Available online at www.elixirpublishers.com (Elixir International Journal)

Mechanical Engineering

Elixir Mech. Engg. 85 (2015) 34101-34106

ISSN: 2229-712X

Experimental Studies on Austenitic Stainless Steel Using Co_2 Laser Cutting Machine

U. Naga Raju, P. Rajesh, T. Vishnuvardhan and G. Harinath Gowd

Department of Mechanical Engineering, Madanapalle Institute of Technology and Science, Madanapalle Andhra Pradesh-517325, India.

ARTICLE INFO

Article history:

Received: 7 March 2015;
Received in revised form:
25 July 2015;
Accepted: 1 August 2015;

Keywords

Co_2 Laser,
Austenitic Stainless Steel,
Parameters,
Surface Roughness,
Burr Heights.

ABSTRACT

Laser machining operation is a thermal, separation process, well suitable for several engineering industrial applications. High cutting speed, superior cut quality and low machining costs made laser cutting to become competitive to existing methods of contour cutting. Austenitic stainless steel is a significant engineering metal and it is complex to cut by oxy–fuel formed oxides and high melting point. So, austenitic stainless steel is mostly appropriate to be cut by laser. The cutting process parameters are highly affects the laser cut quality. In this research 1.9 mm austenitic stainless steel is cut with co_2 laser. Laser power, cutting speed, gas pressure and focal distance are to be varied. The goal of this research is to narrate these conditions to formations of burr and surface roughness of cut edge. These relationships are engendered and approved with a mathematical model, which is used to forecast and reduce burr height and minimizing the cut edge surface roughness.

Introduction

Metal cutting by laser has turn into consistent machinery for industrial production. presently, it is considered as a viable different to conventional cutting and blanking due to its elasticity and capability to process changeable quantities parts of sheet metal in a less time with maximum programmability and less waste. Laser cutting does not need fixtures and jigs for holding and guiding the work piece because it is a non-contact operation. Moreover, it does not need costly or disposable tools and does not produce mechanical force that can damage thin work pieces [K.Abdel Ghany et al]. Laser cutting is categorized as a various thermal technique that has distinct benefits over other known thermal operations due to the great quality and very finished cut surface, thin kerf width, square corners of cut edges, minor HAZ, lass metal deformation, perpendicular& sharp cut sides and no oxide layer [K.Abdel Ghany et al].

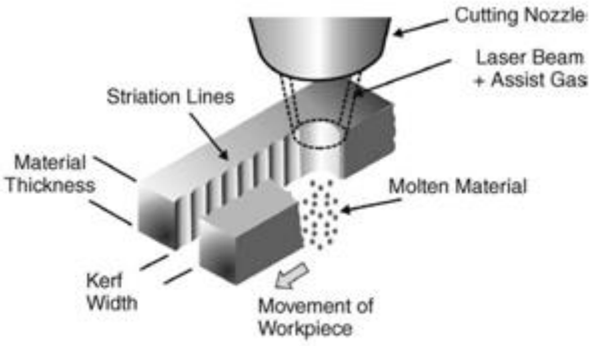

Fig 1. Schematic diagram of laser cutting process

Stainless steel cutting by Laser

Stainless steel material is a special engineering metal, it has high promises in many important industries particularly automobiles and house appliances [K.Abdel Ghany et al] Stainless steel is complex to cut by using conventional oxy-fuel cutting device because the melting point is high and high viscosity of the oxide is formed. Laser cutting process is preferably appropriate for stainless steel and obtained accuracy and productivity. The major factors for the optimum cutting of work pieces are selection of the assisted gas, which could be oxygen (active gas) and variable inputs. The amount of energy transmitted by the flaming response is about 60% for non-reactive metals like mild steel and stainless steels and up to 90% for reactive metals such as titanium [W.K.hamoudi et. al].

But it usually wants high gas pressure to cut stainless steel [D.Havrilla.et al] and low cutting speed to obtain good as an inert gas produces optimistic and finished cut surface and does not disturb the rust resistance of the cut edge cutting quality and dross-free lower surface. It is very significant to enhance the cutting speed and other parameters in order to reduce the amount of pumping gas, thus the total manufacture cost. [K.Abdel Ghany et al].The temperature in the cutting front intervals from 2000 to 2500 ◦C, the exothermal reactions are induced in the work piece and a larger amount of energy related to low carbon steel is free. Also, the thermal conductivity of low carbon steel is greater than that of high alloy austenitic steel, and the effect of lower conductivity and superior energy in the cutting front is that a wider cut is finished than that in low carbon steel.

Optimization of Laser Cutting Parameters

Laser cutting excellence is controlled by several variables; a few of them are allied to the laser apparatus like peak laser power, efficiency, emerging beam diameter and wave length. Further are associated to the sending optics like focused beam diameter, fiber diameter. [K.Abdel Ghany et al]. The left over are allied to the operation such as the cutting speed, nozzle tip diameter, face-off distance, type and pressure of assistant gas. Input parameters that influencing product quality and productivity i.e. the applicability of this technology are: laser type, laser operating mode power/energy and power density of the laser beam, the distribution of power density - TEM mode & the quality of the laser beam, the character of the polarization beam, cutting speed, assist gas for cutting, the type and thickness of the material, surface condition of the work piece, length and focus position, type and standoff, etc. Output parameters that

Tele:
E-mail addresses: gowdmits@gmail.com

depend on input and on the basis of which justifies the application of this technology are: cutting surface roughness, Burr height, the effect of laser power, cutting speed and oxygen assist gas pressure on the cut quality in laser cutting of refractory materials analyzed in [K.F.Tamrin et al]. Mathematical models are describe the dependence of input i.e. more independent variables (cutting speed, focus position, standoff, types and assist gas pressure, laser power, etc.) and output parameters, i.e. dependent variable (Burr height and Surface roughness.). Mathematical models are defined by multiple linear regression analysis. So with defined mathematical models, optimal process parameters of laser cutting of related austenitic stainless steel are achieved with regard to fulfillment of certain objectives (maximum material saving, higher product quality, etc.). The effect in differences of pressure and nozzle distance on burr height and roughness is shown in lesser oxygen gas pressure has a positive impact on both responses, whereas more focal distance on burr height. Logically the larger nozzle reduces the gas flow to the cut zone, thermodynamic stability is important to avoid turbulence in the melt zone which results in pattern formations. The effect of changing cutting speed on both responses is also plotted in Higher cutting speeds within the tested level range improve burr height and roughness, mainly as it minimizes side burning. At low speeds, burning effects disrupts flow of molten material, causing irregular solidifications of the melt at the bottom kerf as shown in fig.3.

Design of Experiments

Response surface methodology

Response surface method (RSM) is an assembly of statistical and mathematical methods that are suitable for the modelling and optimization of the industrial problems. In this method, the main goal is to optimize the output response that are influencing by various input parameters.[M.M.Noor.et.al] RSM also computes the relationship between the manageable parameters and the achieved response. In modelling of the manufacturing processes using RSM, the appropriate data is collected through designed investigation. In general, a second order regression model is developed because of first order models often give lack-off fit [Montgomery.et.al] the optimization of experiments using RSM to understand the effect of important Parameters.

Experimental setup

CO_2 Laser

The most widely used lasers for sheet cutting are continuous wave (CW), CO_2 and pulsed Nd.YAG [Schreck et. al]. High quality cutting surface is obtained by proper selection of parameters and application of appropriate assisted gases. As the laser cutting of steel, using N_2 gets brighter and smoother surface finish. The experimental setup of CO_2 laser as shown in Fig.2. For research purpose, the Laser light was developed by gaseous state CO_2 laser (fig.1) with larger power up to 3200W, frequency 10000 Hz, maximum gas pressure 8.0 bar, maximum cutting speed 5000 mm/sec and prepared with stand-off distance regulating by servo motor and sensory devices. The specifications of laser source as shown in Table No.1.

Work piece material

1.9mm thickness austenitic stainless steel was used. The percentage of chemicals mixed in the austenitic stainless steel as shown in table.2 Austenitic stainless steel sheet was cut using shear machine to square shape with measurements of 200mm×200mm and kept in a dry box to avoid the formation of rust by clean cloth to remove dust before start cutting process [Hud Wahab.et al].

Fig 2. CO_2 Laser Machining process

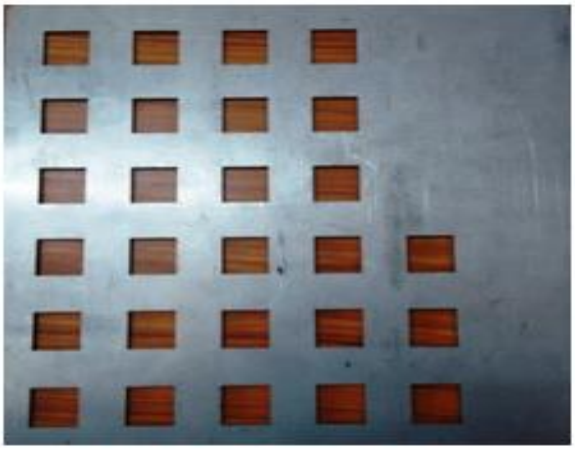

Fig 3. Austenitic Stainless steel material Front side

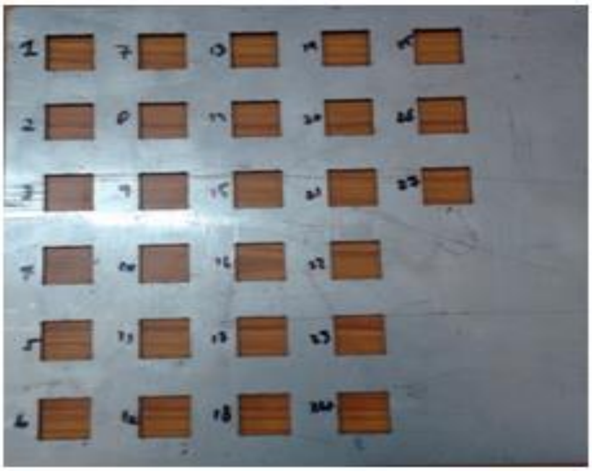

Fig 4. Austenitic Stainless steel material Back side

Design of Experiment

The need of process development is to increasing the performance of the process related to customer expectations. The purpose of DOE should be to understand how to deduct and controlling the variations of a process; however thinks must be made concerning which variables affecting the performance of a process. The process parameters according to the experimental conditions as mentioned in Table. No.3 and the experimental inputs responses of the parameters are mentioned in the Table No.4.

Measuring Equipment

Surface roughness was measured using Talysurf (Mitutoyo) [fig.5] and Burr height was measured using Micrometer (Mitutoyo). The controlled parameters have been the burr height and surface roughness. Surface roughness of the square grooves ware measured in terms of the aggregate roughness *Ra*, using a Talysurf instrument. Roughness was measured along the length of cut at approximately medium of thickness. The size of burr height was measured using a 2 to 25 mm micrometer.

Fig 5. Talysurf equipment

Effects of output responces

Laser power influencing on surface roughness

The influence of laser power on the surface roughness as shown in fig.6.The effect of laser power on the surface roughness of cut reduces as thicker sheet is considered to be cut. The surface roughness values are investigated on the different laser power conditions. A very fast increment in surface roughness is occurred at low, medium and high values of the laser power conditions. The power and surface roughness are directly proportional to each other.

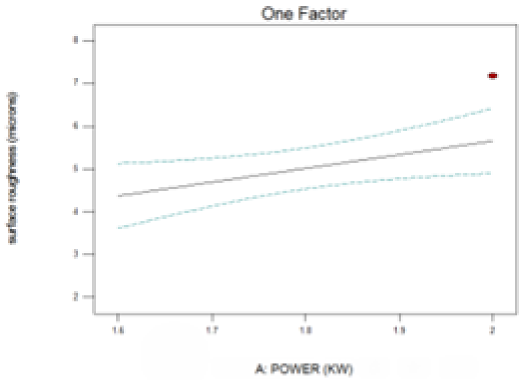

Fig 6. The Relationship between Laser power and surface Roughness

Cutting speed influencing on surface roughness

The influence of cutting speed on the surface roughness as shown in fig.7.The most favorable cutting parameters for a group of related steel is possible on the basis of presented indicators. The higher cutting speeds give maximum surface roughness. The good surface finish is to be obtained at optimal cutting speeds in this investigation.

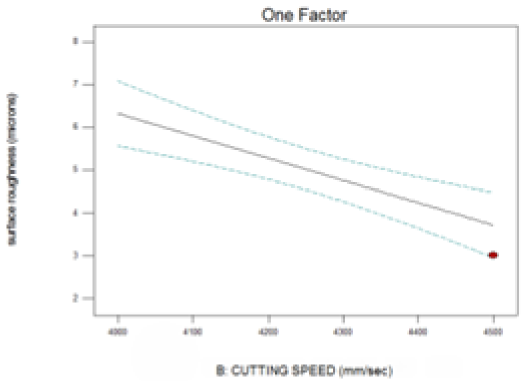

Fig 7. The Relationship between cuttings speed and surface roughness

Gas pressure influencing on surface roughness

The influence of gas pressure on the surface roughness as shown in fig.8.The gas pressure is most significant parameter affecting the surface roughness variation. For obtaining the minimal roughness the gas pressure should be kept at low level.

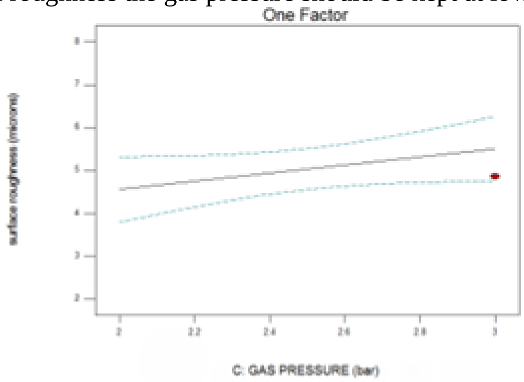

Fig 8. The relationship between Gas pressure and surface Roughness

Focal Distance influencing on surface roughness

The influence of Focal distance on surface roughness as shown in fig.9.The surface roughness value increases if both laser power and focal distance increases. The focal distance has the most significant effect on the surface roughness.

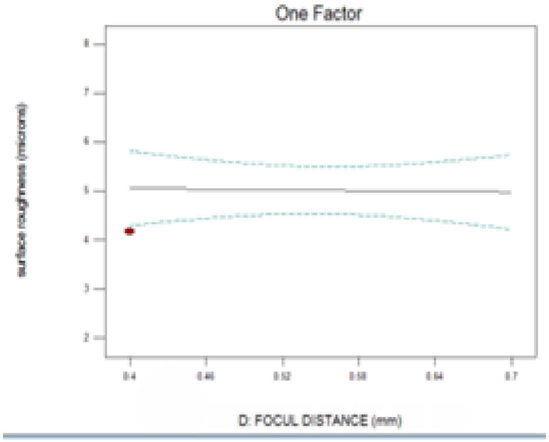

Fig 9. The relationship between Focal Distance and surface roughness

Laser power influencing on Burr height

The influence of Laser power on the burr height as shown in fig.10.During cutting, the laser power develops a Very high temperature in the form of light wave. The laser power is directly proportional to the burr height because more power causes more metal removal. This large amount of metal removal gives an irregular solidification of the bottom surface. These burr height also varies with respect to power fluctuations.

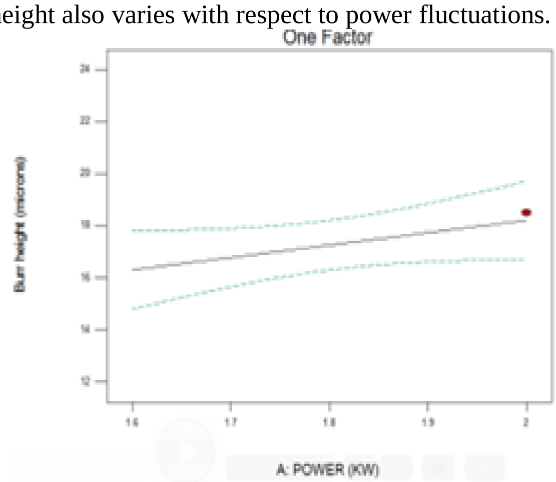

Fig 10. The relationship between Power and burr height

Cutting speed influencing on the Burr height

Table 1. Overview of characteristics data of The Laser source

Wave length (ʎ)	808 – 1055 nm
Power	3.2 KW
Gas	O_2 , N_2
Gas Pressure	12 bar
Cutting Speed	5000 mm/sec
Frequency	10 KH_z
Nozzle Diameter	1 – 2.5 mm
Kerf	0.1 – 0.5 mm

Table 2. Chemical composition (wt%) of austenitic steel

Cr	Ni	Mn	Si	Cu	Mo	Co
18.39	8.72	1.11	0.566	0.355	0.170	0.14

Table 3. Experimental Conditions

Factors	Units	Levels		
		-1	0	1
Power	KW	1.6	1.8	2.0
Cutting Speed	mm/sec	4000	4250	4500
Gas Pressure	Bar	2.0	2.5	3.0
Focal Distance	Mm	0.4	0.55	0.7

Table. 4 Experimental design and measured Responses

R.No	Input Variables				Output Variables	
	Power [KW]	Cutting Speed [mm/sec]	Gas Pressure [bar]	Focal Distance [mm]	Surface Roughness [μm]	Burr Height [μm]
1	1.6	4000	2.0	0.4	6.695	18.05
2	1.6	4000	2.5	0.55	4.536	15.88
3	1.6	4000	3.0	0.7	7.952	13.52
4	1.6	4250	2.0	0.55	3.166	14.24
5	1.6	4250	2.5	0.7	3.925	17.25
6	1.6	4250	3.0	0.4	4.372	19.30
7	1.6	4500	2.0	0.7	3.048	12.28
8	1.6	4500	2.5	0.4	3.704	13.41
9	1.6	4500	3.0	0.55	3.106	20.71
10	1.8	4000	2.0	0.55	5.875	16.87
11	1.8	4000	2.5	0.7	6.987	16.87
12	1.8	4000	3.0	0.4	7.806	19.94
13	1.8	4250	2.0	0.7	4.002	18.14
14	1.8	4250	2.5	0.4	4.183	21.00
15	1.8	4250	3.0	0.55	4.850	13.61
16	1.8	4500	2.0	0.4	2.839	17.47
17	1.8	4500	2.5	0.55	3.020	19.24
18	1.8	4500	3.0	0.7	3.564	16.68
19	2.0	4000	2.0	0.7	8.886	18.48
20	2.0	4000	2.5	0.4	4.635	18.78
21	2.0	4000	3.0	0.55	6.995	20.71
22	2.0	4250	2.0	0.4	6.208	16.48
23	2.0	4250	2.5	0.55	7.175	18.51
24	2.0	4250	3.0	0.7	4.501	22.01
25	2.0	4500	2.0	0.55	2.882	13.97
26	2.0	4500	2.5	0.7	5.852	15.10
27	2.0	4500	3.0	0.4	6.964	17.77

The influence of cutting speed on the Burr height as shown in fig.11.The curve slope is greater at the lower cutting speed because of at high speed there is no sufficient time to diffusion and melting grooves. The larger cutting speeds with in the tested range increase the burr height.

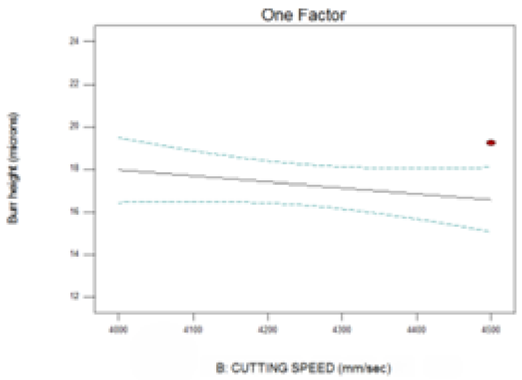

Fig 11. The relationship between Cutting speed and burr Height

Gas pressure influencing on Burr height

The influence of gas pressure on the Burr height as shown in fig.12.The burr height can be explain by increase in some automatic force induce by gas pressure. Although growing the pressure of oxygen gas assures very smooth and burr less surface. The optimal gas pressure even with some unnoticeable burrs is attached to lower surface. Increasing the gas pressure gives an increasing the burr height.

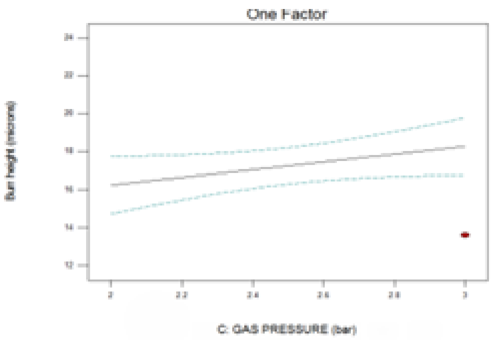

Fig 12. The relationship between Gas Pressure and Burr Height

Focal Distance influencing on Burr height

Influence of the focal distance on burr height as shown in fig.13. The steady values, positive relations effect on burr height with increase in focal distance. Focal distance has the dominant effect on the burr height improvement. For obtaining the optimal burr height while using the maximum focal distance.

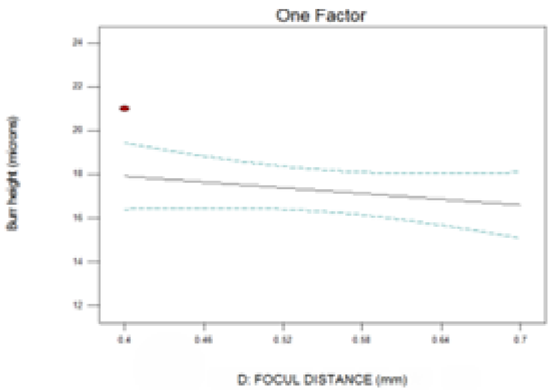

Fig 13. The relationship between Focal distance and Burr Height

Conclusions

Some certain points which can be taken about research can only be applied for the above mentioned material within the limits of the factors investigated:

1)Near ambient oxygen gas pressure is important to avoid burning effects, allowing melt to flow downward with low viscosity. For laser inert-gas cutting, high nitrogen gas pressure is needed to forcefully eject molten material.

2)Higher cutting speeds generally give positive results in maintaining thermodynamic stability and avoid excessive overheating.

3)The nozzle standoff distance is favorably large for laser oxygen cutting as to control gas flow to the melt zone

4)RSM models reveal that power requirement is the most significant design variable in determining surface roughness response as compared to other parameters. A designer can subsequently select the best combination of design variables for achieving optimum surface roughness

Acknowledgements

With deep sense of gratitude, we acknowledge the guidance, help & active cooperation rendered by the following people whose guidance has sustained the effort which led to the successful completion. The authors would like to express their deep gratitude to A. SATEESH KUMAR from Meera Laser Solutions, Ambattur, Chennai for providing equipment facilities.
Lastly we express our sincere thanks to all those who have been helpful directly or indirectly in bringing the paper to the present shape

References

[1] K. Abdel Ghany ∗, M. Newish *Cutting of 1.2mm thick austenitic stainless steel sheet using pulsed and CW Nd:YAG laser* Journal of Materials Processing Technology 168 (2005) 438–447 2005

[2] Miloš Madic, Dušan Petkovic, Miroslav Radovanović *GRA approach for multi-objective optimization of laser cutting* U.P.B. Sci. Bull., Series D, Vol. 76, Issn. 4, 2014 ISSN 1454-2358 2014

[3] Hud Wahab and Jürgen Gröninger *Optimization of Laser Cutting Quality with Design of Experiments* Laser Technik Journal 5/2014

[4] M.M. Noor, K. Kadirgama and M.M. Rahman *analysis of surface roughness for laser cutting on acrylic sheets using response surface method* 2014.

[5] H. A. Eltawahni, A. G. Olabi and K. Y. Benyounis *Investigating the CO2 laser cutting parameters of MDF wood composite material***.** Material Processing Research Centre, School of Mech. & Manu. Eng., Dublin City University,

[6] M. Zaied **b**, E. Bayraktar **a,***, D. Katundi **a**, M. Boujelbene **b,c**, I. Miraoui ***a*** *Effect of laser cutting parameters on surface quality of low carbon steel (S235)* JAIMME. 2012**.**

[7] Miloš MADIĆ1, Miroslav RADOVANOVIĆ2, Laurentiu SLATINEANU3 *Surface Roughness optimization in co2 laser cutting by using taguchi method* U.P.B. Sci. Bull., Series D, Vol. 75, Iss. 1, 2013 ISSN 1454-2358 2013.

[8] K.F.Tamrin a, b,n, Y.Nukman a, I.A.Choudhury a, S.Shirley *a Multiple-objective optimization in precision laser cutting of different thermoplastics* 2014 Elsevier Ltd. All rights reserved

[9] Omer OzgurKardas a, OmerKeles a, SohailAkhtar b, BekirSamiYilbas b,n *Laser cutting of rectangular geometry in 2024 aluminum alloy: Thermal stress analysis* & 2014ElsevierLtd.Allrightsreserved

[10] Dong-Gyu Ahn, Kyung-Won Byun *Influence of cutting parameters on surface characteristics of cut section in cutting of Inconel 718 sheet using CW Nd:YAG laser* Department of

Mechanical Engineering, Chosun University, 375 Seosuk-dong, Dong-gu, Gwang-ju, 501-759, Korea Received 2 March 2009; accepted 30 May 2009

[11] Ahmet Cekic*, Derzija Begic-Hajdarevic, Malik Kulenovic, Alma Omerspahic *CO2 Laser Cutting of Alloy Steels using N2 Assist Gas* 24th DAAAM International Symposium on Intelligent Manufacturing and Automation, 2013

[12] K. Venkatesa, R. Ramanujam, P.Kuppan *Laser Assisted Machining of difficult to cut materials*: Research Opportunities and Future Directions - A comprehensive review 12th Global congress on manufacturing and management, GCMM 2014.

[13] Xavierarockiaraj.S, Kuppan.P *Investigation of cutting forces, surface roughness and tool wear during Laser assisted machining of SKD11Tool steel* 12th global congress on manufacturing and management, gcmm 2014

[14] Yoshihiro Morimotoa,b, Dongjue Hea, Wataru Hijikatac, Tadahiko Shinshic, Takahiro Nakaid, *Naoyuki Effect of high-frequency orbital and vertical oscillations of the laser focus position on the quality of the cut surface in a thick plate by laser beam machining* © 2014 Elsevier Inc. All rights reserved.

[15] Vipul K Shah1, Mr. Hardik J Patel2, Dr. Dhaval M Patel3 *Optimization Of Input Parameters on Surface Roughness during Laser cutting* - A review International Journal For Technological Research In Engineering Volume 1, Issue 5, January – 2014

[16] Ming-Fei Chen a,n, Yu-SenHo Wen-TseHsiao, Tse-HungWua, Shih-FengTseng Kuo-ChengHuang b *Optimized laser cutting on light guide plates using grey relational analysis* Optics and Lasers in Engineering 2010

[17] G. Costa Rodrigues*, H. Vanhove, J.R. Duflou *Direct diode lasers for industrial laser cutting: a performance comparison* with conventional fiber and CO2 technologies 8th International Conference on Photonic Technologies LANE 2014

[18] A.M. Orishicha, A.G. Malikova, V.B. Shulyatyeva,* , A.A. Golysheva *Experimental comparison of laser cutting of steel with fiber and □□2 lasers on the basis of minimal roughness* 8th International Conference on Photonic Technologies LANE 2014