"OPTIMIZATION OF DESIGN PARAMETERS AND NOZZLE WEAR ON CNC PLASMA MACHINE BY EXPERIMENTATION"

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Abstract - *Recently there is consistent research in machining and advancement in innovation. With increment in rivalry in advertise and to accomplish high exactness now a day the non-traditional machining is moved toward becoming help of any industry. A standout amongst the most imperative non-customary machining strategies is CNC plasma Machining. Its high precision, completing, capacity of machining any hard materials and to create mind boggling shape builds its request in showcase. In proposal work writing has been examined in setting to parametric improvement of CNC plasma Machining. With a specific end goal to achieve target and ideal outcomes, after find the optimization parameter the moved towered the optimization in size (design parameters) and minimum wear of nozzle. The fitting orthogonal cluster has been chosen according to number of components and their levels to perform least experimentation. The work bits of mile Steel materials were utilized for explore reason. While optimizing a plasma arc cutting nozzle design parameters to minimize the wear, several but selective machine process parameters and nozzle design parameters given by the various stack holders. This experimentation includes the process parameters as specifications given by manufacturer, dimensional accuracy report, roughness parameters analysis, material removal rate analysis and n addition to this, nozzle design parameters after burning the nozzle as, nozzle shell diameter, nozzle length, nozzle inner shell center pin diameter etc. Experimentation and parameters analysis comes about are given to affirm the viability of this approach.*

Key Words: CNC Plasma, material removal rate, nozzle were, operating parameter, surface roughness etc.

1. INTRODUCTION

The topic for this thesis writing is to Analysis the Process Parameters of CNC Flame Cutting Using Design & Experiment Techniques. The focus on this project is to obtain an optimum condition (setting) to obtain mini MRR and minimum the surface roughness (SR)[1]. A person does not need to be a physicist & chemist to understand the CNC Flame Cutting and Gouging process. There are four states in which physical matter may be found solid, liquid, gas. Changes from one physical state to another occur due to, by supplying or subtracting energy, in the form of heat. Water can be used as an example of these four states of matter. In the solid state it is ice at temperatures of 0 degrees Celsius or colder. With the addition of heat, the ice melts and changes to water, the liquid state. The addition of more heat to temperatures of 212 degrees F. (100 degrees C.) or hotter) converts this liquid to its gaseous state, steam.

If you happen to be reading this by the light emitted by a fluorescent lamp you see flame in action. Flame of glowing tube contains sodium vapor or mercury. It is ionized by a high voltage across electrodes at the ends of the tube and conducts an electric current which causes the flame to radiate which in turn causes the phosphor coating on the inner surface of the tube to glow. For quick cutting of steel plate oxy-acetylene cutting process was preferred. From the last few years' plasma cutting has pretty much taken over, for some very good reasons to perhaps most importantly. The plasma cutting is electrically conductive process [14]. That means that one unit will cut steel, stainless steel, aluminum, copper, bronze, and brass etc.

1.1 Problem Statement

CNC Plasma Arc flame arc cutting can be characterized in terms of two distinct speeds. At cutting speeds on the top of, the flame jet does not track metal plate. At speeds below, the liquid metal to all-time low of the plate, forming the questionable dross and the way to properly choose a flame cutting system. The CNC Plasma Arc flame cutting process employs a flame torch with a very slender bore to produce a transferred arc to the work piece at a mean current density of within the bore of the torch[6]. The energy and momentum of the high-speed flame jet generated by the flame torch melts, vaporizes and removes the metal from the region of impingement of the nozzle. By using the CNC Plasma arc cutting it is required to find out the effective way to conduct the cutting process for mild steel; the most important factors that influence the cutting process and what are the best conditions to achieve optimum performances to design best specifications and minimum wear of nozzle.

2. PRINCIPLE OF PLASMA CUTTING

Plasma cutting are forms that utilization fuel gases and oxygen to cut metals, individually. French specialists Edmond Fouché and Charles Picard turned into the first to create oxygen-acetylene cutting in 1903[1]. Pure oxygen, rather than air, is utilized to expand the fire temperature to permit confined dissolving of the work piece material (e.g. steel) in a room situation. A typical propane/air fire consumes at around 2,250 K (1,980°C; 3,590 °F), a propane/oxygen fire consumes at around 2,526 K (2,253 °C; 4,087 °F) [3], and an acetylene/oxygen fire consumes at around 3,773 K (3,500 °C; 6,332 °F). Plasma is one of the most established cutting forms. Still utilized as a part of industry, in late decades it has been less broadly used in modern applications as other particularly conceived advances have been received.

It is still generally utilized for cutting metal plates and tubes, and in addition repairs work. It is likewise as often as possible appropriate, and supported, for manufacturing a few kinds of metal-based fine art. Also, Plasma has favorable position over electric cutting procedures in circumstances where getting to power (e.g., by means of an additional line or convenient generator would show challenges; it is more independent, and, henceforth, frequently more compact. In Plasma cutting, a light is utilized to warm metal to its fuel temperature. A surge of oxygen is then prepared on the metal, consuming it into a metal oxide that streams out of the kerf as slag.

3. EXCPERIMENTAL SET-UP

Figure No.: 3.1: Mass cutting machine
Source: Kalpak Industries, Ahmednagar 2019

3.1 Bed

It is heavy duty massive construction to provide stiffness to sustain large cutting dynamic force, load of other elements etc. It is made of high quality granite and it acts as foundation for all other parts of the machine.

3.2 Gas Bang

A 2-phase approach is developed to solve the tool magazine arrangement and operations sequencing related problems. By utilizing the benefits of tool sharing concepts, loading of duplicate tools, it will lead to decrease the tooling and operational cost.

While doing this the terms like tool magazine capacity, tool life and its availability are taken into consideration. This will be useful to avoid negative results. The proposed design approach will provide an effective decision making tool for the short term operational decisions of FMS.

3.3 Controller

The control panel is essential component or part of any CNC machine because it has various switches on it. That is used to control the various parameter of machine. By the control panel of CNC flame cutting machine we can control the nozzle movement, flame velocity, gas pressure, air gap as per our need, due to this various switches we can improve accuracy and also save our time.

3.4 Sample

Mild Steel material, four quantity samples, having 10 mm thickness and 200 mm x 200 mm size taken for the experiments.

4. METHODOLOGY

Minimum wear of nozzle is found out by the experimentation done on CNC Plasma arc cutting machine. To start the experimentation firstly optimization of CNC Plasma arc cutting machine design process parameters is done by experimentation analysis. Different machine manufacturers and nozzle suppliers suggest different operating parameters to be used on machine for cutting which leads more wear of nozzle. Hence by experimentation on the machine optimize process parameters and design parameters which gives best results with minimum wear of nozzle for different nozzles as: 1/16; 3/64; 1/32; 5/64.

5. USED MACHINE PARAMETERS SCENARIO

5.1 Operating Parameter used by Industry: (Kalpak Industries)

Sample No.	Cutting Speed (mm/min)	Oxygen Pressure (bar)	LPG Pressure (bar)	Air Gap (mm)
1	400	0.12	0.11	1.50
2	500	0.12	0.12	2.00
3	600	0.12	0.12	1.80
4	700	0.12	0.12	1.10

Table No.: 5.1: Operating Parameters used by Industry: (Kalpak Industries)

5.3 Operating Parameter taken by Nozzle Provider: (ESAB)

Sample No.	Cutting Speed (mm/min)	Oxygen Pressure (bar)	LPG Pressure (bar)	Air Gap (mm)
1	400	0.12	0.11	0.13
2	500	0.12	0.12	0.12
3	600	0.12	0.12	0.12
4	700	0.12	0.12	1.60

Table No.: 5.3: Operating Parameters used by Nozzle Provider: (ESAB)

5.2 Operating Parameters taken by Manufacture: (Mass cutting system machine)

Sample No.	Cutting Speed (mm/min)	Oxygen Pressure (bar)	LPG Pressure (bar)	Air Gap (mm)
1	400	0.10	0.11	1.20
2	500	0.12	0.12	1.50
3	600	0.13	0.12	1.60
4	700	0.12	0.12	1.80

Table No.: 5.2: Operating Parameters taken by Manufacture: (Mass cutting system machine)

5.4 Operating Parameter taken by R & D Department

Sample No.	Cutting Speed (mm/min)	Oxygen Pressure (bar)	LPG Pressure (bar)	Air Gap (mm)
1	400	0.12	0.11	1.2
2	500	0.20	0.12	1.2
3	600	0.11	0.12	1.3
4	700	0.10	0.12	1.2

Table No.: 5.4: Operating Parameters taken by R & D Department

5.5.1 Air Pressure: 110 bar,
5.5.2 Air Filter: 110 bar,
5.5.3 Cooling System: 180C,
5.5.4 Environmental Temperature: 220C,
5.5.5 Current: 227 V,
5.5.6 Vaccum Pressure: 110 bar,
5.5.7 Software: Turbonest,
5.5.8 Operating Language: Hyperthem,
5.5.9 Time required for cutting the sample as per program given from engineering department: 20 Minutes.

6. PARAMETER RESULT

6.1 Dimensional Analysis Report:

Reading No.	Sample 1	Sample 2	Sample 3	Sample 4
1	100.33	100.50	100.50	100.20
2	100.50	100.60	100.55	100.23
3	099.99	100.45	100.45	100.20
4	100.60	100.10	100.10	100.01
5	100.10	100.09	100.09	100.02
6	099.91	099.97	099.99	099.99
7	100.45	099.90	099.95	099.98
8	100.60	100.20	100.10	100.03
9	100.70	099.95	099.98	099.99
10	099.89	100.11	100.01	100.01
Mean	100.307	100.192	100.172	100.066

Table No.: 6.1: Dimensional Accuracy Readings

6.2 Roughness Parameters Report:

Roughness valve	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
Ra	0.040	0.039	0.030	0.025
Rz	0.020	0.021	0.025	0.020
Rq	0.030	0.026	0.020	0.020

Table No.: 6.2: Roughness Parameters Readings

6.3 Amount of Material Removed (gram):

Reading No.	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
1	0.040	0.037	0.028	0.020

Table No.: 6.3: Amount of Material Removed Reading

7. SIMULATIONS OF NOZZLE

7.1 Nozzle:

A nozzle is a pipe or tube of varying cross sectional area, and it modify the flow of a fluid, liquid or gas or it will also directs identical. Spouts square measure regularly won't to the board the speed of stream, speed, heading, mass, shape, and additionally the weight of the stream that rises up out of them. In a very nozzle, the speed of fluid will increase at the expense of its pressure energy. A gas jet, fluid jet, or hydro jet may be a nozzle meant to eject gas or fluid in a very coherent stream into a close medium. Gas jets square measure ordinarily found in gas stoves, ovens, or barbecues. Gas jets were ordinarily used for lightweight before the event of electrical lightweight. Alternative varieties of fluid jets square measure found in carburetors, wherever swish graduated orifices square measure wont to regulate the flow of fuel into associate degree engine, and in Jacuzzis or spas. Another specialised jet is that the bedded jet. This is often a water jet that contains devices to free the pressure and flow, and offers streamline flow, as its name suggests. This offers higher results for fountains. The froth jet is another variety of jet that uses foam rather than a gas or fluid.

Nozzles used for feeding hot blast into a furnace or forge square measure referred to as tubers. Jet nozzles also are employed in giant rooms wherever the distribution of air via ceiling diffusers isn't doable or not sensible. Diffusers that use jet nozzles square measure referred to as jet diffuser wherever it'll be organized within the facet wall areas so as to distribute air. Once the temperature distinction between the availability air and therefore the area air changes, the availability air stream is deflected upwards, to produce heat air, or down, to produce cold air.

7.2 Sample

Mild Steel material, four quantity samples, having 10 mm thickness and 200 mm x 200 mm size taken for the experiments.

7.3 Machine Parameters:

7.3.1 Operating Parameters (Optimized) Used for Optimization of Nozzle Design Parameters as:

Sample No.	Cutting Speed (mm/min)	Oxygen Pressure (bar)	LPG Pressure (bar)	Air Gap (mm)
4	700	0.12	0.12	1.1

Table No.: 7.3.1: Optimized operating parameters used

7.4 Nozzle Sample Details

The material selected as MS for NOZZLE is EN47. The material properties for design are listed in Table No.: VII.IV. Plain carbon steel, chromium vanadium steel, chromium-Nickel-Molybdenum steel, Silicon manganese steel, are the typical materials that are used in the design of Nozzle as shown in Figure No.: 7.4.1.

Parameters	Values
Material selected as MS	En47
Tensile strength	210GPA
Yield strength	1158MPA
Young's modulus(E)	1034MPA
Poisson ratio	0266
Density	7700 kg/mm^3

Table No.: 7.4 - Properties of Nozzle.

Figure No.: 7.4.1 - Nozzle details & assembly

6.1 Dimensional Analysis Report:

Reading No.	Sample 1	Sample 2	Sample 3	Sample 4
1	100.33	100.50	100.50	100.20
2	100.50	100.60	100.55	100.23
3	099.99	100.45	100.45	100.20
4	100.60	100.10	100.10	100.01
5	100.10	100.09	100.09	100.02
6	099.91	099.97	099.99	099.99
7	100.45	099.90	099.95	099.98
8	100.60	100.20	100.10	100.03
9	100.70	099.95	099.98	099.99
10	099.89	100.11	100.01	100.01
Mean	100.307	100.192	100.172	100.066

Table No.: VI.I: Dimensional Accuracy Readings

Nozzle Size: 1/16				
Sr. No.	Plate Thickness mm	Acetylene Pressure (bar)	Propane Pressure (bar)	Oxygen Pressure (bar)
1	06-10	0.20	1.50	1.50
2	11-15	0.21	1.60	1.40
3	16-20	0.22	1.70	1.30

Table No.: 7.5.1 – Design parameters for nozzle size 1/16

Nozzle Size: 1/32				
Sr. No.	Plate Thickness mm	Acetylene Pressure (bar)	Propane Pressure (bar)	Oxygen Pressure (bar)
1	06-10	0.20	1.50	1.50
2	11-15	0.21	1.60	1.40
3	16-20	0.22	1.70	1.30

Table No.: 7.5.3 – Design parameters for nozzle size 1/32

Nozzle Size: 3/64				
Sr. No.	Plate Thickness mm	Acetylene Pressure (bar)	Propane Pressure (bar)	Oxygen Pressure (bar)
1	06-10	0.20	1.50	1.50
2	11-15	0.21	1.60	1.40
3	16-20	0.22	1.70	1.30

Table No.: 7.5.2 – Design parameters for nozzle size 3/64

Nozzle Size: 5/64				
Sr. No.	Plate Thickness mm	Acetylene Pressure (bar)	Propane Pressure (bar)	Oxygen Pressure (bar)
1	06-10	0.20	1.50	1.50
2	11-15	0.21	1.60	1.40
3	16-20	0.22	1.70	1.30

Table No.: 7.5.4 – Design parameters for nozzle size 5/64

8. NOZZLE RESULT ANALYSIS

8.1 Nozzle Design Parameters:

Various nozzle parameters are available based on the nozzle size and plate thickness as given in the Table No.: 7.5.1, 7.5.2, 7.5.3 and Table No.: 7.5.4. However 10mm thick mild steel plate is taken for experimentation hence corresponding nozzle parameters taken as given below in Table No.: 8.1:

Design Parameters	Optimized Parameters (Process /CNC)	Nozzle No. 1 (1/16)	Nozzle No. 2 (3/64)	Nozzle No. 3 (1/32)	Nozzle No. 4 (5/64)
Plate Thickness (mm)	10	10	10	10	10
Cutting Speed (mm/min)	700	700	700	700	700
Acetylene Pressure (bar)	0.2	0.2	0.2	0.2	0.2
Oxygen Pressure (bar)	0.12	1.5	1.5	1.5	1.5
Propane Pressure (bar)	0.12	1.5	1.5	1.5	1.5
Air Gap (mm)	1.1	1.1	1.1	1.1	1.1

Table No.: 8.1 – Nozzle results analysis

9. NOZZLE RESULT ANALYSIS

9.1 Dimensional Analysis Report:

Reading No.	Sample 1	Sample 2	Sample 3	Sample 4
1	100.21	100.10	100.40	100.21
2	100.49	100.09	100.45	100.19
3	099.97	100.06	100.42	100.18
4	100.62	100.01	100.38	100.16
5	100.11	100.09	100.21	100.01
6	099.93	099.99	100.05	099.99
7	100.47	099.99	099.99	099.98
8	100.61	100.01	100.10	100.02
9	100.71	099.99	099.99	099.99
10	099.88	100.01	100.03	100.02
Mean	100.300	100.034	100.200	100.076

Table No.: 9.1: Dimensional Accuracy Readings

9.2 Roughness Parameters Report:

Roughness valve	1st Sample	2nd Sample	3rd Sample	4th Sample
Ra	0.020	0.008	0.030	0.021
Rz	0.019	0.009	0.025	0.020
Rq	0.030	0.021	0.026	0.029

Table No.: 9.2: Dimensional accuracy readings

9.4 Nozzle shell diameter: (Dia. 6mm)

Sample No.	1st Sample	2nd Sample	3rd Sample	4th Sample
Diameter after burning	6.12	6.04	6.16	6.14

Table No.: 9.4: Nozzle shell diameter readings

9.5 Nozzle length after burning: (Length 62.5mm)

Sample No.	1st Sample	2nd Sample	3rd Sample	4th Sample
Diameter after burning	62.44	62.48	62.41	62.46

Table No.: 9.5: Nozzle length after burning readings

9.6 Nozzle inner shell center pin diameter: (Diameter. 0.90mm)

Sample No.	1st Sample	2nd Sample	3rd Sample	4th Sample
Diameter after burning	0.91	0.90	0.91	0.92

Table No.: 9.6: Nozzle Inner shell centre pin diameter readings

9.3 Amount of Material Removed (gram):

Sample No.	1st Sample	2nd Sample	3rd Sample	4th Sample
Amount of Material removed	0.032	0.019	0.026	0.029

Table No.: 9.3: Amount of material removed readings

10. RESULT ANALYSIS AND DISCUSSION

Nozzle Size	Dimensional Analysis (Mean)	Roughness Parameters	Amount of Material Removed (gram)	Nozzle shell diameter: (6mm)	Nozzle length after burning: (Length 62.5mm)	Nozzle inner shell centre pin diameter: (Dia. 0.90mm)
1/ 16	100.300	Ra-0.020, Rz-0.019, Rq-0.030	0.032	6.12	62.44	0.91
3/ 64	100.034	Ra-0.008, Rz-0.009, Rq-0.021	0.019	6.04	62.48	0.90
1/ 32	100.200	Ra-0.030, Rz-0.025, Rq-0.026	0.026	6.16	62.41	0.91
5/ 64	100.076	Ra-0.021, Rz-0.020, Rq-0.029	0.029	6.14	62.46	0.92

Table No.: 10: Nozzle design parameters result summery

From the experimentation analysis done on PLASMA arc cutting machine as shown in Figure No.: III.I, with sample nozzles as given in Table No.: X, for dimensional accuracy as given in Table No.: IX.I, roughness parameters as given in Table No.: IX.II, amount of material removed as given in Table No.: IX.III, nozzle shell diameter as given in Table No.: IX.IV, nozzle length after burning as given in Table No.: IX.V and nozzle inner shell centre pin diameter as shown in Table No.: IX.VI is conducted. The above experimentation analysis concludes the 3/64 type nozzle as shown in Figure No.: VII.IV.I, gives the best results in all respect.

11. CONCLUSIONS

Literature survey on method parameters of plasma arc cutting has been studied and Experimental work has been administrated. From that it is concluded that:

1) MRR and surface roughness values are affected by cutting parameters such as Gas pressure and maintained arc gap as shown in Table No.: 6.2, 6.3, 9.2 and Table No.: 9.3.

2) There are different operating parameters suggested by Kalpak industry, Nozzle provider (ESAB), Mass cutting machine provider, operating parameters taken by operator and company expert as per expertise (R & D) as given in Table No: 5.1, 5.2, 5.3 and Table No.: 5.4. So among these parameters advised for right parameters selection as given in Table No.: 7.3.1.

3) From Dimensional analysis it is concluded that after cutting, sample width varies at different sections as given in Table No.: 6.1 and Table No.: 9.1.

4) Material removal rate is higher while amount of material removed is less.

5) As the Material removal rate increases the time required to cut the part is less.

6) The surface roughness is having lower value resulting surface finish of part is good that reduces the cost of after processing operations.

6) In nozzle wear analysis found that the 3/64 type nozzle is the best for all results as shown in Table No.: 10.

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BIOGRAPHIES

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