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THERMAL ANALYSIS OF LASER CUTTING USING ANSYS

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Abstract: Lasers are widely used in industry as cutting tools due to ultra-flexibility of the cutting conditions, obtaining high quality end product, quick set up, nonmechanical contact between the workpiece and the tool, and small size of the heat affected zone. In the present study, the FEA analysis of grey cast iron specimen is performed using ANSYS software at different speed of 2.5mm/sec and 5mm/sec of cutting and laser power i.e. 1000W and 1600W. The equivalent stress plot and temperature variation along with kerf width and HAZ (Heat Affected Zone) is studied. The findings have shown that HAZ and thermal stresses are influenced by both parameters laser power and cutting speed.

Key Words: Laser cutting, FEA, Thermal Analysis

1. INTRODUCTION:

Laser cutting is a thermal, non-contact and highly automated process well suited for various manufacturing industries to produce components in large numbers with high dimensional accuracy and surface finish [8]. They also stated that high power density beam when focused in a spot melts and evaporates material in a fraction of second and the evaporated molten material is removed by a coaxial jet of assist gas from the affected zone as shown in Figure 1.

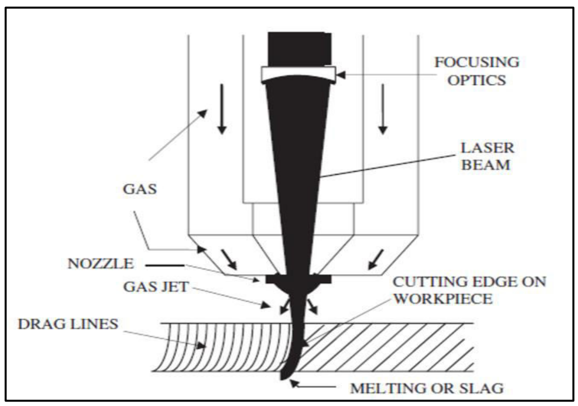

Figure 1. Schematic diagram of laser beam cutting [9]

2. LITERATURE REVIEW

Chen et al [1] has found from his experimental testing of laser cutting operation that clean cut was obtained with an argon gas pressure of 10 bar at a cutting speed of 25 mm/s and an acceptable quality cutting region does not exist for pure oxygen at a pressure of 10 bar, with power ranging from 0.6 to 1.4 kW.

Yilbas et al [2] investigated the effect of cutting parameters on kerf width and cut quality. The statistical method of evaluation has shown that increasing laser power will increase kerf width and increasing laser scanning speed will reduce kerf width.

Hamoudi et al [3] investigated effect of cutting speed, assist gas on HAZ in mild steel. The findings have shown that with increase in cutting speed, the kerf width and the HAZ decreased and vice versa.

Sheng and Joshi et al [4] conducted numerical investigation on 304 stainless steel. The results obtained from numerical investigations are in close agreement with experimental results. The material removal rate (MRR), HAZ and kerf width are also evaluated.

Dilthey et al. [5] investigated cutting operation of mild steel and stainless steel. The results obtained has shown that good quality cutting of stainless steel can be achieved using TEM00 up to 1.5 kW. The dross free cutting can be achieved by making some adjustments in focus position and gas jet.

Cadorette and Walker et al. [6] investigated the efficacy of new laser equipment in in an operational manufacturing environment. The findings have shown that cut quality depends upon various factors like O_2 purity, assist gas pressure, cutting speed and laser power

Wang and Wong et al. [7] have studied the laser cutting of sheet steels coated with zinc and aluminium with thickness ranging from 0.55 to 1 mm. It was shown that by proper control of the cutting parameters good-quality cuts are possible at a high cutting speed of 5000 mm/min. It was revealed that high laser power above 500 W results in a poor- quality cut. They reported that the kerf width generally increases with increasing gas pressure and laser power, and with a decrease in cutting speed. They recommended a method of setting the parameters to control and optimize the process.

3. OBJECTIVE

The objective of this project is to study thermal stresses and structural stresses on aluminium specimen due to laser cutting operation. The CAD model of specimen is developed in Creo design software and analysed in ANSYS software. The investigation is conducted for 1000W and 1600W laser power.

4. METHODOLOGY

The CAD model of specimen is prepared using Creo 2.0 design software. Creo is sketch based, feature based, parametric 3d modelling software developed by PTC and having properties of bidirectional associativity and parent child relationship. The dimensions of specimen are 50mm * 25mm [10]. Laser beam passes through colored slices in mid portion.

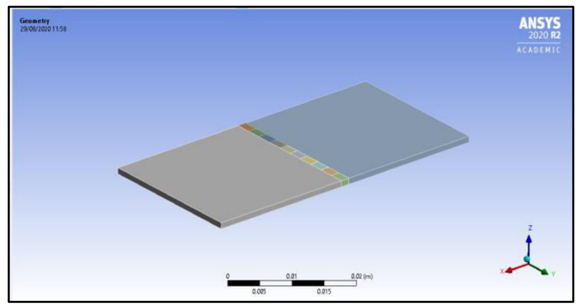

Figure 2: CAD model of specimen

The CAD model is meshed using hexahedral elements with fine sizing. Inflation high, size function adaptive, span angle coarse. Number of elements formulated is 3880 and number of nodes formulated is 22856.

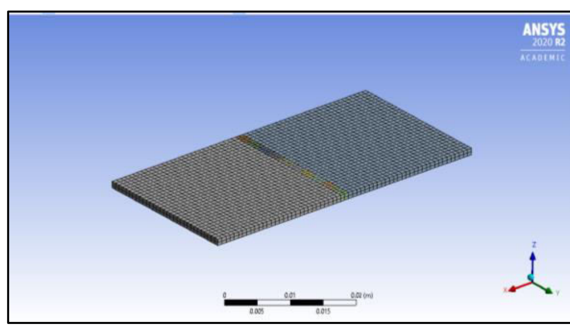

Figure 3: Meshed model of specimen

Thermal flux of 1000W magnitude is applied on different segments. The analysis is time dependent and thermal flux is shifted to next segment in subsequent time intervals. The heat flux boundary condition is shown in and figure 4 below. The analysis is performed for 10 counter secs under transient state thermal analysis.

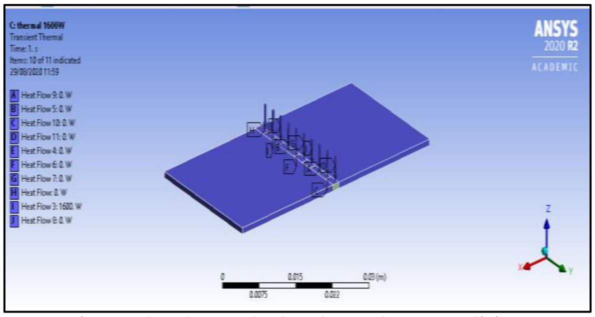

Figure 4: Thermal Flux boundary condition

Software carries out matrix formulation, matrix multiplication and inversions. Global stiffness matrix is formulated and results are carried out at each node and results are interpolated for entire element edge length. In postprocessing stage contour plots of temperature are plotted at different time intervals and segments. The results of thermal analysis are exported to static structural analysis module. The boundary conditions are assigned here with frictionless support on left end as shown in figure 5. In this analysis software computes stresses and deformation at each load step.

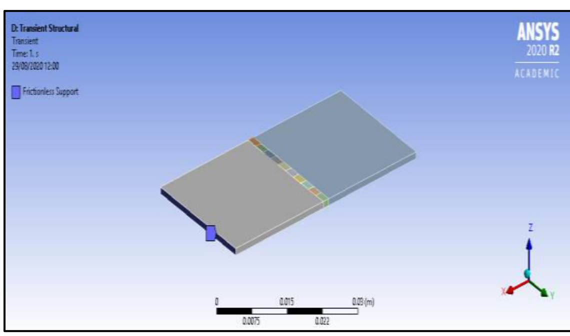

Figure 5: Frictionless support on left end of specimen

Transient structural analysis is performed and stresses are calculated at each thermal load. Deformation is also computed at each load steps.

5. RESULTS AND DISCUSSION

Thermal analysis is conducted on cast iron specimen using ANSYS and temperature contours are plotted. The analysis is conducted using 1000W laser which is applied in the form of heat flux. The analysis is carried out for 10 secs and divided in 10 load steps. In each load step the thermal flux moves on to next segment.

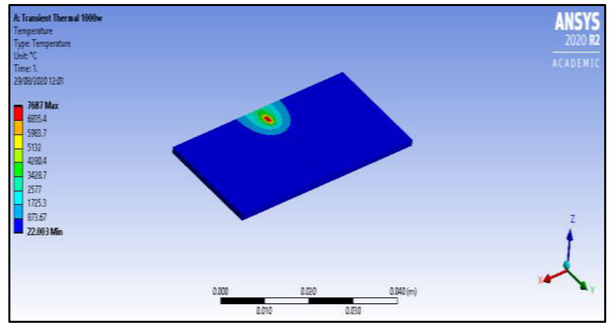

Figure 6: Temperature plot at 1 secs

Figure 6 above shows temperature plot at 1 secs after laser cutting operation. The maximum temperature is 7687°C and minimum temperature is 873.67°C. The temperature reduces as we move away from cutting zone depicted by red colour to light blue colour.

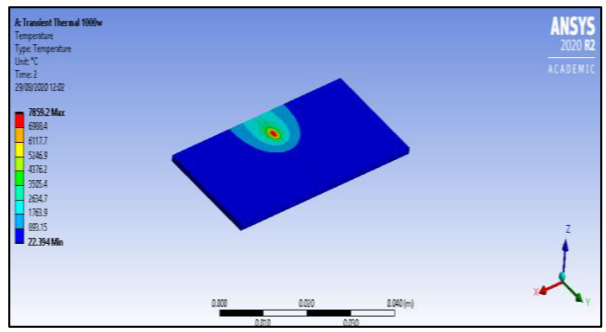

Figure 7: Temperature plot at 2 secs

Figure 7 above shows temperature plot at 2 secs after laser cutting operation. The maximum temperature is 7859.2°C and minimum temperature is 893.15°C. The temperature reduces as we move away from cutting zone depicted by red colour to light blue colour.

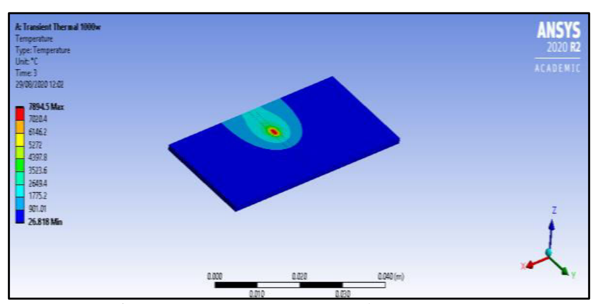

Figure 8: Temperature plot at 3 secs

Figure 8 above shows temperature plot at 3 secs after laser cutting operation. The maximum temperature is 7894.5°C and minimum temperature is 901.01°C. The temperature reduces as we move away from cutting zone depicted by red colour to light blue colour.

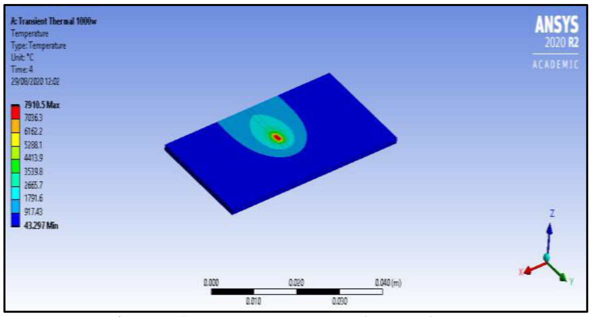

Figure 9: Temperature plot at 4 secs

Figure 9 above shows temperature plot at 4 secs after laser cutting operation. The maximum temperature is 7910.5°C and minimum temperature is 917.43°C.

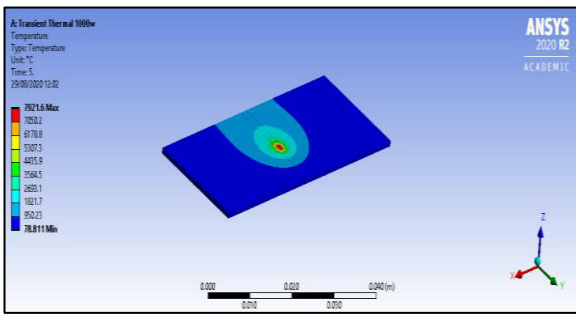

Figure 10: Temperature plot at 5 secs

Figure 10 above shows temperature plot at 5 secs after laser cutting operation. The maximum temperature is 7921.6°C and minimum temperature is 950.23°C.

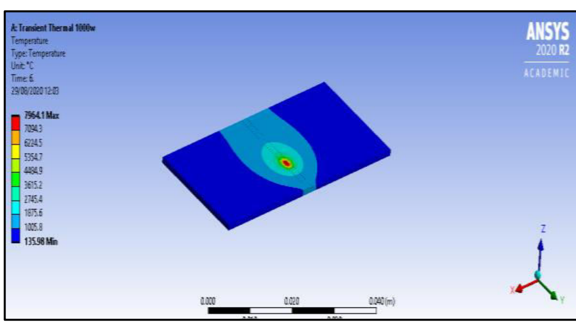

Figure 11: Temperature plot at 6 secs

Figure 11 above shows temperature plot at 6 secs after laser cutting operation. The maximum temperature is 7964.1°C and minimum temperature is 1005.8°C. The temperature reduces as we move away from cutting zone depicted by red colour to light blue colour.

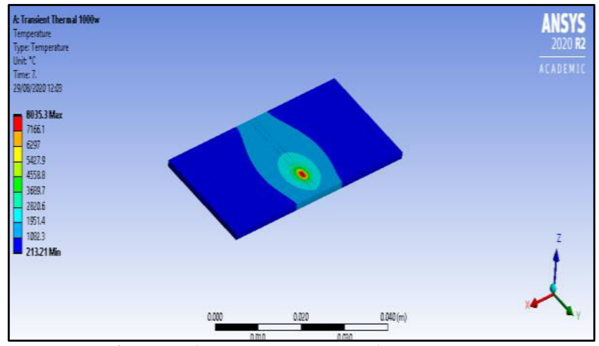

Figure 12: Temperature plot at 7 secs

Figure 12 above shows temperature plot at 7 secs after laser cutting operation. The maximum temperature is 8035.3°C and minimum temperature is 1082.3°C. The temperature reduces as we move away from cutting zone depicted by red colour to light blue colour.

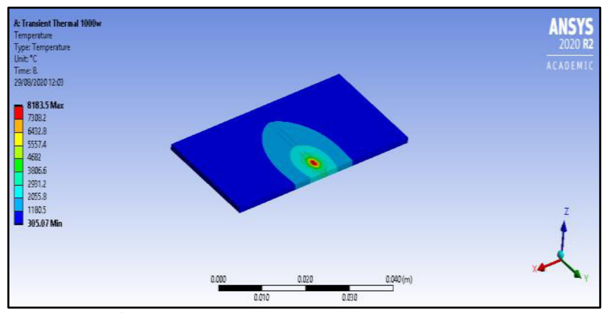

Figure 13: Temperature plot at 8 secs

Figure 13 above shows temperature plot at 8 secs after laser cutting operation. The maximum temperature is 8183.5°C and minimum temperature is 1180.5°C. The temperature reduces as we move away from cutting zone depicted by red colour to light blue colour.

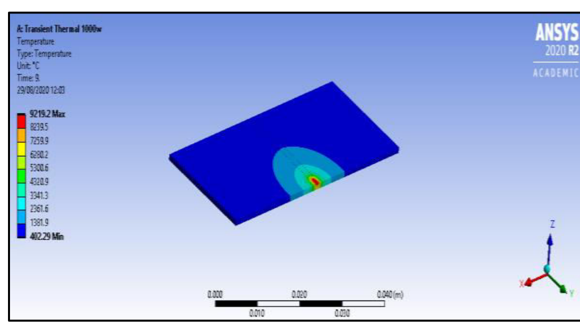

Figure 14: Temperature plot at 9 secs

Figure 14 above shows temperature plot at 9 secs after laser cutting operation. The maximum temperature is 9219.2°C and minimum temperature is 1381.9°C. The temperature reduces as we move away from cutting zone depicted by red colour to light blue colour.

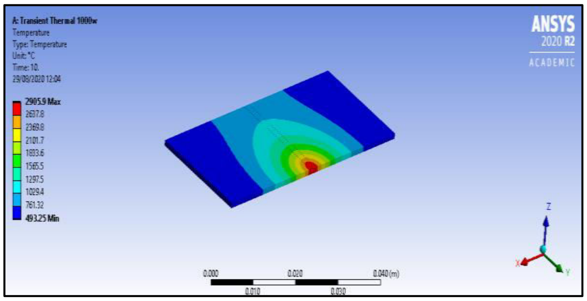

Figure 15: Temperature plot at 10 secs

Figure 15 above shows temperature plot at 10 secs after laser cutting operation. The maximum temperature is 2905.9°C and minimum temperature is 761.32°C. The temperature reduces as we move away from cutting zone depicted by red color to light blue colour.

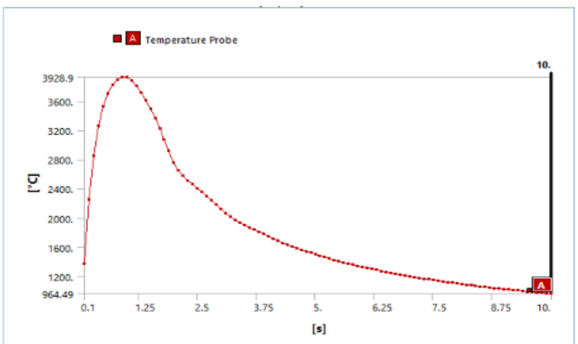

Figure 16: Temperature plot at at 1mm distance

Figure 16 shows temperature time curve at a point 1mm away from cutting zone which shows increase in temperature up to 3982.9°C and reduces to 1400°C

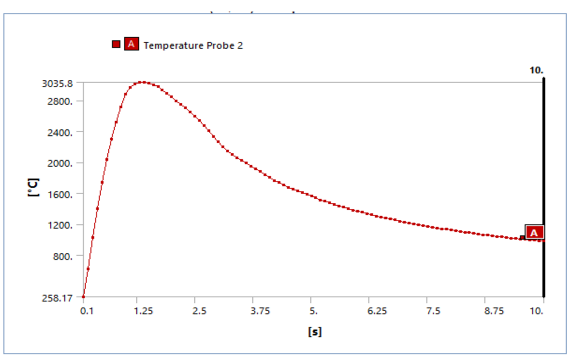

Figure 17: Temperature plot at at 2mm distance

Figure 17 shows temperature time curve at a point 2mm away from cutting zone which shows increase in temperature up to 3058.8°C and reduces to 1180°C

Width of HAZ [11] = Kerf width + 2*HAZ = 3.56

Table 1: Heat Affected Zone using 1000 and1600W laser

LASER POWER	1000W	1600W
HAZ	3.56	3.98

Table 2: Max temperature attained using 1000W and 1600W laser

LASER POWER	Max Temp (° C)	Max Equivalent Stress MPa
1000W	9219.2	4040
1600W	11150	6007.9

Table 3: Max temperature attained using 1600W at 2.5mm/sec and 5mm/sec

Speed	Max Temp (° C)	Max Equivalent Stress MPa
2.5mm/sec	11150	6007.9
5mm/sec	8994	5087.3

6. CONCLUSION

The FEA analysis is conducted on thin aluminium specimen using ANSYS software for different thermal flux i.e. 1000W and 1600W and also at different speed of laser cutting i.e. 2.5mm/sec and 5mm/sec. The temperature plot along with thermal stresses are determined. The detailed results are as:

1> HAZ determined from analysis shows higher value for 1600W heat flux i.e. 3.98 as compared to 1000W heat flux.

2> Laser power has effect on maximum temperature as well as HAZ. Lower laser power i.e. 1000W develops lower maximum temperature of 9212°C and higher laser power i.e. 1600W develops higher maximum temperature of 11150^0C.

1> The equivalent stress generated from 1000W laser power is 4040MPa and equivalent stress generated using 1600W laser power is 6007.9MPa which shows that equivalent stress generated is directly affected by laser power.

2> The equivalent stress, HAZ and maximum temperature is affected by cutting speed. Increasing cutting speed of cutting decreases HAZ and equivalent stress while reducing cutting speed led to increase in HAZ, equivalent stress and maximum temperature attained.

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