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Optimization of Laser Beam Machine for AISI-1040 Material using Taguchi Methodology

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Abstract: ***There are various input parameters that affects the laser cut but most widely input parameters which affects surface roughness and kerf taper are Laser Power, Gas Pressure, Cutting Speed. Optimization is done by "Taguchi Methodology". The Taguchi methodology involves reducing the variation in a process through robust design of experiment. It works mostly when there are intermediate number of variable (3-5) and when only few variables contribute significantly. The research paper tells us the optimum characteristics of surface roughness and kerf taper by using "Minitab" software. It also tells us about new trends and future scope of "LBM". Cutting parameters are adjusted such a that provide the quality of cut desired. In this research work input parameters are taken as Cutting Speed, Gas pressure, laser powers are studied. Simultaneously their optimum set is analyzed by using Taguchi Methodology from Minitab software for Surface Roughness and Kerf taper as output Parameter for the AISI-1040 Material.***

Keywords: laser beam machining, cutting speed, laser power, gas pressure, Taguchi methodology, Minitab, AISI-1040, Surface roughness, Kerf taper.

I. INTRODUCTION

The quality of laser cut is the most important factor in laser cutting process. All cutting parameters might have significant influence on the resulting quality of work. In general, cutting parameters are adjusted and tuned to provide the quality of cut desired. But this consumes exhaustive (enormous) amount of time and effort. Laser-beam machining is a thermal material-removal process that utilizes a high-energy, coherent light beam to melt and vaporize particles on the surface of metallic and non-metallic work pieces. Lasers can be used to cut, drill, weld and mark. LBM is particularly suitable for making accurately placed holes. Now a day there is many new technologies were incurred in manufacturing filed. Laser cutting can produce high quality cut, complex cut, cut several part simultaneously, produce clean cutting edge which require minimal finishing as well as low edge load during cutting which will reduce distortion. New derived material having high hardness value. This development leads to many new challenges because of, sometimes very precise and accuracy is required. Laser beam machining (LBM) is a machining method primarily used for metals that would be difficult to machine with traditional techniques with higher accuracy. The non-contact machining technique has been continuously evolving from a simple tool and dies making process to a micro-scale application machining alternative attracting a significant amount of research interests. Laser machining has significant applications in the automobile, aerospace and electronics industries for cutting, drilling and milling

II. TAGUCHI METHODOLOGY

Taguchi method was developed by Genichi Taguchi. He developed a methodology for designing experiments to investigate how various input parameters affect the process performance characteristic that defines how well process is functioning The Taguchi methodology involves reducing the variation in process through robust design of experiments.

The overall objective of the method is to produce the high quality product at low cost to the manufacturer. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied.

Instead of having to test all possible combinations like the factorial design, the Taguchi method tests pairs of combinations. This allows for collection of the required data to determine which factors most affect the product quality with minimum number of experimentation hence it saves time and resources.

III. LITERATURE SURVEY

Literature survey is shown in following Table

Ref no	Paper title	Material Used	I/P Parameters	O/P Parameters	Method
1	Taguchi method based Modeling of Surface Roughness Prediction In Laser machining	Mild Steel	Cutting Speed, Frequency, Duty Cycle	Surface Roughness	Taguchi method
2	An Investigation Of Quality in CO2 Laser Cutting of Aluminium	Aluminium - 5-xxx Series of Aluminium Alloy	Laser Power, Cutting Speed, Pressure & Flow Rate, Pulsing Frequency	Kerf Width , HAZ, Cutting Edge Surface Roughness, Cutting Quality	Taguchi method
3	Evaluation Of Surface Roughness In Laser Assisted Machining of Aluminium Oxide Ceramics With Taguchi Method	Aluminium Oxide Ceramic	Depth OF cut, Rotational Speed , Feed, Pulsed Frequency	MRR , Tool Life (Tool Wear), Surface Roughness	Taguchi method
4	Review on laser beam machining Process parameter optimization	Mild Steel	Focal length Cutting speed wavelength	Quality of cut Surface rougness	Taguchi method
5	Surface Roughness Optimization In CO2 Laser Cutting By Using Taguchi Method	Mild Steel(EN S355J2G)	Cutting Speed, Laser Power Assist Gas Pressure	Kerf Width Surface Roughness HAZ	Taguchi method

B. Identified Gaps from Literature

After a study of the literature, following gaps have been found in Laser Beam machining

1) Very limited work on Mild Steel on the effect of machine parameter such as laser power, cutting speed & Gas Pressure.
2) No experimental study on Mild Steel where output parameter such as kerf taper and surface roughness
3) Also the researchers have carried very limited work has been reported on kerf taper.

C. Identified input Process parameters

1) *Cutting speed (Vc)*-It is a travel of a point on the cutting edge relative to the surface of cut in unit time in the process accomplishing the primary cutting motion. It is expressed in mm/min.
2) *Gas Pressure (P)* - Pressure is the expression of force exerted on a surface per unit area. Symbol of pressure is P and unit is Kg/cm
3) *Laser power (P)* –It is rate at which energy is emitted from lasers. Unit is Watt.

IV. MATERIAL SELECTION

Literature survey reveals that material selection is not mentioned in many papers. Selection of material is a crucial step in optimization procedure. Material should be selected which has wide applications in industry and also not in focus or in less focus, so it has scope for further optimization. AISI-1040 Material.

A. AISI/SAE No. 1040 (American Iron and Steel Institute)

1) The first digit indicates that this is plain carbon steel.
2) The second digit indicates there are no alloying elements
3) The last two digits indicates that the steel contains approximately 0.40 percent carbon

4.1 Chemical composition AISI 1040 Carbon Steel (UNS G10400)

Constituent	C	Fe	Mn	P	S
% Composition	0.37-0.44%	98.6-99%	0.60-0.90%	0.040% Max	0.050% Max

4.2 Physical Properties of AISI 1040 (Carbon Steel)

Sr. No	Properties	Metric	Imperial
1	Density	7.845 g/cc	0.2834lb/in^3
2	Melting Point	1521˚c	2770˚c

4.3 Mechanical Properties of MILD STEEL

Properties	Metric	Imperial
Tensile strength	620 MPa	89900 psi
Yield strength	415 MPa	60200 psi
Bulk modulus (typical for steels)	140 GPa	20300 ksi
Shear modulus (typical for steels)	80 GPa	11600 ksi
Elastic modulus	190-210 GPa	27557-30458 ksi
Poisson’s ratio	0.27-0.30	0.27-0.30
Elongation at break (in 50 mm)	25%	25%

B. Design Of Experiment Using Taguchi Method

Classical experimental design methods are too complex and are not easy to use. A large number of experiments have to be carried out when the 86 number of process parameters increase. To solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with only a small number of experiments. Three super plastic forming parameters are considered as controlling factors. They are Pressure, Temperature and Time. Each parameter has three levels – namely low, medium and high, denoted by 1, 2 and 3 respectively. According to the Taguchi method, if three parameters and 3 levels for each parameters L9 orthogonal array should be employed for the experimentation. Orthogonal Arrays (often referred to Taguchi Methods) are often employed in industrial experiments to study the effect of several control factors.

C. Surface Roughness Tester

A digital Surface Roughness Tester is used for measuring the roughness of the work pieces after machining at the GCE,Karad (MQC LAB).

D. Optical Microscope

An optical micrometer with 10 X magnification is used for measuring the thickness of the work piece and kerf taper after each machining operation the GCE,Karad (MQC LAB).

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E. Methodology For Analysis Of Changing Parameter

1) *Surface Roughness (Ra) :* Surface roughness often shortened to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. In surface metrology, roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface. However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for a purpose.

In this work the surface roughness was measured by Mitutoyo roughness tester. The surface tester is a shop–floor type surface-roughness measuring instrument, which traces the surface of various machined parts and calculates the surface roughness based on roughness standards, and displays the results in µm.

Table 4.1: Response Characteristics

Response Name	Response Type
Surface Roughness	Lower is Better
Kerf taper	Lower is Better

F. Experimental Result

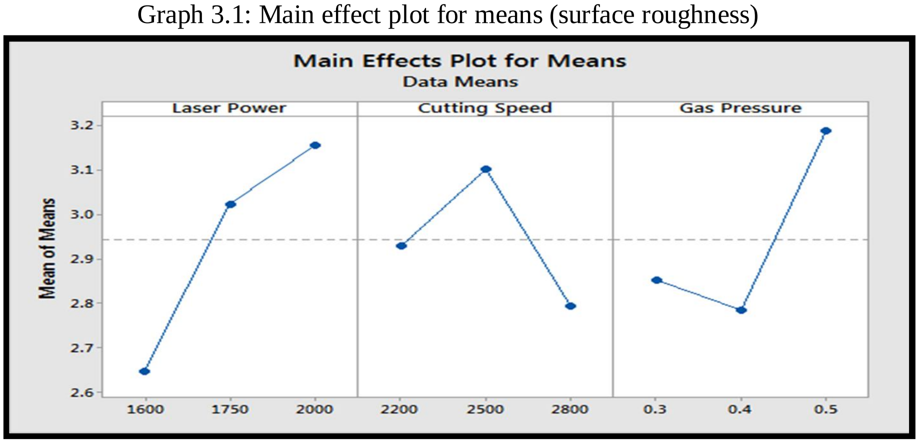
After completion of experimentation, surface roughness and kerf taper of 9 specimen measured. Their results are given i table 4.4.

Table 4.2 Experimental results

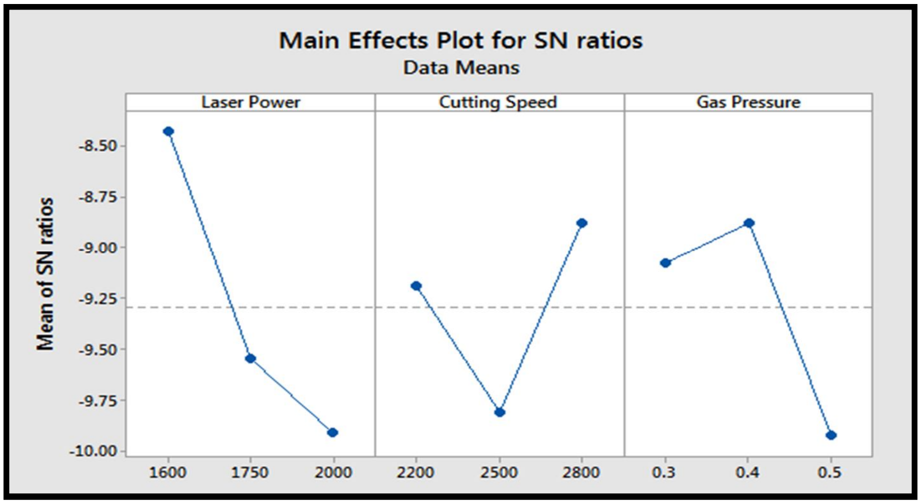
Exp. No.	Laser power mm/min.	Cutting Speed Kg/cm	Gas pressure Watt	Kerf Taper (Degree)	Surface Roughness (Micron)
1	1600	2200	0.3	1.718	2.531
2	1600	2500	0.4	1.661	2.996
3	1600	2800	0.5	1.343	2.419
4	1750	2200	0.4	1.718	2.528
5	1750	2500	0.5	1.89	3.414
6	1750	2800	0.3	3.719	3.131
7	2000	2200	0.5	2.233	3.733
8	2000	2500	0.3	2.291	2.899
9	2000	2800	0.4	2.233	2.834

Hence from experimental result table it is clear that to get minimum kerf taper and surface roughness we have to select laser power (1600 mm/min), cutting speed (Kg/cm) and gas pressure(Watt) from number 3rd experiment from where we will get 1.343 degree kerf taper and 2.419 Micron.

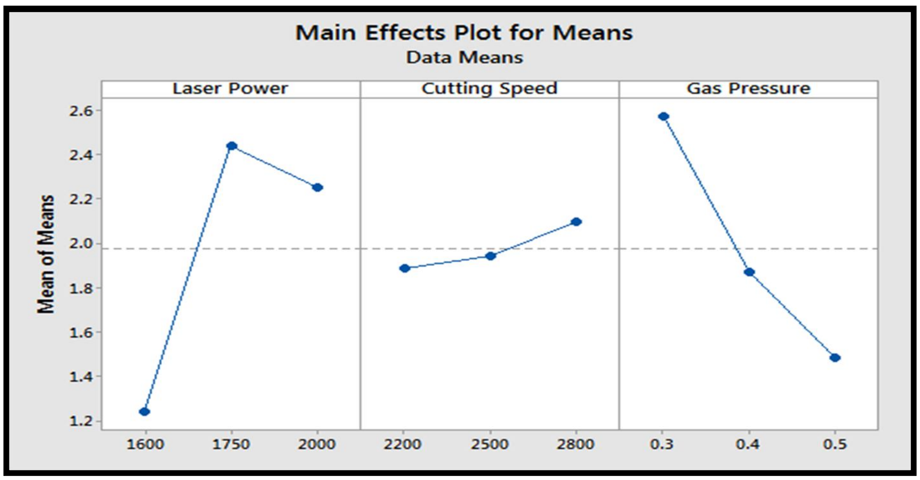
Graph 3.1: Main effect plot for means (surface roughness)



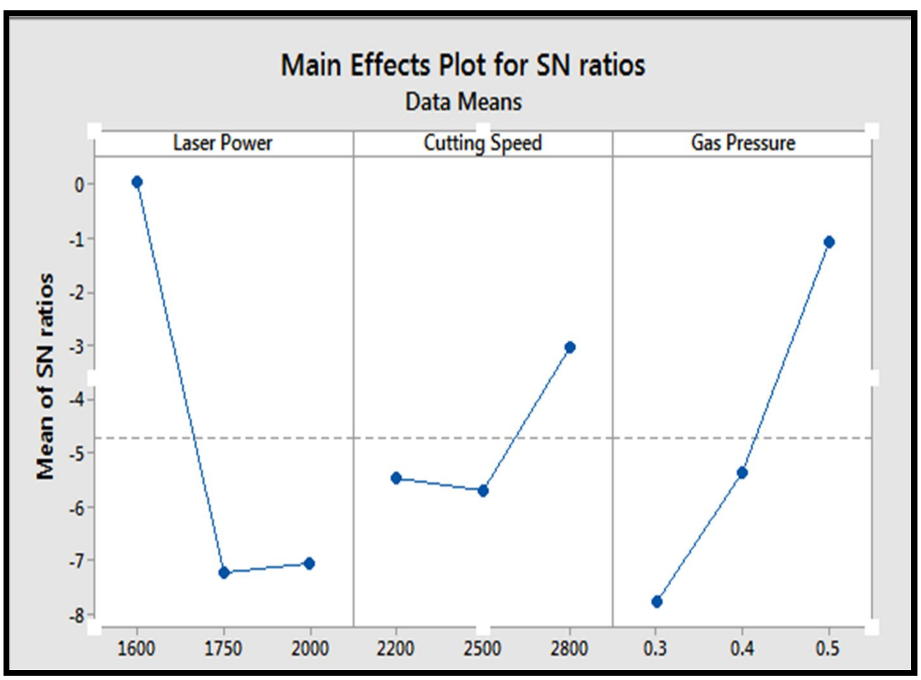
Graph 3.2 : Main effect plot for SN ratios (surface roughness)



Graph 3.3 : Main effect plot for means(Kerf taper)



Graph 3.4 : Main effect plot for SN ratios (Kerf taper)



V. CONCLUSION AND FUTURE SCOPE

A. Conclusion

1) It is clear that Taguchi Methodology only considers limited search space and searches the optimal solution lies in that space so finally it comes out with local optimal solution. But it is not case with in a sense that it searches the optimal solution in wide range of search space so that we get the ultimate optimal solution.
2) Parameter values for multiple responses using Taguchi Methodology gives settings that Gas pressure 0.5, and Cutting speed 2500, laser power 1750
3) Surface roughness is 2.419 µm and kerf taper ranges from 1.343 degree.

B. Future Scope

1) Experimentation can be carried out on different material with different input parameters combinations.
2) Mixed optimization can be also done.
3) Different methodology of analysis and also for optimization can be used.

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