A novel and comprehensive method for laser forming of cylindrical surfaces with arbitrary radius of curvature

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ABSTRACT

Laser forming is a flexible forming process that needs no hard tooling or external forces. In this paper, laser forming of cylindrical surfaces with arbitrary radius of curvature is investigated analytically and experimentally. As the laser forming process is a die-less forming process, production of a desired shape from initial blank that directly affect the final shape of the produced part. Also, in addition to the above mentioned parameters, in the laser forming process of a cylindrical surface, a new parameter says the number of irradiating lines is added to variable parameters. Therefore complexity of laser forming of a cylindrical surface will be more than a simple laser bending. In this paper, an analytical and experimental results show that with the proposed analytical method, cylindrical surfaces with arbitrary radius of curvature can be produced with very good accuracy.

Please cite this article using:
1- Defocused laser beam
2- Temperature gradient mechanism (TGM)
3- Buckling mechanism (BM)
4- Upsetting mechanism (UM)
5- Response surface methodology
2- کار تجربی

رهنمایی

راهبرد برای تولید سطوح استوانهایی با شما انعطاف دامنه

3- مدل‌سازی

3- Coordinate Measuring Machine (CMM)
4- Easson ENC-565

Fig. 1 The equipment used in experimental tests
شکل 1 چگالی‌سازی مورد استفاده در آزمایش‌های تجربی

Fig. 2 The Power-meter used to measure laser power
شکل 2 دستگاه‌ای برای اندازه‌گیری توان لیزر

Fig. 3 A sample of cylindrical parts produced by laser and using the proposed method
شکل 3 نمونه‌ای از قطعات استوانه‌ای تولید شده به کمک لیزر با استفاده از روش

1- Reci laser- Model: W6
2- Macken instruments- Model: P-100

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مهندسی کانال‌کشی، سال 1394، دویره 15، شماره 12
Fig. 4 Experimental setup used to measure the allowable distance between adjacent irradiating lines

Fig. 5 Irradiating pattern used to produce cylindrical surface

Fig. 1-PSIP 310
Fig. 6 Schematic of the relationship between final bending angle of plate, bending angle in each irradiating line and also the number of heating lines in the pattern with parallel irradiating lines

Fig. 7 Schematic of created curvature in the plate as a circular sector after irradiating with parallel heating lines

\[ b = \frac{1}{\pi} N \times a \]

\[ c = 2 \times b \]

\[ L = R \times c \]

\[ L = R \times N \times a \]

\[ \text{in which } L, R, N, a, b, c \text{ and } R_e \text{ are the length of the total line, the radius of curvature, the number of heating lines, the length of each heating line, the length of each sector, and the radius of the curvature, respectively.} \]

\[ \text{with } R_e = \frac{L}{N} \]

\[ \text{and } R = \frac{L}{c} \]

\[ \text{where } L \text{ and } R_e \text{ are the length of the total line and the radius of the curvature, respectively.} \]

\[ \text{with } L = R \times N \times a \]

\[ \text{and } R = \frac{L}{c} \]

\[ \text{where } L, R, N, a, b, c \text{ and } R_e \text{ are the length of the total line, the radius of curvature, the number of heating lines, the length of each heating line, the length of each sector, and the radius of the curvature, respectively.} \]

\[ \text{with } R_e = \frac{L}{N} \]

\[ \text{and } R = \frac{L}{c} \]
RAOIEH XESH WROK MINASANIB TAGEHRAF VETR BIROY DIDEHE MI SHOD.

FIG. 8 Allowable distance between adjacent irradiating lines, a- Schematic of various positions of the thermocouple from irradiating line, b- The diagram of transferred heat to adjacent points with different displacements related to irradiating line

Table 1 Changes in surface temperature and bending angle of the sheet in accordance with the change of laser power

<table>
<thead>
<tr>
<th>Zaweheh Xesh (°C)</th>
<th>300</th>
<th>600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spand (Wans)</td>
<td>0.82</td>
<td>1.24</td>
</tr>
<tr>
<td></td>
<td>2.74</td>
<td>1.93</td>
</tr>
<tr>
<td></td>
<td>3.24</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td>2.74</td>
<td>1.93</td>
</tr>
</tbody>
</table>

Table 2 Changes in surface temperature and bending angle of the sheet in accordance with the change of scanning speed

<table>
<thead>
<tr>
<th>Zaweheh Xesh (mm/min)</th>
<th>120</th>
<th>210</th>
<th>250</th>
<th>355</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sareh (Wans)</td>
<td>3.42</td>
<td>2.81</td>
<td>2.34</td>
<td>1.63</td>
</tr>
<tr>
<td></td>
<td>0.92</td>
<td>0.92</td>
<td>0.92</td>
<td>0.92</td>
</tr>
</tbody>
</table>

**Table 3 Changes in surface temperature and bending angle of the sheet in accordance with the change of beam diameter**

<table>
<thead>
<tr>
<th>Zaweheh Xesh (mm)</th>
<th>0.5</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spand (Wans)</td>
<td>2.51</td>
<td>2.33</td>
<td>1.82</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>882</td>
<td>801</td>
<td>640</td>
<td>400</td>
</tr>
</tbody>
</table>

**Fig. 8** Diagrams of various positions of the thermocouple from irradiating line, a—Schematic of various positions of the thermocouple from irradiating line, b—The diagram of transferred heat to adjacent points with different displacements related to irradiating line.
یک خط ناشی به‌دست آمده در مجاورت خط ناشی دیگر یک نشان دهنده وجود یک تیز در مجاورت خط ناشی دیگر است. این نشان دهنده وجود یک تیز در ارتفاعات یک خط ناشی است. این نشان دهنده وجود یک تیز در ارتفاعات یک خط ناشی است.

4.2 محدودات

4.2.1 محدودات شماژن

4.2.1.1 محدودات انتخاب

4.2.2 محدودات انتخاب

4.3 محدودات

4.3.1 محدودات انتخاب

Table 4 The results of measurement of bending angle in each irradiating plane and total bending angle of the sheet after each irradiation

<table>
<thead>
<tr>
<th>رابطه خشک در هر خط (Degrees)</th>
<th>تاثیز دهی</th>
<th>رابطه خشک در هر خط (Degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.17</td>
<td>3.34</td>
<td>1.17</td>
</tr>
<tr>
<td>2.34</td>
<td>2.34</td>
<td>5.51</td>
</tr>
<tr>
<td>3.51</td>
<td>2.34</td>
<td>3.51</td>
</tr>
<tr>
<td>4.68</td>
<td>2.34</td>
<td>4.68</td>
</tr>
</tbody>
</table>

5- تحقیق گیری

5.1 ماهیت و روش

5.1.1 ماهیت

5.1.2 روش

5.2 محدودات

5.2.1 محدودات شماژن

5.2.2 محدودات انتخاب

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</tr>
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<td>4.68</td>
<td>2.34</td>
<td>4.68</td>
</tr>
</tbody>
</table>

5.4 نتایج

5.4.1 نتایج غیر باریک

5.4.2 نتایج خشک

5.5 نتایج

5.5.1 نتایج غیر باریک

5.5.2 نتایج خشک
Table 5: Investigation and comparison of the results of proposed method and experimental work

<table>
<thead>
<tr>
<th>Shaping Method</th>
<th>Transverse Strain (%)</th>
<th>Transverse Strain (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer 1</td>
<td>Layer 2</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>2.0</td>
<td></td>
</tr>
</tbody>
</table>