Abstract

Laser melting of gray cast iron was carried out using a 600W continuous wave Yb:YAG fiber laser under different parameters of laser, processing, and material surface roughness, based on Taguchi L16B design of experiments. The variables are, laser power (80,230,380 and 530 W), beam diameter (1.5, 1.9, 2.4 and 3.3 mm), traverse speed (2.5, 5.10 and 20 mm/s), shrouding gas flow rate(0.5,10 and 20 SLPM), and surface roughness (0.203, 2.127,3.623 and 5.363 µm). The output of Taguchi design of experiments is described by volume of melt, also the relation between spot diameter and the melt width was investigated. Different equations were obtained that explain the relation between laser parameters and the geometrical dimensions, time to melt, peak temperature and normalized temperature of heat affected zone.

Methods and Materials

Yb: YAG fiber-diode laser was used in these experiments with 1080 nm is fixed into the head of CNC machine. The spot size of the laser beam is controlled by changing the distance between the work-piece and the focus point of focusing lens. Argon was used as shrouding gas. Gray cast iron samples with dimensions of (80, 40, 5) mm on were used with properties illustrated by Rehab [5]. Gray cast iron were used and their surfaces were prepared to be with different four surface roughness before firing the laser. 2. Table 1 includes the chemical composition of as received samples

Table 1 Chemical composition of as received gray cast iron.

<table>
<thead>
<tr>
<th>Element</th>
<th>Carbon</th>
<th>Silicon</th>
<th>Phosphorus</th>
<th>Sulfur</th>
<th>Manganese</th>
<th>Phosphorus</th>
<th>Sulfur</th>
<th>Manganese</th>
</tr>
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<tbody>
<tr>
<td>C</td>
<td>3.66</td>
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<td>0.03</td>
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<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
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<tr>
<td>Si</td>
<td>2.12</td>
<td>2.01</td>
<td>0.04</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>P</td>
<td>0.03</td>
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<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>S</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
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<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
</tr>
</tbody>
</table>

- Calculation of melt volume:

\[ V_{\text{melt}} = \frac{\pi}{4} (D_{\text{spot}} - h)^2 h \times \frac{1}{2} \text{mm}^3 \] (1)

- Calculation of time to melt:

\[ t_m = (\pi D_{\text{spot}} h)^2 \] (2)

- Calculation of peak temperature of HAZ:

\[ T_p = 0.5 \times T_{\text{spot}} + 0.5 \times T_{\text{scan}} + T_{\text{ambient}} \] (3)

- Calculation of normalized temperature

\[ T_n = \frac{T_p - T_{\text{ambient}}}{T_{\text{spot}} - T_{\text{ambient}}} \] (4)

- Calculation of peak temperature

\[ T_{\text{peak}} = \frac{2 k T_m}{\pi d^2} + \frac{1}{T_{\text{ambient}}} \] (5)

Result and Discussion

Volume of melt

- Fig. 1 Relation between the power irradiance and the volume of melt per unit time.

It is clear that the theoretical volume is more than experimental and both of them increase with increasing power irradiance. It means that there is high amount of heat lost, either to the ambient, consumed by the shrouding gas, dissipated by the inclusions or conducted to the bulk.

The relation between theoretical and experimental volumes of melt per unit time, and the traverse velocity is represented in Figure 2.

Fig. 2 Relation of theoretical and experimental volume of melt per second and the traverse velocity.

Figure 2 shows that the volume of melt increases as the traverse velocity increases, because the delivered heat is consumed in melting and not allowed to be conducted to the bulk.

The relation of the surface average roughness with the theoretical and experimental volume of melt per unite time is represented in Figure 3.

Fig. 3 Relation of surface average roughness with theoretical and experimental volume of melt.

Figure 4 shows that surface average roughness have little effect on the volume of melt, and there is no direct proportional relation between roughness and volume of melt. Reducing the volume of melt for increasing the roughness till 2µm and increasing it as the roughness increases more than 3.66 µm is may be due to the contributions of other parameters of laser. And it agree with Bergström [7].

Conclusions

- The experimental volume of melt is less than theoretical, and increases as laser power irradiance increases.
- There is no important effect of average surface roughness on the volume of melt.
- For irradiance more than melting threshold, increasing the time of melt increases volume of melt.

References