iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 Issue: IV Month of publication: April 2022

DOI: https://doi.org/10.22214/ijraset.2022.41176

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue IV Apr 2022- Available at www.ijraset.com

Optimization of CO_2 Laser Cutting Process Parameter for AL7075-T6 Sheet Using Response Surface Methodology

Pramod S. More[1], Dr. Y.U. Sathe[2]
[1]PG Student, Mechanical Engineering Department, Government College of Engineering, Aurangabad. India (MH)
[2]Assistant Professor, Mechanical Engineering Department, Government College of Engineering, Aurangabad. India (MH)

Abstract: Aluminium alloys are used in the aerospace and automotive industries because of their light weight and excellent corrosion resistance. Since aluminium material has highly reflective and thermally conductive in nature, it is difficult to apply laser cut on it. The cut quality is mainly determined by the combination of the laser processing parameters. Surface roughness, cutting width and cutting cone were the most important quality indices for evaluating CO_2 laser cutting, and the processing parameters considered were laser power, speed and gas pressure. For analysing the laser cutting variables and to determine the optimal value for the surface roughness mainly three approaches are used - Design of Experiments (DOE), Analysis of Variance (ANOVA), and Response Surface Methodology (RSM). The analysis in proposed work shows that the cutting speed has a greater influence on the response behaviour than the cutting speed and the laser power. In proposed work, the optimized values for above mentioned parameters are calculated for laser cutting process.

I. INTRODUCTION

Aluminium and its alloys are successfully used in industrial applications, from packaging to the aerospace industry with so many great varieties. For its exceptional properties like high strength-to-weight ratio, enlarge corrosion resistance, high thermal and electrical conductivity as well as ease for operations like formability and machinability, these alloys have an advantage over other traditional structural materials. Aluminium alloys continue to be the dominant structural materials for aircraft. Large uses of aluminium alloys have also been found in the automotive industry, as the use of lightweight materials can help to achieve a reduced vehicle weight and improve fuel economy. The variety of shapes of aluminium alloys in general and sheet metal shapes is specified used in the aerospace and automotive industries [1-2]. Because of its some disadvantages, for laser cutting it is required to investigate the machining of aluminium alloy. The main disadvantage is that it has a higher reflectivity in the range of 10.6m, which makes aluminium alloys difficult to cut. This reflectivity causes recasting layers to form, resulting in an uneven profile and a poor nature of surface finishing. Other disadvantage is that use of high-power lasers gives a large kerf width which becomes a big drawback in manufacturing small features and high tolerance parts. The efficiency of CO2 laser cutting relates with the combination of various control process parameters, such as the strength of the laser beam power, the gas velocity and even the cutting speed. Therefore, when cutting carried out using CO2 laser, the main focus is to reduce the wear rate and cutting size of the Al7075-T6 2mm sheet [3-4]. Interesting research studies on the process of laser cutting were conducted, and it was discovered that most of the researchers mainly paid attention on consistency characteristics like tool wear and kerf width. R. Adalarasan et al. [2015] studied the effects of CO2 laser cutting parameters on aluminium composite kerf width and surface finish. Eltawahni et al. [2012] studied the laser cut parameters which are associated with kerf and roughness of stainless-steel material. Stournaras et al. [2009] investigates regarding laser cutting of Aluminium alloys and discovered that coupling cutting speed and laser beam power have creates an impact on kerf width. A. Riveiro et al. [2010] investigated the effect of CO2 laser cutting parameters on the content of aluminum-copper alloy (2024-T3) and discovered acceptable quality for high power yields. [8-10]. The laser beam power was discovered to be the most important parameter influencing the width and roughness of the kerf. Milos Madic and Miroslav Radovanovic [2012] discovered that for mild steel cutting by CO2 laser cutting, the Artificial Neural Network (ANN) makes prediction of significantly better surface quality as compared to the Multiple Regression Analysis (MRA). These optimization techniques are used in advanced manufacturing, but only a few applications of the laser cutting process are documented in various literatures. This paper focuses on improving surface roughness in CO2 laser cutting of aluminium 7075-T6 using a Response Surface Methodology to find out an important parameter for better quality [5-12].

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue IV Apr 2022- Available at www.ijraset.com

II. EXPERIMENTAL SETUP

Experiments were carried out on the 3D CNC laser cutting machine Domino 400 CP at the Marathwada Auto Cluster. This machine used a CO2 laser with 10.6 µm wavelength having a nominal power output of 4000W at continuous mode. The lens focal length is 1.3 mm used, the diameter of nozzle is 2.0 mm, the stand-off distance was 1 mm. The workpiece material is Al 7075-T6 with a thickness of 2 mm. Table 1 shows the technical specifications of the laser cutting machine Domino 400 CP.

Table No.1 Technical Specification of 3D laser Cutting

Models Parameters	Specification
Laser Source	CO_2 4000W
Working area	300mm(X) × 1500mm(Y) × 400mm(Z)
Axis Speed	X&Y axis 1000m/min, Z axis 50m/min
Wavelength	10.6
Assist Gas	Nitrogen
Mode	Continues Mode

The 7075-T6 aluminium provides a good balance of properties, which makes it a dependable choice for a wide range of jobs. The 7075-aluminium alloy, with zinc as the dominant alloying element, is the first high strength alloy which composed of Al-Zn-Mg-Cu and it is able to successfully collaborates the benefits of chromium inclusion to provide a high stress-corrosion-cracking resistance in a sheet product.

Aluminium 7075-T6 is a good choice material of application in the aerospace, marine, and transportation industries, where there is a requirement of light weight and stress resistance at higher level. However, it has well-balanced set of properties, it is widely used in a most of the other industries. Table 2 contains the chemical composition of Al 7075-T6[13-14].

Table No. 2 Chemical composition of Work piece Material

Al	Cr	Mn	Mg	Si	Ti	Zn	Fe	Cu
90.4	2.00	0.3	2.9	0.4	0.2	6.1	0.5	2

III.DESIGN OF EXPERIMENT

According to Dubey and Yadava [15], the DOE approach is used in the majority of laser processing for the materials. Qiu et al. [16] discovered that the Box–Behnken design decreases the number of experiments required while maintaining optimization accuracy. Hence Design of experiment approach (DOE), Analysis of Variance (ANOVA) and Response Surface Methodology (RSM) are used to find out the cutting parameters in consideration with the workpiece surface roughness and identify the regions of optimized parameters. RSM also provides the relation between surface roughness of material and interaction of two cutting variable. Following Table 3 depicts the numerical values of a control parameters for cutting the aluminium 7075-T6 alloy at the lower and higher levels. Seventeen experiments were carried out using the Box-Behnken design with five centre points.

Table No.3 Laser cutting variables and its levels used in the experiments for aluminium 7075-T6 alloy.

Cutting Parameter	Level1	Level 2	Level 3
Laser Power (W)	2900	3000	3100
Cutting Speed(mm/min)	4000	4500	5000
Pressure (Bar)	6	7	8

A series of experiments were carried out as part of the research work to investigate what are the effects of process parameters on processed surface roughness and to achieve a critical relationship demonstrating roughness variations as a function of these parameters. Design-Experts [12] statistical software is used to code the variables and created design matrix in following Table 4.

Table No.4 Experimental Design

Std	Run	Factor 1 Power (Watt)	Factor 2 Cutting Speed (mm/min)	Factor 3 Pressure (Bar)	Response 1 Surface response (µm)
4	1	3100	5500	7	2.37
15	2	3000	5000	7	2.557
14	3	3000	5000	7	2.588
2	4	3100	4500	7	2.577
8	5	3100	5000	8	2.416
16	6	3000	5000	7	2.595
10	7	3000	5500	6	2.43
12	8	3000	5500	8	2.487
3	9	2900	5500	7	2.376
17	10	3000	5000	7	2.595
1	11	2900	4500	7	2.55
11	12	3000	4500	8	2.595
7	13	2900	5000	8	2.434
6	14	3100	5000	6	2.432
13	15	3000	5000	7	2.539
9	16	3000	4500	6	2.719
5	17	2900	5000	6	2.491

IV. RESULT AND DISCUSSION

Table No. 5 ANOVA table for Surface Roughness

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.1419	9	0.0158	28.85	0.0001	significant
Power	0.0004	1	0.0004	0.7172	0.4251	
Cutting Speed	0.0757	1	0.0757	138.43	< 0.0001	
Pressure	0.0025	1	0.0025	4.48	0.0720	
Power x Speed	0.0003	1	0.0003	0.4981	0.5031	
Power x Pressure	0.0004	1	0.0004	0.7689	0.4096	
Speed x Pressure	0.0082	1	0.0082	14.99	0.0061	
Power x Power	0.0514	1	0.0514	94.11	< 0.0001	
Speed x Speed	0.0001	1	0.0001	0.1217	0.7374	
Pressure x Pressure	0.0019	1	0.0019	3.41	0.1075	
Residual	0.0038	7	0.0005			
Lack of Fit	0.0012	3	0.0004	0.6371	0.6295	not significant
Pure Error	0.0026	4	0.0006			
Cor Total	0.1457	16				

The influence of each parameter and the adequacy of the data is achieved by using ANOVA technique on the experimental data. Table 5 provides a summary of the findings. A lower P-value (i.e., <0.05) shows the statistical significance of the source on the corresponding response (i.e., = 0.05, or 95% confidence level), indicating that the source is significant. This indicates that the obtained models are statistically significant, and it is desirable because it shows that the terms in the model have an important effect on the response. Table 5 shows various factors such as- the degrees of freedom (DF), sum of squares (SS), mean squares (MS), F-values (F-VAL.), and probability (P-VAL.), as well as the percentage contribution (Contr. percent) of each factor.

For the given model F-value of 28.85 indicates that it is significant. The F-value could occur here due to noise only is 0.01 percent of the time. Model terms are significant if the P-value is less than 0.0500. In this case, Speed, Speed x Pressure, and Power x Power are important model terms. Values greater than 0.1000 indicate that the model terms are unimportant. Model reduction may improve your model if it contains a large number of insignificant model terms (excluding those required to support hierarchy). The Lack of Fit F-value of 0.64 indicates that the Lack of Fit is insignificant in comparison to the pure error value. A large Lack of Fit F-value due to noise has a 62.95 percent chance of occurring. We want the model to fit, so a non-significant lack of fit is desirable.

The Predicted R^2 value of 0.8364 is in valid range with the Adjusted R^2 value of 0.9400; i.e., the difference between them is less than 0.2. Adequate Precision calculates the signal to noise ratio. It is desirable that ratio should be greater than 4. Here, ratio of 20.189 shows an adequate signal. This model can be used for navigating the design space.

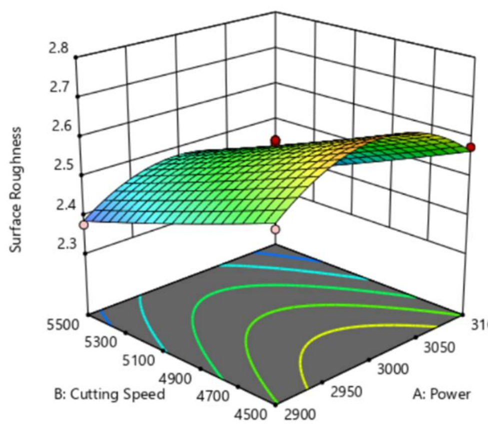


Fig 1. A Surface Roughness vs Speed and Power

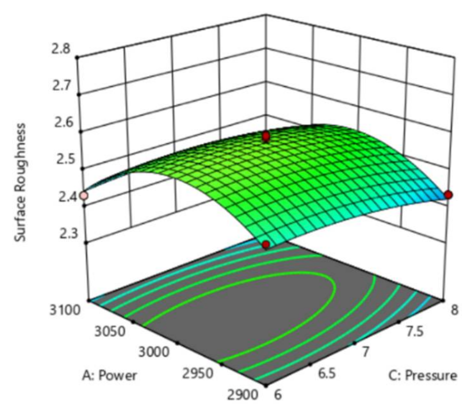


Fig 1. B Surface Roughness vs Power and Pressure

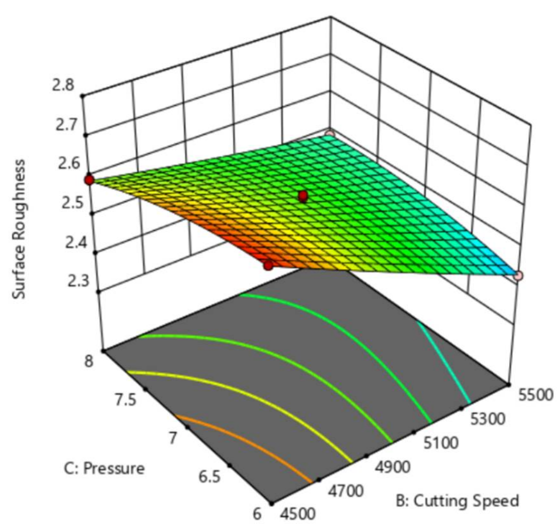


Fig 1. A Surface Roughness vs Pressure and Speed

Fig. 1 **a** Roughness versus Power and Speed, b Roughness versus Power and Pressure, **c** Roughness versus Speed and Pressure.

For the three responses, the second-order equations for response surface have been mounted and the equations can be provided in terms of coded values of the independent variables as given.

SR = -93.3804 + 0.0663525 x Power + -0.000492 x Speed + -0.48315 x Pressure + -1.65e-07 x (Power x Speed) + 0.0001025 x (Power x Pressure) + 9.05e-05 x (Speed x Pressure) + -1.10525e-05 x Power x Power + 1.59e-08 * (Speed x Speed) + -0.021025 x (Pressure x Pressure)

The relationship among the laser parameters and the surface roughness are depicted in Figures 1a–c. According to Fig. 1a, as the power rises up to centre point (3000 W), the surface roughness is also increases; however, if the power increases beyond the centre point value (3000W), the surface roughness starts to decrease. From the results, it can also be depicting that, the surface roughness is inversely proportional to cutting speed, as shown in Fig. 1a. The surface roughness is decreases with increase in cutting speed, because the exposure of high-intensity of laser power at higher cutting speed is less, which results in less surface roughness. According to Fig. 1b, surface roughness increases and then decreases smoothly as pressure increases, However, up to 3000-Watt roughness increases abruptly and then abruptly decreases with increase in power. Afterwards that point, Surface roughness increases steeply with increasing pressure and speed, which is depicted in Fig. 6c. It should also be noted that the surface roughness gradually decreases as the speed increases.

V. OPTIMIZATION OF LASER CUTTING PARAMETER

In this study, a single response is used to optimise laser cutting process parameters using the Design Expert v13 Software, and surface roughness is optimised concurrently using the established models [3]. Table 6 shows the optimality solution for minimised Surface roughness.

Table No. 5 Optimum Parameter

Power	Cutting Speed	Pressure	Surface response
Watt	mm/min	Bar	µm
3060	5500	6	2.378

VI. VALIDATION OF OPTIMIZED RESULTS

Table No. 5 Confirmation test for Surface Roughness

Power	Cutting Speed	Pressure	Surface Roughness µm		Error
Watt	mm/min	Bar	Predicted	Experimental	%
3060	5500	6	6	2.406	1.17

A confirmation test is performed using the same experimental setup to confirm the above results and determine the accuracy of the model developed. The confirmation test demonstrates that the surface roughness obtained after cutting is 2.4061 m with 1.17 percent error, which is within the acceptable range [1]. As a result, the confirmation test validates the result.

VII. CONCLUSION

In present work optimized values of the surface roughness has been find out using response surface method for CO_2 laser-cutting of aluminium 7075 T6 sheet of 2mm thickness.

The conclusion made can be drawn on the basis of the obtained results are depicted below:

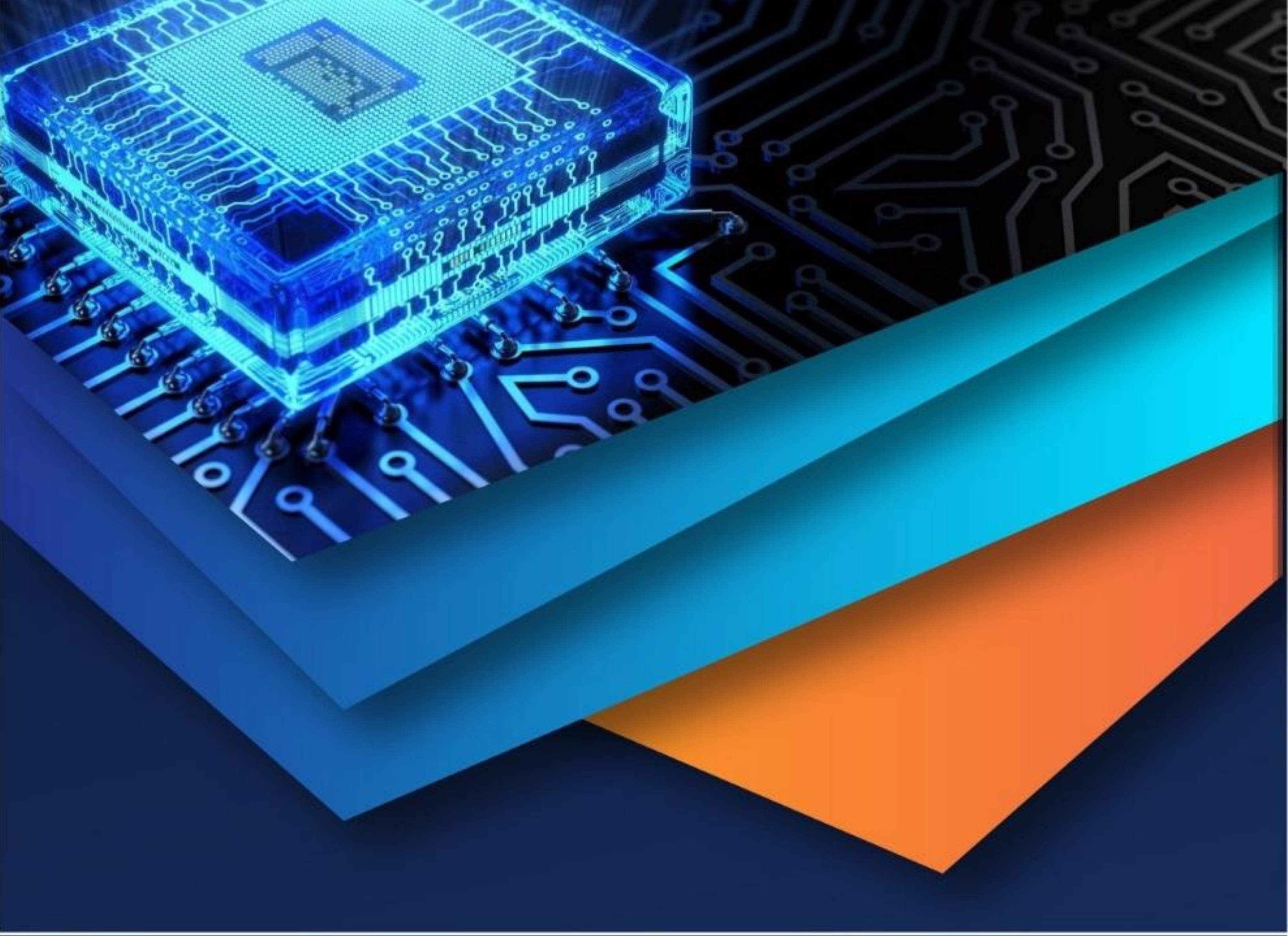
1) Result of Response Surface methodology which shows that minimum surface roughness for Al 707T6 sheet of 2mm thickness can be achieved by operating with the input parameters- Laser Power = 3060 W, Cutting Speed = 5500mm/min, and gas pressure = 6bar.

Here, by using the response surface methodology (RSM), the effect of laser power, speed, and gas pressure on surface roughness was investigated and it can be concluded that pressure is the most important factor influencing surface roughness.

REFERENCES

[1] Davis JR (1998) Aluminium and aluminium alloys. ASM International, Metals Park, pp 6–7

[2] Dr J. Powell, Dr A. Kaplan, Laser cutting: from first principles to the state of the art, Pacific International Conference on Application of Lasers and Optics 2004.
[3] Ujihara K (2006) Reflectivity of metals at high temperatures. J Appl Phys 43:2376 2383
[4] Ciftci I (2006) Machining of austenitic stainless steel using CVD multi-layer coated cemented carbide tools. Tribol Int 39(6):565–569
[5] Dhaval P Patel and Mrugesh B Khatri, "Optimization of High-Power CO2 Laser Machining Centre's Machining Parameters by Experimental Analysis", International Journal of Engineering Research and Applications, vol. 2, pp. 1190-1196. 2012.
[6] Eltawahni. H. A, Hagino. M, Benyounis. K.Y, Inoue. T and Olabi. A. G., "Effect of CO2 laser cutting process parameters on edge quality and operating cost of AISI316L", Optics & Laser Technology, vol. 44, pp. 1068–1082. 2012.
[7] Milos Madic and Miroslav Radovanovic, "Comparative modelling of CO2 laser cutting using multiple Sciences. vol. 7, 2012, 2422–2430. 2012.
[8] Milos Madic, Miroslav Radovanovic and Laurentiu Slatineanu, "Surface Roughness Optimization In CO2 Laser Cutting by Using Taguchi Method", U.P.B. Sci. Bull., Series D, vol. 75. 2013.
[9] Stournaras. P, Stavropoulos. K, Salonitis. G and Chryssolouris, "An investigation of quality in CO2 laser cutting of aluminium", CIRP Journal of Manufacturing Science and Technology. vol. 2, pp. 61–69. 2009.
[10] Umang V Patel and Shrenik M Sanghavi, "Parametric Analysis of Process Parameters of Laser Cutting Machine (Mazak Hyper Gear 510) by Using Anova Method On SS 304", International Journal Of Engineering Sciences & Research Technology. vol. 3,pp. 3007- 3011. 2014.
[11] P. Sabarish et al 2019 IOP Conf. Ser.: Mater. Sci. Eng. 623 012011.
[12] M D Udayakumar et al 2019 IOP Conf. Ser.: Mater. Sci. Eng. 623 012018.
[13] Xuesong Zhang a, *, Yongjun Chen b,**, Junling Hu a" Recent advances in the development of aerospace materials" Progress in Aerospace Sciences 97 (2018) 22–34.
[14] Tolga Dursun a,⇑, Costas Soutis b "Recent developments in advanced aircraft aluminium alloys" Materials and Design 56 (2014) 862–871
[15] Dubey AK, Yadava V (2008) Laser beam machining—a review. Int J Mach Tools Manuf 48:609–628.
[16] Qiu P, Cui M, Kang K, Park B, Son Y, Khim E, Jang M, Khim J (2014) Application of Box–Behnken design with response surface methodology for modelling and optimizing ultrasonic oxidation of arsenite with H2O2. Cent Eur J Chem 12:164–172.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY