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A Study on the Laser Preheating Effect of Inconel 718 Specimen with Rotated Angle with Respect to 2-axis

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Lately, LAM(Laser Assisted Machining) is a newly developed method for processing of difficult-to-cut material. LAM is a processing method which softens the difficult-to-cut material by laser preheating. The purpose of this research is to study the laser preheating effect of Inconel 718 specimen with rotated angle with respect to 2-axis in LAM. A specimen with rotated angle with respect to 1-axis is difficult to predict preheating temperature because focus of the laser is changed from circle to ellipse. And, temperature prediction of the specimen with rotated angle with respect to 2-axis is even more difficult because focus of the laser is changed once again to modified ellipse. In this paper, a study on the laser preheating effect of the specimen with rotated angle with respect to 2-axis is carried out. And, preheating experiments are performed to compare with the analysis results. It is expected that the proposed methods can be used to predict the preheating temperature for the specimen with rotated angle.

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1. Introduction

Researches for processing of difficult-to-cut material have been actively performed by developing new processing technologies. Processing of difficult-to-cut material such as fine ceramics, high heat resistance alloy and titanium alloys is difficult to process because difficult-to-cut material has high strength and brittleness.[1-4]

LAM (Laser Assisted Machining) is a processing method which softens the difficult-to-cut material by laser preheating, and then the ductility of the material can be increased.[5] Researches had been performed for processing of various shape such as plane or square shaped bar by using the LAM.[6] The laser power prediction to maintain sufficient temperature is important for the processing by the LAM. The laser power and temperature prediction for complicated specimens such as processing of specimen with rotated angle with respect to 2-axis is more difficult than plane or square shaped bar, because the shape of laser heat source is changed along the processing path.[7] The focus of the laser is changed to elliptical shape for specimen with rotated angle with respect to 1-axis. And, the focus of the laser is changed to modified elliptical shape for specimen with rotated angle with respect to 2-axis.

Kim et al. predicted preheating temperature of specimen by using thermal analysis with Heat source projection method in LAT (Laser Assisted Turning) of square bar.[6] Rozzi et al. carried out researches about prediction of surface temperature of silicon nitride in LAM.[8] Wang et al. proposed a method to predict the distribution of temperature for moving heat source in welding.[9]

In this study, an analysis method to obtain the laser preheating effect for specimens with rotated angle with respect to 2-axis is proposed. The experiments and analyses for Inconel 718 are performed by the proposed method.

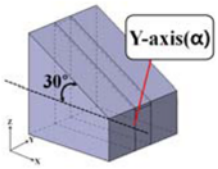
2. Finite Element Model

2.1 Analysis modeling

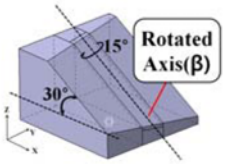
The modeling is made using CATIA V5R19 software as shown in Fig. 1. The rotated specimen with respect to y-axis (α) is shown in Fig. 1(a), and the rotated specimen with respect to y-axis (α) and rotated-axis (β) is shown in Fig. 1(b). Table 1 shows the boundary conditions for the thermal analysis such as convective heat transfer coefficient, density and laser heat source diameter, etc.

2.2 Thermal analysis method

Heat source projection method suggested by the present author is used.[7] The laser heat source is radiated consecutively according to feed



(a) Rotated wrt y-axis (α)



(b) Rotated wrt y-axis (α) and rotated-axis (β)

Fig. 1 Analysis model according to rotated axes

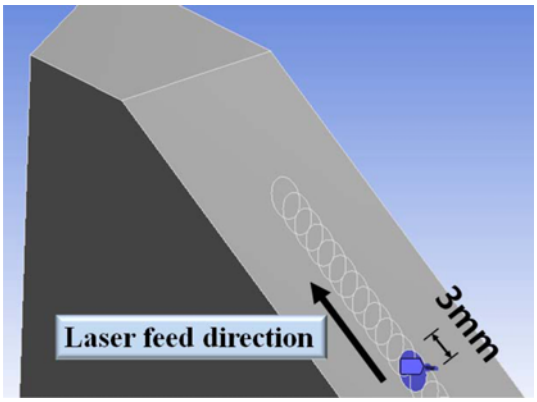


Fig. 2 Sequence of analysis for laser preheating

Table 1 Boundary conditions of the analysis

Material	Inconel 718
Convective heat transfer coefficient	5 W/m^2°C
Heat source diameter	3 mm
Density	8193.23 kg/m^3
Laser power	100, 120, 140 [W]
Laser feed rate	100, 150, 200 [mm/min]
α	0°, 15°, 30°
β	0°, 15°, 30°

rate by the overlaps along laser feed direction, as shown in Fig. 2. The analyses are performed according two cases. One case is that laser power is fixed, and the other case is that feed rate is fixed. ANSYS workbench 13.0 is used as analysis software.

2.3 Results of analysis

Table 1 represents the results of analyses for laser power and feed rate. α and β are 0, 15 and 30, respectively. Analyses are performed for 45 cases.

Fig. 3 shows analysis cases according to α and β. Table 2 shows the analysis results for the case that laser power is 140 W and feed rate is 100 mm/min.

Preheating temperature of specimen with rotated angle with respect to α and β is lower than that of the specimen with rotated angle with respect to α. Laser heat source is deformed to modified elliptical shape

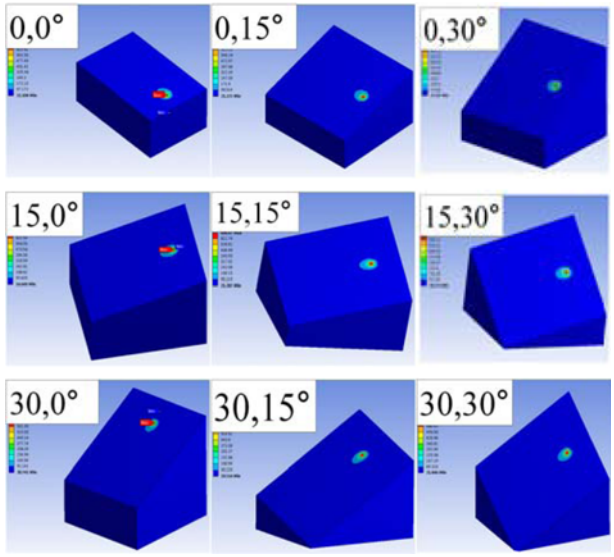


Fig. 3 Analysis cases according to α and β

Table 2 Result of thermal analysis by 140 W and 100 mm/min

Angle (°) α, β	Maximum Temperature (°C)
0, 0	705.68
0,15	698.84
0,30	663.48
15, 0	698.52
15,15	686.67
15,30	656.36
30, 0	663.35
30,15	655.95
30,30	632.3

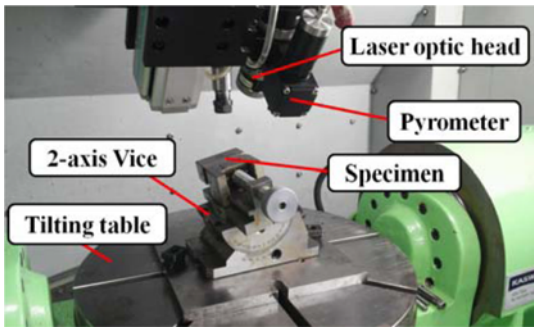


Fig. 4 Experimental setup

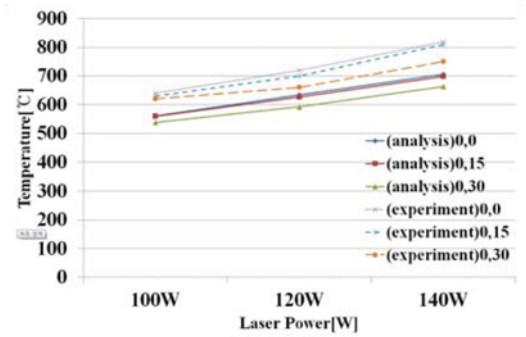
with respect to the α and β. Preheating temperature of specimen is measured as low because heat input for laser heat source was decreased.

3. Experiment

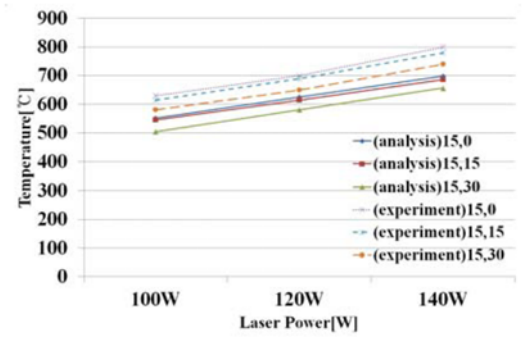
3.1 Experimental equipment

Preheating experiments are performed by using CNC 5-axis machining center. Fig. 4 shows the laser devices, jig and fixture attached on the 5-axis machining center.

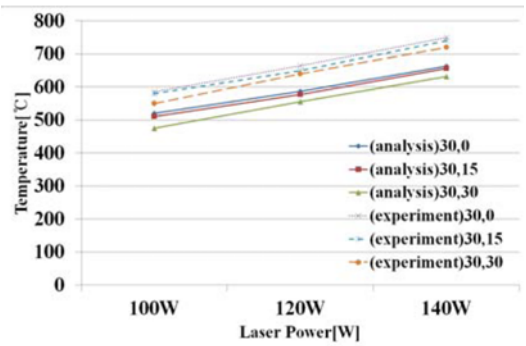
The material used in this preheating experiment is Inconel 718. Inconel 718 is extensively applied in the automobile parts, gas turbine



(a) 0° rotated angle wrt α and β

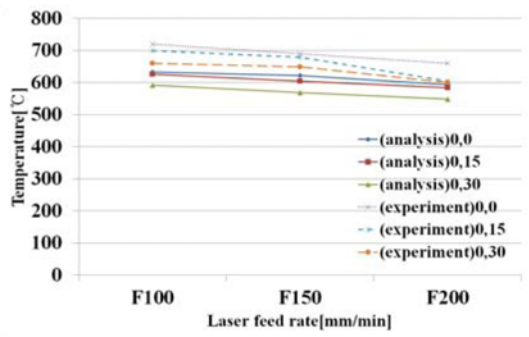


(b) 15° rotated angle wrt α and β

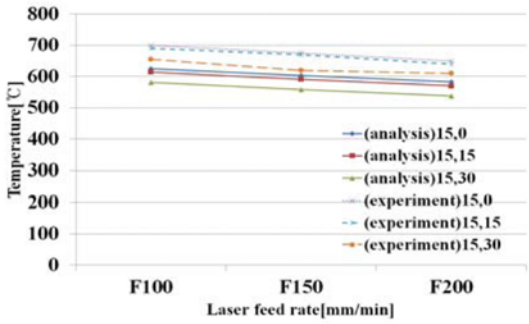


(c) 30° rotated angle wrt α and β

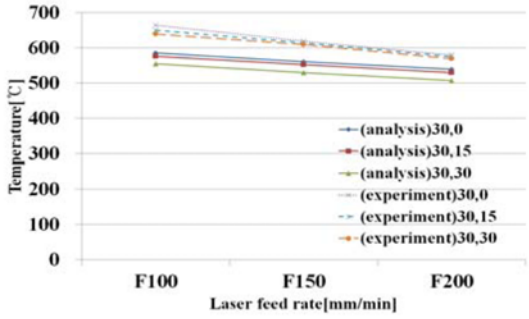
Fig. 5 Comparison of the results for the cases of feed rate is 100 mm/min



(a) 0° rotated angle wrt α and β



(b) 15° rotated angle wrt α and β



(c) 30° rotated angle wrt α and β

Fig. 6 Comparison of the results for the cases of laser power is 120 W

and nuclear industries. But, processing of Inconel 718 is difficult, because Inconel 718 is a heat resisting alloy, and has superior strength and corrosion resistance. And, hardening and abrasion can be occurred easily by machining. So, the processing of Inconel 718 using LAM can obtain good machining results.[10-13]

3.2 Comparison of preheating experiment results

Experiments and analyses are carried out by varying the laser power as 100 W, 120 W and 140 W, and fixing the feed rate 100 mm/min for the specimens according to rotated angles 0°, 15°, 30° with respect to α and β.

Fig. 5 shows the comparison of analyses and experimental results for the 27 cases which the feed rate is fixed as 100 mm/min. Similar tendencies of the preheating temperature are shown for each cases. Preheating temperature increases as laser power increases, and preheating temperature decreased as rotated angle increases.

By comparing the preheating experiments and analyses, the preheating temperature by experiments and analyses show error rates about 9-14%.

Fig. 6 shows the comparison of analyses and experimental results for the 27 cases which the laser power is fixed as 120 W. Similar tendencies of the preheating temperature are shown for each cases. Preheating temperature increases as feed rate decreases, and preheating temperature decreased as rotated angle increases.

By comparing the preheating experiments and analyses, the preheating temperature by experiments and analyses show error rates about 6-11%.

4. Conclusion

In this study, analyses and experiments for laser preheating effect of Inconel 718 specimen with rotated angle with respect to 2-axis are performed. Analyses are performed for the various cases of laser power, laser feed rate and rotated angle, and showed good agreement with the experiments. The results of this study are as follows.

1) Preheating temperature of specimen with rotated angle with respect to 2-axis is lower than that of the specimen with rotated angle with respect to 1-axis. Laser heat source is deformed to modified

elliptical shape with respect to the 2-axis. So, preheating temperature of specimen is measured as low.

2) It is shown that the preheating temperature increases as laser power increases, and preheating temperature decreased as rotated angle increases. And the preheating temperature increases as feed rate decreases, and preheating temperature decreased as rotated angle increases.

3) Estimation of adequate laser power and feed rate to maintain sufficient preheating temperature by the suggested analysis and experiment is necessary to obtain good processing results.

It is expected that proposed methods in this study can be used to predict the preheating temperature for the specimen with rotated angle.

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