

Temperature Distribution and Stress Analysis of Aluminium Oxide Work-Piece during Laser Micro Machining Operation

Salila Ranjan Dixit¹, Prof. Debabrata Dhupal², And Prof. B.K Nanda³

¹PhD Research Scholar, Department of Production Engineering VSSUT, Burla, Sambalpur, Odisha, PIN: 768018.

²(Professor, Department of Production Engineering VSSUT, Burla, Sambalpur, Odisha, PIN: 768018.)

³(Retired Professor, Department of Mechanical Engineering NIT, RKL, Odisha, PIN-769008)

Corresponding Author [E-Mail—salila.simple@gmail.com](mailto:salila.simple@gmail.com)

Abstract. The current study investigates the temperature distribution, stress analysis and material removal of aluminum oxide work piece. Temperature distribution of Aluminum Oxide work-piece when a laser beam (of laser cutting machine) is focused on it to create a micro groove as a part of machining process. Present Demand of industry currently focus on ceramics because of its vast and potential use in many fields such as vehicle sector(automobile), aerospace and bio-medical engineering applications, etc. As part of machining process, a micro groove needs to be created on a crude design material. Aiming at this, a laser cutting machine is employed to create a micro groove which works on a principle that when a high power laser beam is focused on a surface of the body, material gets removed as a result of large amount of heat energy released by the laser beam. Achieving a desired groove of specific dimensions is possible by having control over process parameters of a laser cutting machine which in turn governs the amount of material removed. To tackle with this it is essential to study the temperature distribution (due to heat energy released by laser beam) in the body that is responsible for material removal. ANSYS FEA is used to simulate and analyze this temperature distribution. In this paper temperature graphs for 40W, 50W, Material removal for 40W, 50W, Equivalent stress for 40W, 50W are shown.

Keywords: FEM, laser, Temperature, Thermal stress, ceramic material, Ansys

1. Introduction

Increased demand for advanced machine-intensive materials and the availability of high-power lasers have stimulated interest among researchers in the development of laser beam machining (LBM) processes. The LBM, which is a thermal energy-based machining process, is now widely applied to meet current needs for high flexibility and productivity, non-contact processing, finishing operations elimination, automation adaptability, increased material utilization, processing of materials regardless of electrical conductivity, minimum area affected by heat (HAZ) and green manufacture. In this process, the material is evacuated by (a) melting, (b) vaporization, and (c) chemical degradation where substance bonds break causing corruption of materials. At the point when a high energy density laser beam is centered around a work surface, the heat energy that is heated, assimilated and the work volume is changed into a liquid, vaporized or artificially changed express that can be effortlessly evacuated by the jet stream of High weight auxiliary gas. This procedure likewise does not suggest any mechanical power of cutting and wear of the device. July-August, 2015 Anita Pritam[9] In this paper, a test and numerical investigation on laser percussion drilling was done. A two-dimension (2D)



axisymmetric finite element (FE) show for simulation of temperature field and continuing of entire arrangement amid percussion drilling was produced. The impacts of laser peak power, pulse frequency, pulse width on MRR were investigated by the developed models and experiments comes about were in great concurrence with the analyses. In light of the exploratory and numerical investigation, the procedure parameters were improved and a penetrated opening with low taper and low scatter affidavit was gotten utilizing a 2.5kW CO₂ laser. In this paper, CO₂ laser percussion penetrating of thick-area (5-mm-thickness) 316 stainless steel was examined. It was discovered that the MRR increments with increment in pulse width, pulse frequency and peak power at a given thickness. A. M. Sifullah JAN 2016 [6] amid laser cutting of stainless steel-304 sheet, fleeting variety happens, while stresses are produced. Likewise grain refinement and carbide arrangement is occurred, which starts heat affected zone (HAZ) that need to distinguish. In the mean time, far reaching simulation of CO₂ laser cutting procedure of stainless steel-304 sheet is perplexing as it includes thermo-mechanical issue. In this manner, in this investigation a coupled thermo-mechanical finite element method is created utilizing ANSYS to anticipate the worldly variety together with thermal stress and width of (HAZ). The reproduction results of warm examination demonstrate that the width of HAZ increments with an expansion in laser power and reductions with an expansion in cutting speed. Besides the temperature rises strongly close to the engaged laser beam. However, thermal gradient decreases sharply and gradually with the increase of distance from the cutting edge. From the structural analysis the outcomes of thermal stress was identified.. From the basic examination the results of thermal stress was recognized. It was discovered that maximum stress concentrations were observed at the cutting edge especially at the middle of the work piece which was supported by the analysis of optical microscope and SEM. C.H. Fu1 2015 [7] In this investigation, design of experiment (DOE) based 3-dimensional (3D) finite element analysis was produced to reveal insight into process instruments of laser cutting NiTi. The impacts of cutting speed, peak pulse power, and pulse width on kerf width, temperature, stress, and HAZ were examined. A DFLUX client subroutine was created to demonstrate a moving volumetric (3D) heat flux of a pulsed laser utilized that consolidated super versatility and shape memory of NiTi. Expanding cutting speed decreasing kerf width, stress magnitude in the subsurface, and HAZ thickness, while the impact of pulse peak power is in actuality. pulse width does not have noteworthy effect on kerf width, temperature distribution, and HAZ thickness. Notwithstanding, it will influence the stress distribution. Pulse peak power rules stress arrangement and normal power rules kerf age. Among the different sorts of lasers utilized for machining in industries, the CO₂ and Nd: YAG lasers are the most settled. In spite of the fact that CO₂ lasers are broadly utilized as a part of business sheet metal cutting tasks, the advantages of the Nd: YAG laser make it a fascinating field of research. The exploratory outcomes demonstrate that the Nd: YAG laser has some one of kind qualities. Despite the fact that the normal beam power is moderately low, the beam intensity might be generally high because of a shorter pulse duration and better centering conduct. A littler cutting width, smaller micro holes, smaller HAZ and a superior cutting profile can be gotten in the Nd: YAG LBM process. The lower thermal load offered by the Nd: YAG laser permits the machining of some brittle materials, for example, SiC ceramics, which can't be machined by CO₂ laser without splitting harm. As based on the demand in current industry laser micro machining operation paced a important role but to find a good and smooth dimensional groove, analysis of temperature distribution and analysis of thermal stress is required because for temperature distribution and thermal stress is played a vital role in laser micromachining process. The temperature and Thermal stress modelling is one amongst the complicated method that uses the weld parameters and material properties at higher temperatures. The temperature distribution is non-uniform like fusion zone with liquefied metal, heat affected zone and therefore the base metal zone. Stress analysis may be a general term accustomed describes analyses wherever the results quantities embody stresses and strains. In the present work Temperature dissemination, stress analysis and material removal of Aluminum Oxide work-piece when a laser beam is centered around it to make a micro groove as a piece of machining procedure.

2. ANSYS:

Based upon the today's demand of researcher ANSYS is best simulation software for simulation work. This crates vast field to simulate the problem very quickly and easily. in my research work I am

continuously using Ansys for simulation work. This paper mostly focuses on simulation work using Ansys.

3. Geometry of Work Piece:

A dummy body is created to simulate the effect of Laser beam and is small enough to control the heat flow from this body into work piece. The dimensions of Work-Piece= 4mm X 25 mm X 25 mm. The Fig. 1 shows the geometry of work-piece

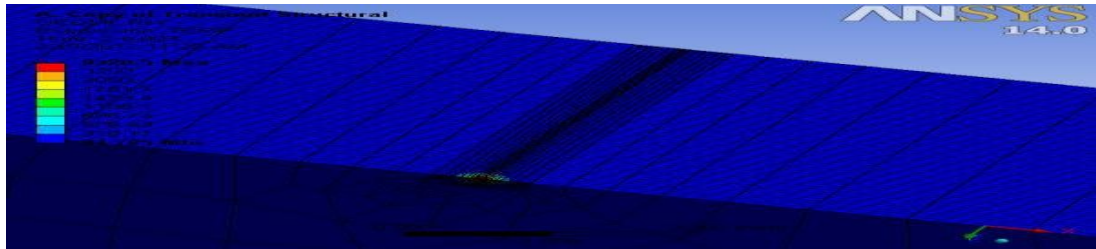


Fig.1 Geometry of work piece where laser like a spot move in work piece

4. Material properties.

Following material properties are the input in Ansys for simulation work.

TABLE: 1—MATERIAL PROPERTIES

Properties	Unit	Value
Density	Kj/Cm3	3.97
Specific Heat	J/Kg	0.900
Thermal conductivity	W/mk	35
Thermal Expansion Coefficient	10^{-6} 1/k	5.4
Vaporization Temperature	k	3250
Emissivity		60%
Volumetric resistivity		10^{16}
Relative permittivity	k'	10
Young's Modulus	Gpa	380
Shear Modulus	Gpa	158
Hard Ness		2000
Poisons Ratio		0.22
Dielectric Strength	Ac-) kv/mm (volts/mil	16.9
Compressive Strength		2600
Flexural Strength	Mpa	379
Bulk Modulus	Gpa	228
Elastic Modulus	Gpa	375
Dielectric Constant	@1MHz	9.8
Dissipation Factor	@1KHz	0.002
Convective Heat Transfer Coefficient	$W/m^2 k$	20

5. Boundary condition.

1. 40W and 50W of Heat is contribution as Heat Flux characterized on the base face of the fake laser body.
2. 25 mm of displacement is defined on the face of a dummy body to simulate the laser beam movement.
3. The base faces of the work-piece are constrained all over.
4. Convection of is described on each one of the qualities of the work-piece displayed to including temperature.
5. Surrounding Temperature is considered as 35 °C.
6. Intensity distribution of laser body 0.1mm

6. Results Analysis:

The Temperature distribution for 40W, 50W and are figured here. With this Material removal and equivalent stress charts also showed. As we know that the Aluminum oxide ceramic material have m melting temperature is 2050 °c. When the laser beam is applied on the material at that time it increases the temperature of that material. When the material temperature is increased to 2050 °c at the point where laser beam was focused the material starts melted. When the temperature again increased at that point above 3050°c the material stars vaporizing then we find the required groove dimension. Simulation result it start melted at 2050 °c and which shown in deep yellow color and start vaporizing at 3050 °c which shows in red color in fig 2, Fig 3 of temperature distribution diagram of laser power 40w, 50w, respectively. Fig 2 And Fig 3 generally represents, when laser is applied to material at that time how many areas of that material affected by temperature known as Heat Affected Zone (HAZ) In fig 2 which is temperature distribution diagram of laser power 40w, the generation temperature is maximum approximately 10000°c but it immediately fluctuates at very instant of time to 5000°c which maintain at constantly till end of the process which is shown in fig 4. In fig 3 which is temperature distribution diagram of laser power 50w, the generation temperature of material will goes to maximum 12000°c but it immediately fluctuate to 7000°c which is maintain at constantly at end of process which is shown in fig 5. Fig 4 And Fig 5 represents the how temperature fluctuates with respect to time(s). So, in this research found that when we increase the laser power the generation temperature will increase so that the material removal process will good because it will achieve its specified groove dimension very easily and quickly due to generation temperature will more shown in fig 6, fig 7, for 40w, 50w respectively. As we know that the thermal stress effect in material removal process has a good hold for achieving the desire result. In fig 8 the thermal stress effect more on red color will varies from 4.60×10^{-14} MPa to 3.68×10^{-5} MPa as the value is very less and it will fluctuate constantly till the end of process as shown in fig 9. Those have less effect in material removal process. Fig 8 and Fig 10 shows the effect of stress on material when laser beam is applied and Fig 9 and Fig 11 shows the Fluctuation of Stress with respect to time(s) when laser beam applied on material. In fig 10 the thermal stress effect more on red color which varies from varies from 4.60×10^{-14} MPa to 3.68×10^{-5} MPa as the value is very less and it will fluctuate constantly till the end of process as shown in fig 11 that have less effect in material removal process.

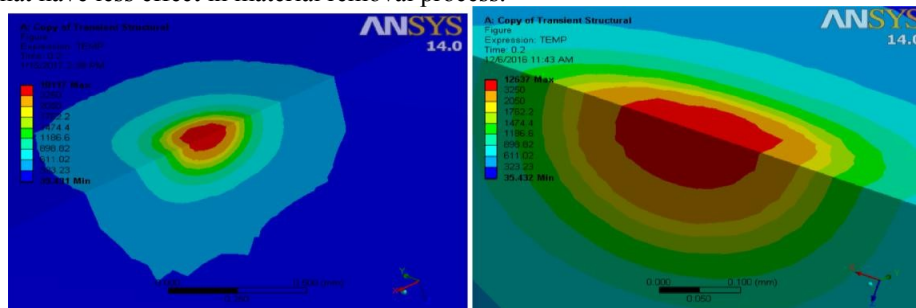


Fig. 2: Temperature Distribution Diagram of 40W Fig. 3: Temperature Distribution Diagram 50 W

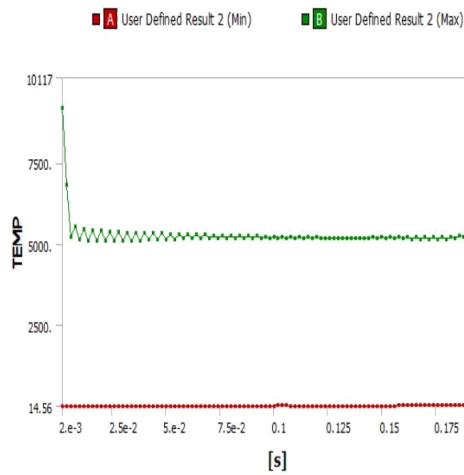


Fig. 4: Temperature Graph of 40W

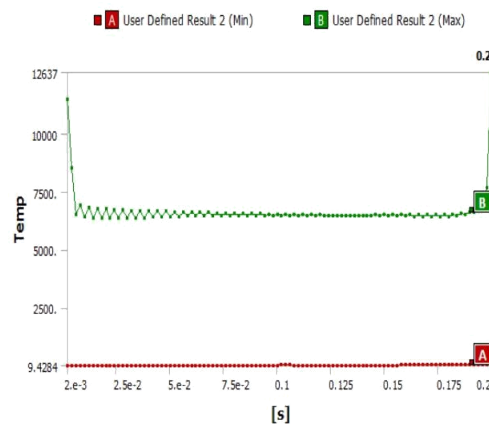


Fig. 5: Temperature Graph of 50W

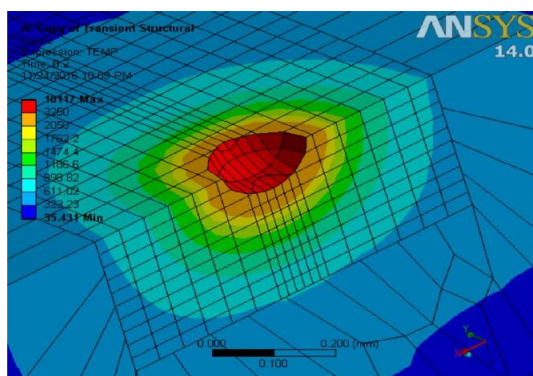


Fig. 6: Material Removal For 40 W

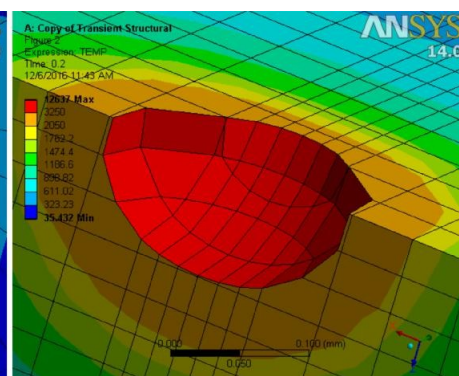
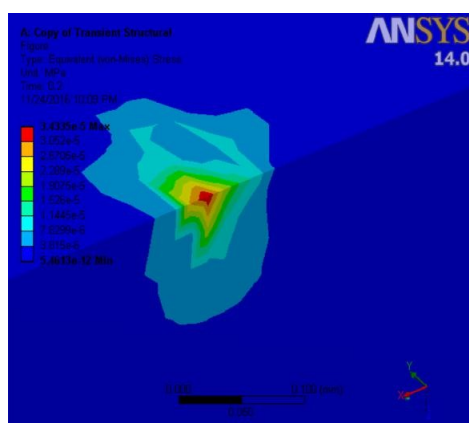


Fig. 7: Material Removal For 50 W



8: Equivalent Stress Diagram for 40 W

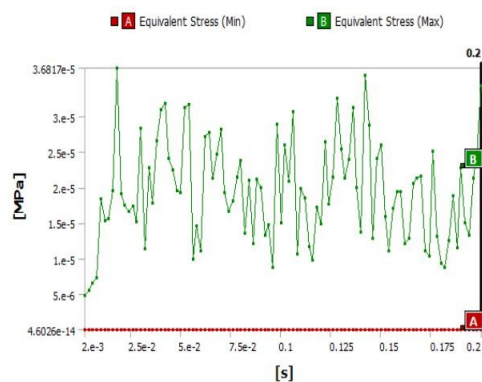


Fig. 9: Equivalent stress Graph 40W

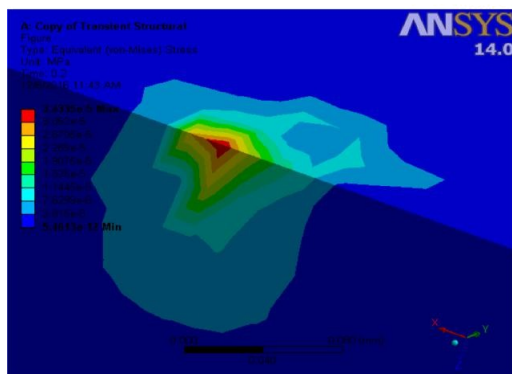


Fig. 10: Equivalent stress Diagram for 50W

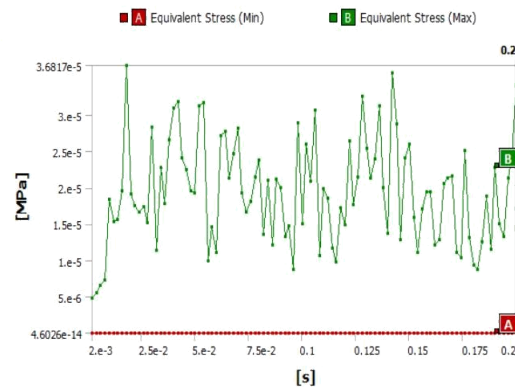


Fig. 11: Equivalent Stress Graph 50W

In this simulation result found that in 40W, 50W, the thermal stress variation is increased and decreased at every instant of time and give less effect on material removal process but the laser power increased above 50W the thermal stress is continuously increased and give more effect on material removal process. Also when increased the Laser power above 50W then the thermal stress value also higher.

As we know that the aluminum oxide ceramic material will start vaporizing at 3250°C. In every laser power the material will vaporize at 3250°C but when we increased the laser power the generation temperature will more and achieve good quality groove with specified dimension very easily and firstly because it takes very less time for vaporization as it is shown in fig for 40W, 50W.

7. Conclusions:

As the laser beam moves along the straight line, the heat flows into the work-piece through convection phenomenon ultimately rising the temperature of the work piece. Observation from the results is that, as the laser beam allows the heat flow into the work piece the temperature is raised at that instant. As the melting & vaporization temperature of aluminum oxide are 2050°C & 3250°C respectively, with respect to stress analysis. it was also found that when laser applied to the aluminum oxide material at a single point where it transfer heat through convection at that point and created a heat affected zone (HAZ) which is easy to simulate temperature distribution at that point. Because of creation of HAZ at that point it takes very less time for temperature generation at point beyond melting point temperature of that material again heat is continuously supplied and vaporize the material at that point and created a accurate dimensional groove which is shown in fig. The Advantage of that is no thermal damage, high machining quality, heat sensitive material machining unmatched accuracy. This is possible by increasing the heat flow of the laser beam (power) or the diameter of the laser beam. Further improvement in the temperature distribution result shall be possible through even smaller time step & mesh size. Because in this paper we are only showing the temperature distribution at a single point where laser is applied but when laser is moving through along a work piece it required more area to simulate. However, this becomes computationally expensive. In simulation, playing around with the input heat of the laser beam may result in the desired dimensions of material removal. Temperature distribution, stress analysis and material removal of aluminum oxide work piece explained.

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