Experimental and Optimization of Parameters on Laser Beam Machining to Minimize Kerf, Surface Roughness and Dross of SS304.

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ABSTRACT

In conventional machining on laser beam machine, the kerf taper is sizeable and surface roughness isn't uniform and optimum due to this the quality of workpiece may get affected, which hampered assembly of finished parts. Here we have a tendency to defines there happens a amendment in mathematical values of kerf taper, Kerf width and surface roughness, whereas conducting tests on SS-304 Stainless steel using Nitrogen as assistance gas of CO_2 *laser cutting. To decide the laser cutting parameter specification so as to widen the material removal rate while at the same time in view of practical process limitation related to dross formation, The laser kerf width and cut edges quality was affect by the process parameters like cutting speed (V), Assist gas pressure level (p) and laser power (P). The experiment was set up and followed on the support of orthogonal array. A prognostic model is create by make use of response surface methodology via ANOVA and and enforced to search out relative influence of process parameters on kerf geometry and surface roughness.*

Key words: *CO2 Laser cutting, Kerf Geometry, Laser cutting parameters and Dross*

Introduction:

Laser cutting is a thermal radiation based advanced machining method in which material is removed by concentrating the laser beam on the work piece plane. Relying on the prevailing state, the material may be removed by various mechanisms like fusion, reactive fusion, ablation, vaporization and controlled fracture [11]. Laser cutting finds several applications in several manufacturing industries, where a range of components in large numbers are needed to be machined with top quality and adjacent tolerance at low prices.

AISI 304 stainless steel is wide utilized in industrial implementation. It has captured approximately half of the world's stainless steel manufacturing and consumption. As of its aesthetic perspective in architectures, high mechanical strength, corrosion and chemical resistance, it has become the favorable engineering material.

LASER is a concise for Light Amplification by Stimulated Emission of Radiation. The foremost vital applications of laser are laser cutting. The machining of difficult-to-cut materials by traditional material removal processes causes less material removal rate, high surface roughness and shorter tool life. Laser cutting is the machining processes demand a laser beam as a heat source. It's a non-contact method, that doesn't involve any mechanical cutting forces and tool wear. During this method, the substrate material is domestically heated by the targeted laser supply. The molten is then blown out of the matter with the assistance of assist gas that flows throughout the material with the help of laser beam. In metal cutting operations, oxygen or nitrogen is employed. [13]

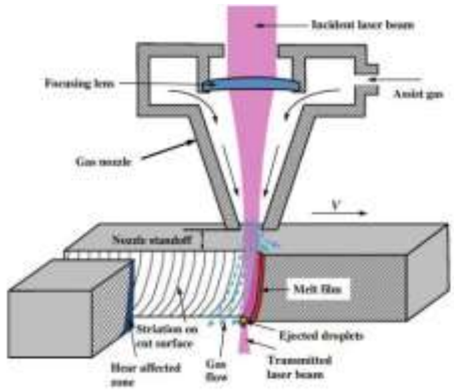

Figure 1.1: Laser Beam Cutting Process [12]

Figure 1 shows a schematic diagram of a laser cutting method. It's discovered that the surface quality within the laser cutting depends on several method parameters as well as laser power, cutting speed, gas pressure, beam diameter, beam incident angle, stand-off distance, pulse frequency and focus positions.

1.1 Laser:

Laser could be a coherent and amplified beam of electromagnetic wave. The key component in creating a sensible laser is the light amplification achieved by restorative emission because of incident photons of high energy.

Types of Laser:

Lasers have two sorts, i.e. solid laser and gas laser. These are often of periodical or of continuous type:

- **Solid Lasers**

Solid state lasers (e.g. ruby and Nd: glass), work below 1 ~ 2 Hz frequency and are worn only for low pulse implementation such as spot welding, drilling, etc.

- **Gas Lasers**

CO_2 lasers release light with a wavelength of 10.6 μm and possess overall effectiveness of approx. CO_2 lasers are continuously utilize a gas mixture to get the laser beam. This laser gas mixture always include of helium, nitrogen, CO_2 and perhaps other supplements.

Types of Laser Cutting:

In laser cutting, there are three kinds of the methods

- Oxygen laser cutting
- Fusion laser cutting
- Evaporative laser cutting

Oxygen Laser Cutting: The laser beam heats the workpiece to flaming temperature. The oxygen inoculates into the kerf burns the workpiece and removes the slag formed. The combustion method generates extra energy. With the standard of the cut being endlessly high, a definite association between the purity of the oxygen and the highly possible cutting speed can be show.

Fusion Laser Cutting: The material gets combine in the traverse point by laser radiation. The melt is removed from the kerf by a still gas. Aggressive fusion laser cutting is proving to be increasingly in oxide-free cutting of unstained steels. It's employed in cutting delicate steels and Al. Nitrogen is used as the machining gas. The cutting gas pressure level at the cutting nozzle may be 20 bar or lot of.

Evaporative Laser Cutting: The substance to be cut is vaporized at the traversing point of the laser beam. An inert gas, e.g., nitrogen or argon, remove the outgrowths from the kerf. This cutting method is employed with materials that don't have any liquid section or soften, as is that the case with paper, wood, many artificial materials or plastics, textiles, and ceramics.

CO_2 lasers have tried appropriate tools for quick 2-D laser cutting of skinny sheets because of their smart focus ability and high laser beam performances. [12]

Laser Beam parameters and Cutting Process parameters:

A) Laser Beam parameters

1. **Wavelength: -** The wavelength depends on stirred emission with relevance the physical mechanisms involves in energy coupling and the process effectiveness, stability and quality, the wavelength plays a big role
2. **Power, intensity and spot size: -** Power of laser decides its size. The power of laser system is the total energy release in the form of laser light per second. The intensity of the laser beam is the power separated by the beam focused space. Spot size is that the irradiated space of laser beam.
3. **Continuous wave and pulsed laser power:-**Both the continual wave and pulsed laser power can do the high intensity required for laser cutting.

B) Cutting Process parameters

1. Focusing of Laser Beams: - The focal distance of lens is regarding the gap from the position of focal lens to the focal spot.

2. Focal Position: - The centre of attention position should be controlled so as to urge optimum cutting result.

3. Process Gas and Pressure: - The unremarkably used gases are the oxygen and nitrogen. Nitrogen is principally used for pure steel and aluminum, whereas the oxygen is employed for mild steel. Once cutting thick material, the gas pressure level should decrease with the swell in thickness, so as to avoid the burning result, whereas the nozzle diameter is inflated.

4. Nozzle Diameter, Stand-Off Distance: - Assisting gas is bringing through the nozzle. To reduce turbulence weld material stand-off distance is unbroken between 0.5 mm to 1.5 mm which is distance between nozzle and material.

5. Cutting Speed: - The cutting speed should be balanced with the gas flow and therefore the power. As cutting speed will increase, it reduces the flow of excess heat through the matter reducing the HAZ. [7]

1.2 Response parameters:

1) Surface roughness (Ra)

It is a element of surface texture. It's qualified by vertical deviations of the important surface from its ideal type.
The unit is micrometer.

2) Kerf taper (Kf)

Kerf taper is special and unenviable geometrical feature inherent to laser beam machine. It's the angle that ranges from 0.1° to 2˚ in traditional condition and measured in degree.

3) Dross (Br)

Dross is residual soften that remains connected to the face of the cut edge when the cutting operation is complete. With some beam/materials merger (eg CO_2 laser cutting steels) dross is insignificant. But dross may be a retardant once when cutting thicker section steels.

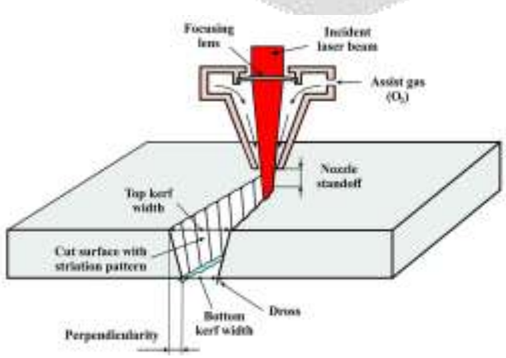

Figure 1.2 Response Parameter Considered in the Formulation of the Optimization Problem [15]

1.3 Objectives:

A. To minimize the kerf taper and kerf width in Laser Beam Cutting.
B. To optimize and reduce surface roughness.
C. To reduce the dross formation during the machining process (Laser Beam Cutting).

2. Material and Methodology:

2.1 Material:

SS 304 is that the common place stainless; it's the foremost versatile and most generally used stainless steel, accessible in an exceedingly wider varies of product, forms and finishes than the other. It's glorious forming and fastening characteristics. The steady austenitic structure of SS 304 permits it to be severely deep drawn while not intermediate tempering, that has created this grade dominant within the manufacture of drawn untainted elements like sinks, hollow-ware and saucepans. For these applications it's common to use special "304DDQ" (Deep Drawing Quality) variants. SS 304 is quickly brake or roll shaped into a range of elements for applications within the industrial, discipline and transportation fields. SS 304 additionally has outstanding fastening characteristics. Post

weld tempering isn't needed once fastening skinny sections. The austenitic structure additionally provides these grades wonderful toughness, even all the way down to cold temperatures.

Typical Chemical Composition of SS 304:

Table No. 1.1: Chemical Composition of SS 304[14]

Grade/ Thickness	%	C	Mn	Si	P	S	Cr	Ni	Fe
304/ Gen	Standard	0.08	2.0	1	0.045	0.03	20.0	10.5	74
304/ 1mm	Standard	0.07	2.0	0.75	0.045	0.03	19.50	10.5	74
	Observation	0.027	1.47	0.45	0.019	0.001	18.63	8.67	66.345
304/ 3mm	Standard	0.07	2.0	0.75	0.045	0.03	19.50	10.5	74
	Observation	0.05	1.60	0.73	0.019	0.025	19.40	8.45	66.345
304/ 6mm	Standard	0.07	2.0	0.75	0.045	0.03	19.50	10.5	74
	Observation	0.05	1.41	0.33	0.036	0.009	19.15	8.45	66.345
304/ 8mm	Standard	0.07	2.0	0.75	0.045	0.03	19.50	10.5	74
	Observation	0.049	1.42	0.29	0.030	0.009	19.12	8.42	66.345

Mechanical Properties:

Table No. 1.2: Mechanical Properties of SS 304 [14]

Grade/ Thickness	Range	Tensile Strength (Mpa) ≥	Yield Strength ≥ (MPa) at 0.2% Offset	Elongation at Break (%)	Hardness	
					Brinell Hardness (HBW) ≤	Rockwell Hardness (HRBW) ≤
SS304/ Gen	Standard	505	215	70	123	70
SS304/ 1mm	Standard	517.1	206.84	40	92	90
	Observation	608.92	325.84	40.88	92	90
SS304/ 3mm	Standard	517.1	206.84	40	84	--
	Observation	668.25	347.38	55	84	--
SS304/ 6mm	Standard	517.1	206.84	40	101	--
	Observation	844.26	710.11	34.02	101	--
SS304/ 8mm	Standard	517.1	206.84	40	89	88
	Observation	852.95	720.77	34.05	89	88

2.2 Methodology:

RSM makes an attempt to investigate the influence of the freelance variables on a particular response. The aim of mathematical models relates the method responses to facilitate the optimisation of the method. The mathematical model ordinarily used for the method responses is delineate as:

Y = F (Xa, Xb, Xc…………) + ε -------------------------------- 1

Where Xa, Xb, Xc… Xn are process variables and ε shows error which is normally concerning the discovered responseY.

Coefficients of process variables mistreatment RSM is delineate as

[B] = Inverse ($[Za]^T$ *[Za])*$[Za]^T$ *[F]--------------------------------2

Where [B]: array of coefficients of process variables, [Z]: orthogonal array with values of selected process variables, [F]: array with values of measured feedback and [Z] T: interchange array of [Z]

In order to consider the accuracy of the expected model, share of deviation Φ i and average share of deviation Φ are outlines as:

Φ I = [(Absolute[R measured – R predicted]) /(R measured)]* 100 ----------------------3

Wherever Φ i: share deviation of single sample information.

R measured: measured feedback.

R expected: predicted feedback.

Φ = (ΣΦi)/n -------------------------------4

Wherever Φ: average share deviation of all sample information.

n: the scale of sample information.

3.0 Results and Discussion

The goal of the formulation and determination of the laser cutting improvement drawback with constraints was to see the set of main laser cutting variables values that are to be used for cutting components fabricated from SS 304. In an supreme case, a additional increase within the gas pressure throughout reactive laser fusion machining might turn out poor cut quality and dross formation because of excessive burning effects.[11] To investigate the impact of the laser cutting variables on kerf quality characteristics main impact plots were generated. A main impact plot may be plot of the mean response values at every level of outline parameter. The most impact of a variable is outlined because the average modification within the response once the extent of the variable is modified from a down to a upper level. A positive gradient indicates that with a rise in variable value there's a rise in feedback value, and a negative gradient means that a decrease in feedback value.

However, the relative input of every laser cutting variable on the kerf quality aspect was resolve through ANOVA that permits a lot of correct determination of the best process variable levels.

Conclusion

The mathematical modelling and the response surface methodology for design of investigation are mostly used to seek out the optimum value of control variables to attain minimize the kerf taper, reduce surface roughness and minimize the dross throughout laser cutting at base.

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