545	1.82
14	4.5	35	0.43	3	65.2173	1.35

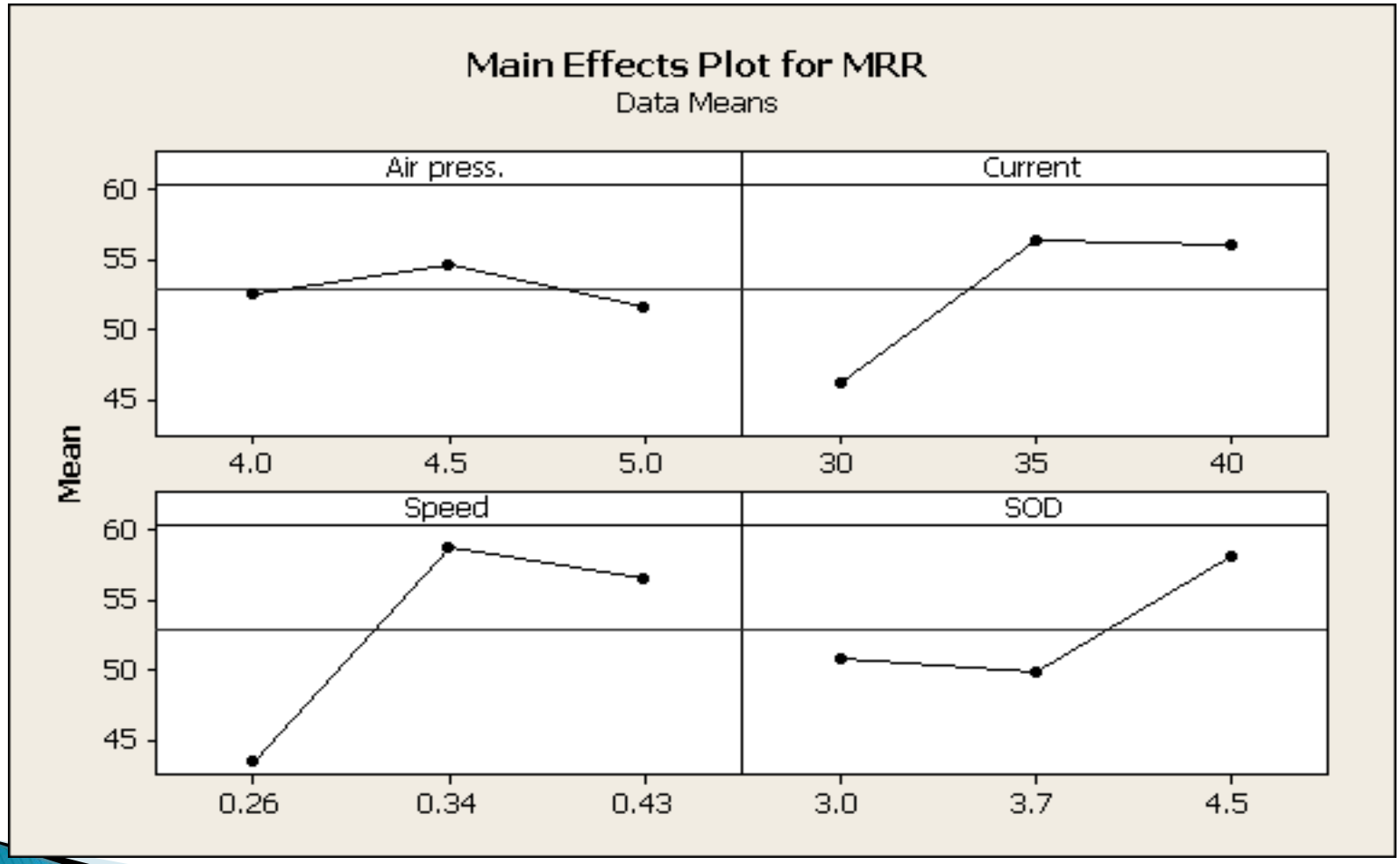
Sr NO.	Air press.	Current	Speed	SOD	MRR	Ra
15	4.5	35	0.43	3	68.1818	2.05
16	4.5	40	0.26	3.7	50	1.21
17	4.5	40	0.26	3.7	48.7804	0.99
18	4.5	40	0.26	3.7	36.5853	1.6
19	5	30	0.43	3.7	45.4545	2.38
20	5	30	0.43	3.7	45.4545	2.1
21	5	30	0.43	3.7	45.4545	4.5
22	5	35	0.26	4.5	47.619	5
23	5	35	0.26	4.5	46.5116	2.1
24	5	35	0.26	4.5	58.1395	1.25
25	5	40	0.34	3	48.387	5.53
26	5	40	0.34	3	62.5	1.52
27	5	40	0.34	3	64.5161	1.72

Anova anaylsis

- The purpose of the statistical analysis of variance (ANOVA) is to investigate which design parameter significantly affects the material removal rate(MRR) and surface roughness(Ra)

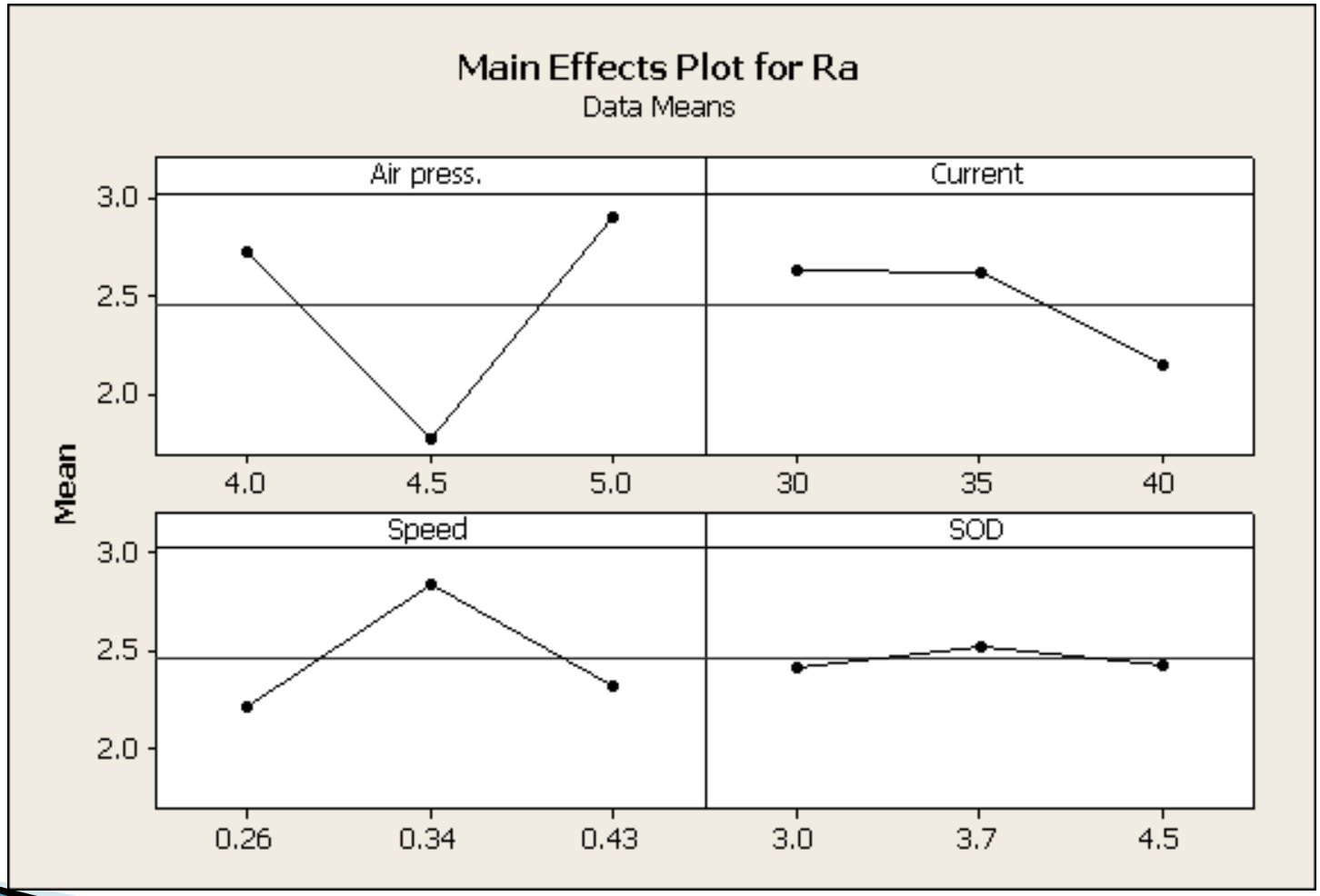
- ANOVA helps us to compare variabilities within experimental data

Main effect plot for MRR



- From above plot we conclude that MRR is increase with increase in Air pressure, cutting speed and current. while MRR is decrease with increase in stand off distance at mid point and then after MRR is decrease with increase in Air pressure, cutting speed and current. while MRR is increase with increase in stand off distance.

Main effect plot for Ra



- From above plot we conclude that surface roughness is increases with increase in cutting speed and stand off distance. while Ra is decreases with increase in air pressure and current. at mid point and then after Ra is decrease with increase in cutting speed and stand off distance. While Ra is increase with increase in Air pressure.

ANOVA table for MMR

Parameter	DF	Seq SS	Adj SS	Adj MS	Percentage contribution
Air Press.	2	41.4	41.4	20.7	0.90
Current	2	602.4	602.4	301.2	13.09
Speed	2	1241.4	1241.4	620.7	26.97
SOD	2	367.0	367.0	183.5	8.61
Error	18	2348.3	2348.3	130.5	50.40
Total	26	4600.6			100

ANOVA table for SR

Parameter	DF	Seq SS	Adj SS	Adj MS	Percentage contribution
Air press.	2	6.717	6.717	3.359	16.01
Current	2	1.370	1.370	0.685	3.26
Speed	2	2.016	2.016	1.008	4.80
SOD	2	0.061	0.061	0.031	0.146
Error	18	31.782	31.782	1.766	75.76
Total	26	41.947			100

Mathematical Modeling

- Regression analysis is a mathematical measure of the average relationship between two or more variables in terms of the original units of the data.
- In regression analysis there are two types of variables. The value whose value is influenced or is to be predicted is called *dependent variable* and the variable which influences the values or is to be used for prediction is called *independent variable.*

First order linear model for MRR

- The regression equation is
  - MRR = – 21.2 – 1.06 Air press. + 0.984 Current + 75.3 Speed + 4.99 SOD

- R-Sq = 31.1%

First order linear model for Ra

- The regression equation for SR (Ra) is:

  Ra = 3.13 + 0.183 Air press. – 0.0482 Current + 0.49 Speed + 0.005 SOD

- R-Sq = 2.9%

Conclusion

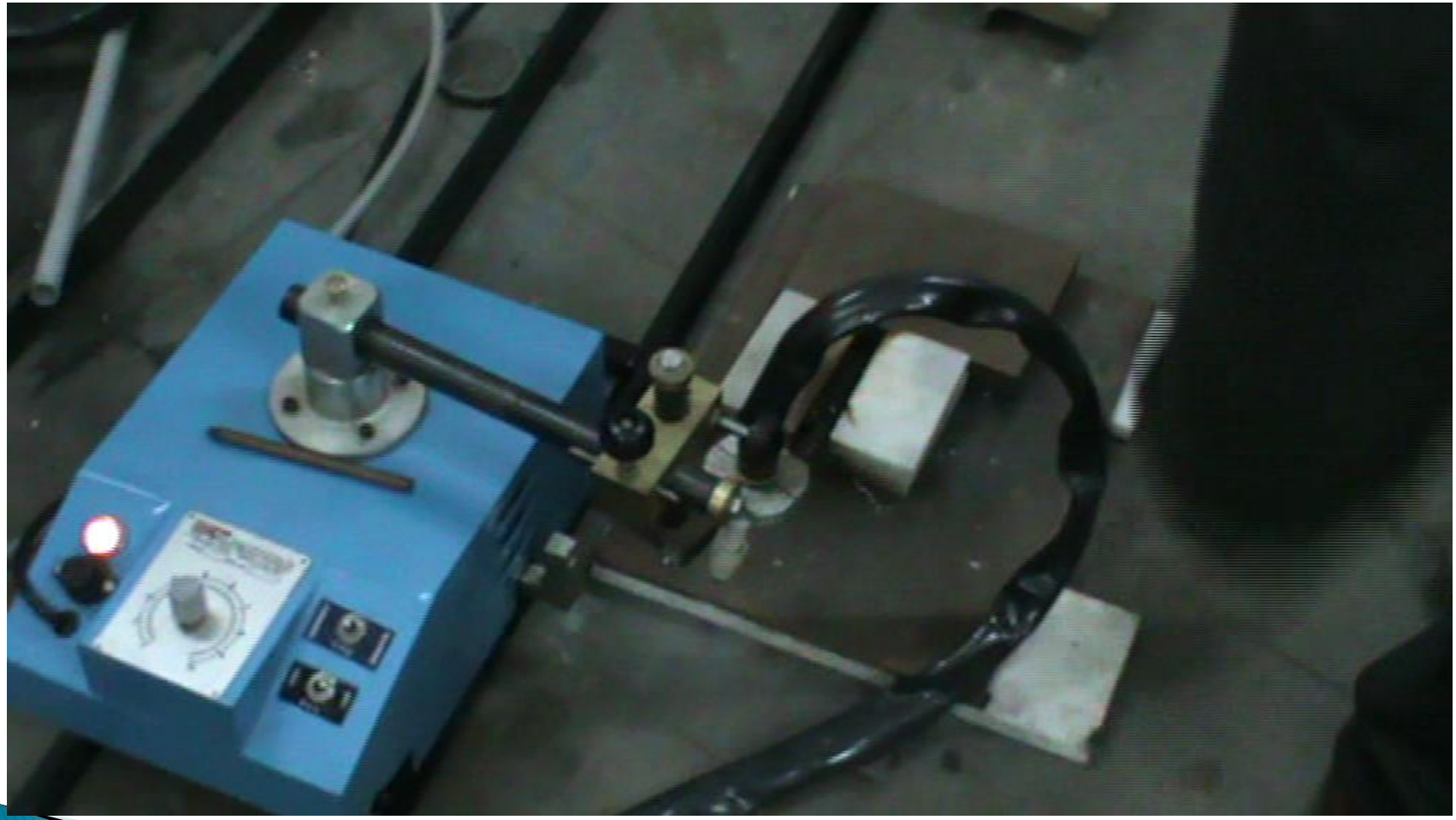
- From the exploratory experiment it was found that PAC for EN 31 material can be applied in the range of current between 30 A and 40 A. Current of 30 A is capable to melt the 6 mm thick metal plate, while 40 A current is maximum available range of plasma arc cutting machine used in this work. Also in case of pressure and stand-off distance a range of 4 bars to 5 bars and 3 mm to 4.5 mm range can be selected respectively. These combinations of stand-off distance and pressure can provide through cut with reasonable cut quality. While for cutting speed uniform levels cannot be selected for selected current range. Whereas, same range for pressure and stand-off distance can be adopted.

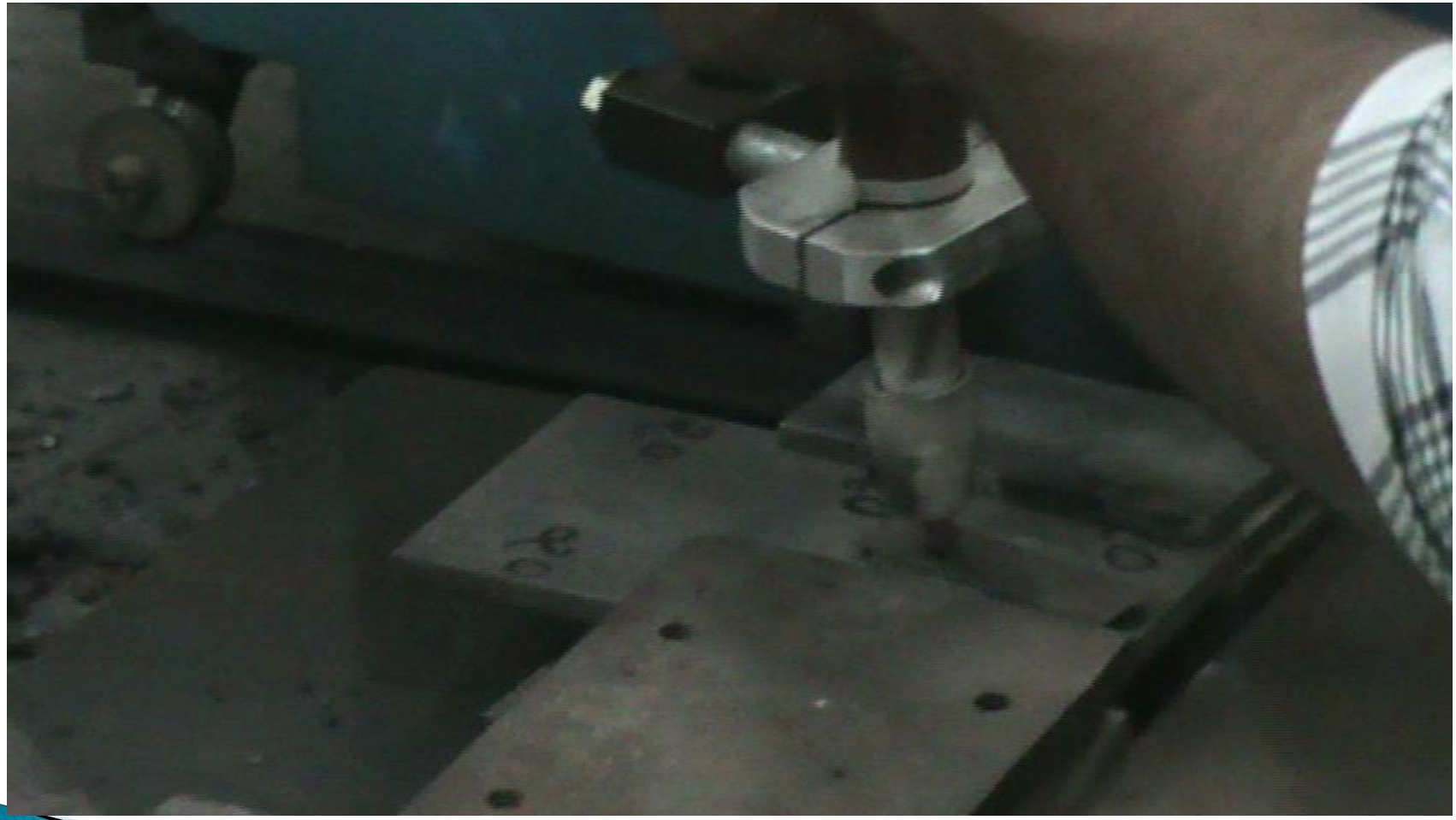
- Based on the experiments, the effect of selected input parameters on the output responses like material removal rate and surface roughness are studied.

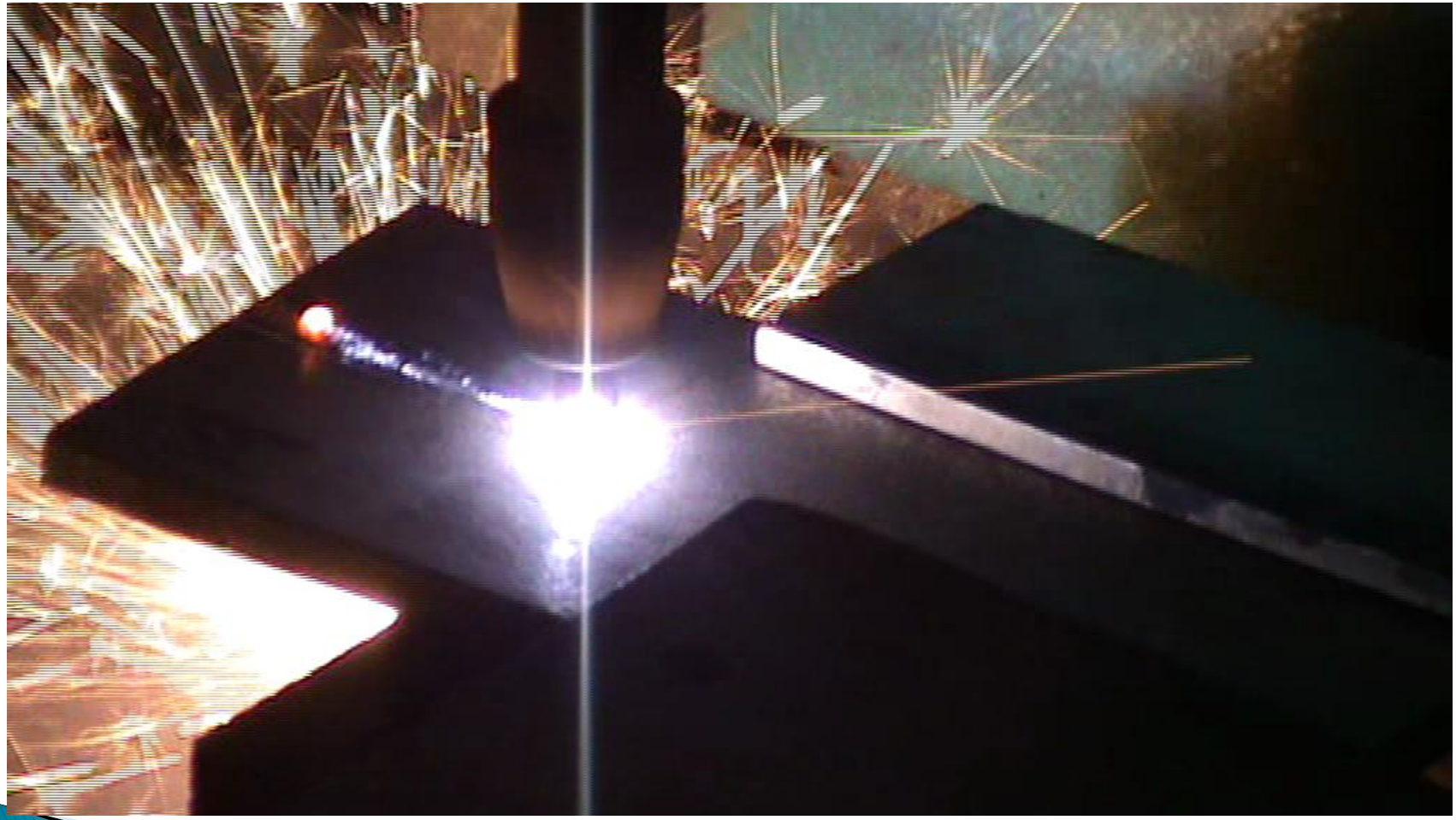
- From graphical representation and main effects plot for MRR the current and speed are most significant parameter followed by pressure and stand-off distance. With increase in current and speed MRR increases. While for air pressure slight increase and then decrease is observed in MRR and for stand-off distance the effect is reverse as compared to pressure.

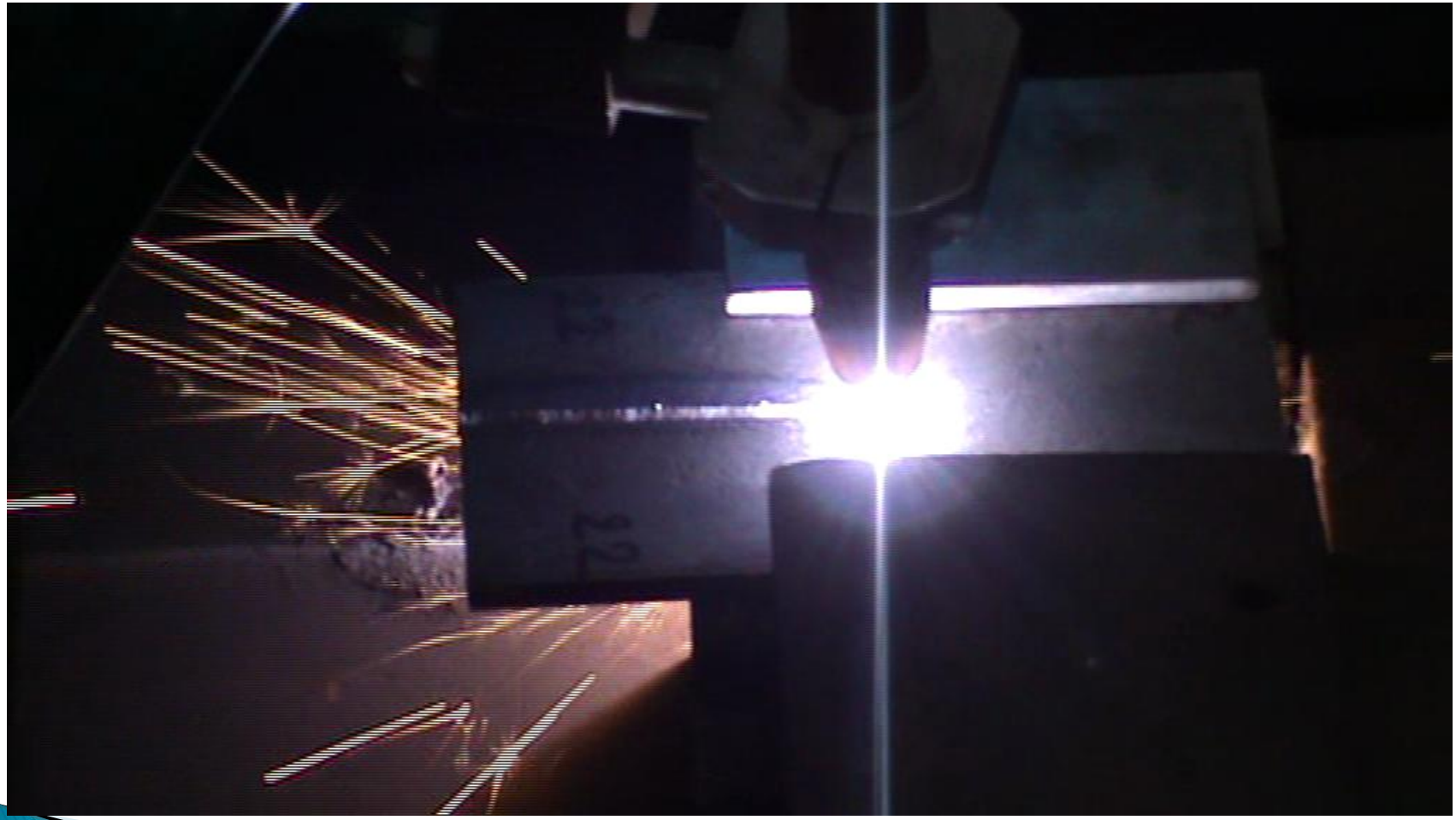
- From graphical representation and main effects plot for Ra the stand-off and speed are most significant parameter followed by pressure and current. With increase in stand-off distance and speed Ra increases. While for air pressure slight increase and then decrease is observed in Ra and for current the effect is reverse as compared to pressure.

During work photo graphs







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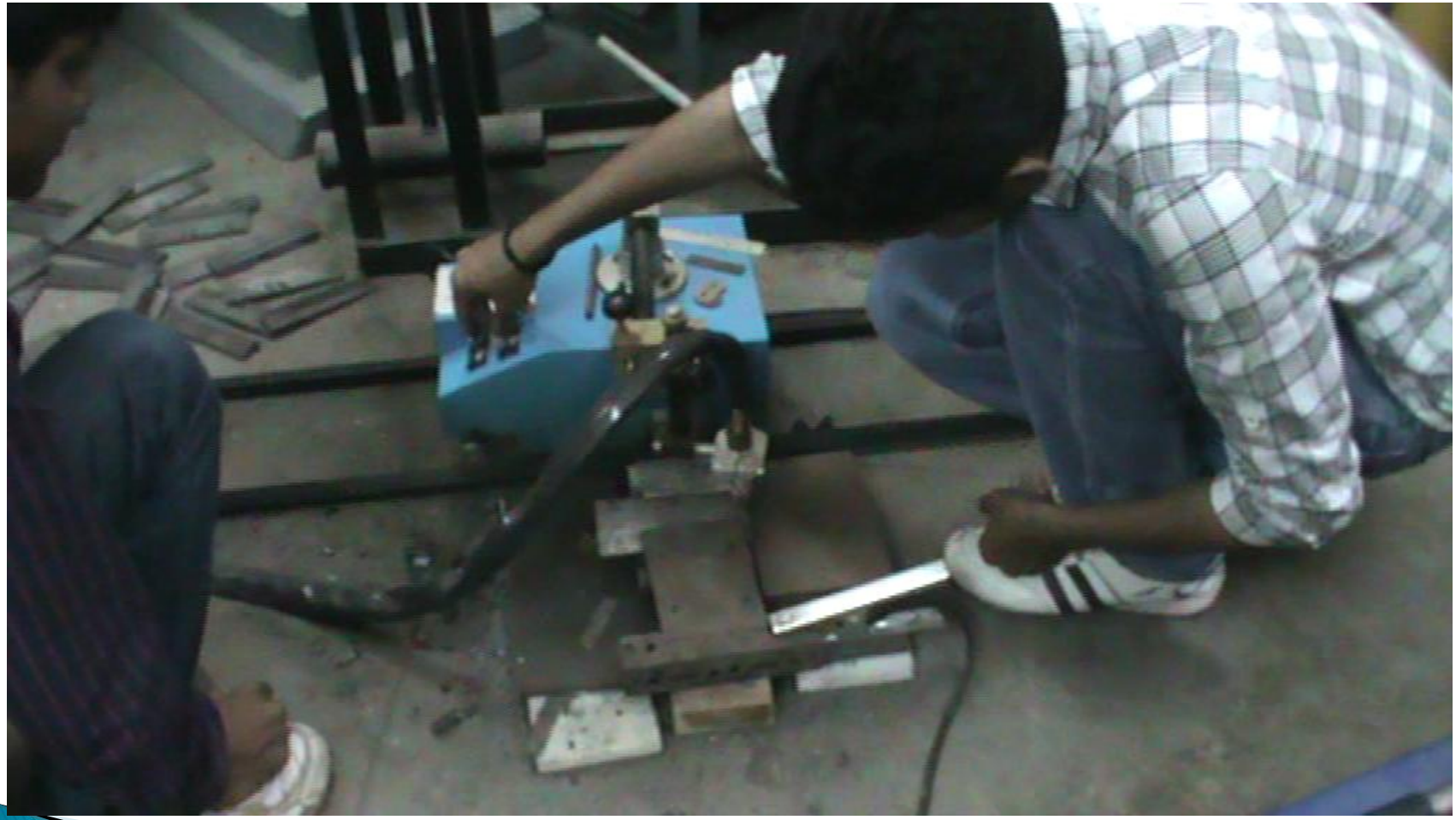

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Thank you