Forming of Thick Steel Plates with Diode Laser†

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Diode lasers have the great merit of high energy conversion efficiency compared with CO_2 or Nd:YAG lasers which are commonly used for materials processing. Their high efficiency allows a small size of oscillator, power supply and cooling chiller unit. Recently they have also demonstrated high power and high power density, such as kW level and 100kW/cm^2 level. These features can have merit when applied to not only the small size manufacturing field but also the large size construction field. However, their beam qualities are still not good for thick plate welding which requires a high power density and long focusing distance.

Laser forming does not require a high power density compared with other welding processes, because it utilizes a laser only for heating materials but not for melting it. Therefore it will be one of the most suitable applications for the direct diode laser having a low power density. A 2kW high power diode laser system was tested for laser forming of steel of 5mm or 10mm in thickness.

Figure 1 shows an experimental apparatus for diode laser forming. The size of the SUS304 stainless steel specimens was 100mm x 125mm with a thickness of 5mm or 10mm. Laser power was fixed at 1000W and the beam diameter was selected as 2.7mm, 3.2mm and 3.6mm, which corresponded with the mean power density of 8.3kW/cm^2, 10kW/cm^2 and 13.4kW/cm^2, respectively. A beam scanning speed was fixed at 1.0m/min or 1.5m/min. The

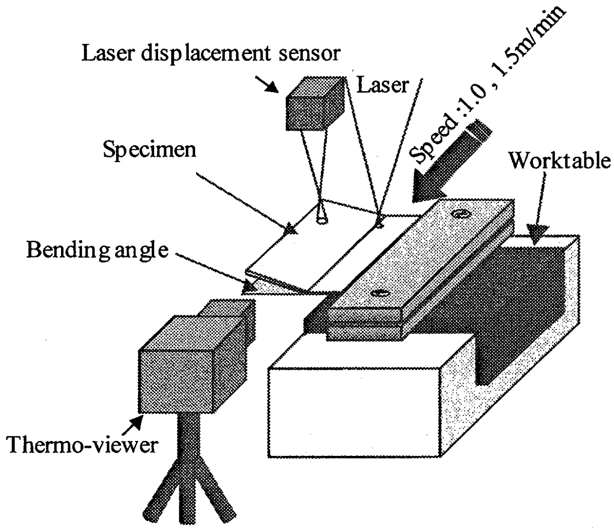

Fig. 1 Experimental apparatus

deformation of the specimen was measured by a laser displacement sensor. Temperature distribution was measured by a thermo viewer from the front of laser scanning direction.

Figure 2 shows the 3D temperature distribution during laser irradiation, the 2D temperature distribution 10mm behind the laser irradiation point and surface appearances after irradiation of 5mm thick plates for the various beam diameters. Since the measured temperature distribution by thermo viewer at the laser irradiation point was saturated because of the narrow temperature range of the sensor, 2D temperature distribution 10mm behind the laser irradiation point was selected as the distribution

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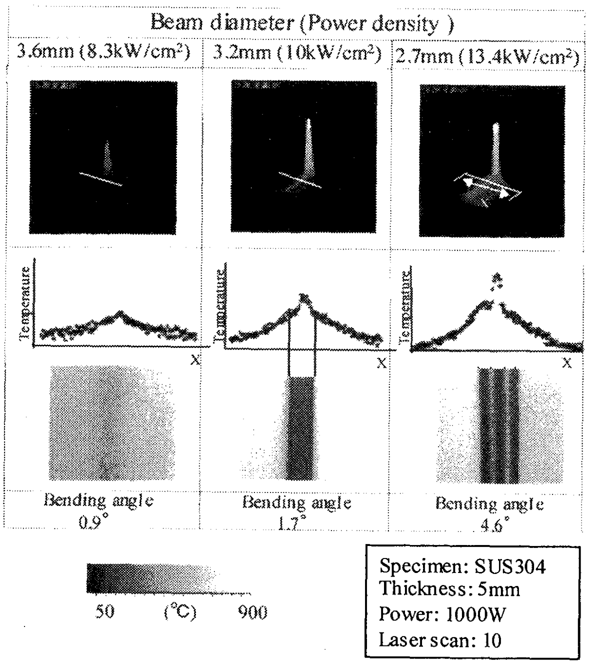


Fig. 2 Temperature distribution and surface appearance

measurement point. When the beam diameter was 3.6mm and the mean power density was 8.3kW/cm^2, the bending angle after 10 laser scans was 0.9 degrees. The temperature distribution was flat and the burning pattern could not be recognized on the specimen's surface. When the beam diameter decreased to 3.2mm and the mean power density increased to 10kW/cm^2, the temperature distribution became steep and a burning pattern was clearly seen. The specimen's surface was not melted and the bending angle of 1.7 degrees was obtained after 10 laser scans. When the beam diameter was focused to 2.7mm and the mean power density became 13.4kW/cm^2, the specimen's surface was melted, and the bending angle increased to 4.6 degrees. From the 2D temperature distribution, it was found that the temperature of the center part was extremely high and the melting zone of the specimen corresponded to this high temperature zone. This is because the beam profile of diode laser was quit non-uniform at this focal length.

Figure 3 shows the comparison of temperature distribution of 5mm thick specimen and 10mm thick specimen at the same beam diameter of 3.2mm and the different scanning speeds of 1m/min and 1.5m/min. At the same irradiation conditions for the 5mm thick specimen of 3.2mm and 10kW/cm^2 beam and scanning speed of 1.5m/min, a 10mm thick

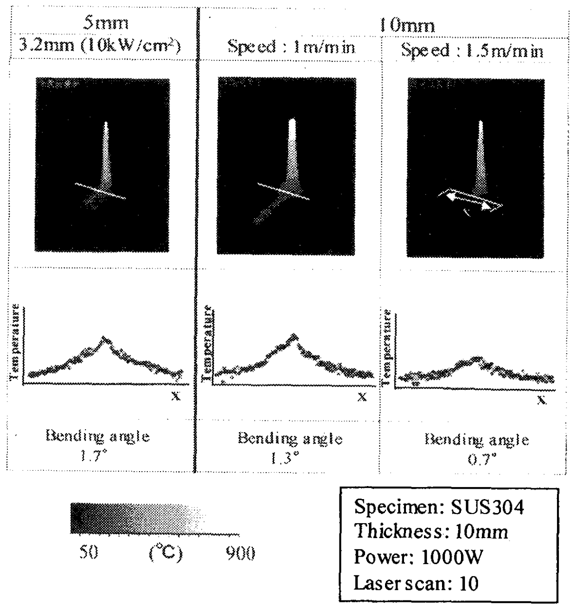
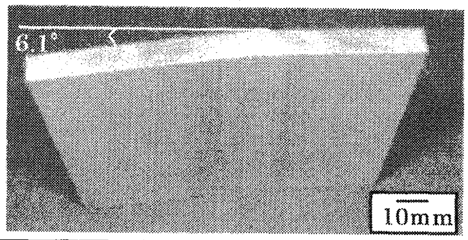


Fig. 3 Comparison of temperature distribution between steel plates with different thickness



Power : 1000W Specimen : SUS304 Thickness : 10mm
Scanning speed : 1.0m/min Laser scan : 50

Fig. 4 Laser forming of 10mm thick SUS304 steel plate by high power diode laser

specimen showed very small bending angle of 0.7 degrees. The temperature distribution 10mm behind the irradiation point was quit similar to that of the low power density case of 8.3kw/cm^2 in Fig.2. It is thought that as the heat capacity of the 10mm thick specimen was large than that of 5mm specimen, it dose not show the temperature distribution as well as that of 5mm thick specimen. When the scanning speed was decreased to 1.0m/min, the temperature distribution became similar to that of 5mm thick specimen and the bending angle of 1.3 degrees was obtained. **Figure 4** shows the example of laser forming with 50 laser scans for 10mm thick SUS304 stainless steel plate at the optimum irradiation conditions. It is concluded that the high power diode laser can be applied to laser forming of thick steel plate and in order to achieve large bending angles, a sufficient temperature rise with uniform beam profile is necessary.