The Influences of Extrusion and Multi-Directional Forging (MDF) Processes on Microstructure, Shear Strength and Microhardness of AM60 Magnesium Alloy

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ABSTRACT
In the present study, AM60 magnesium alloy was cast and then subjected to hot extrusion process. Next, Multi Directional Forging (MDF) experiments with six pass numbers were conducted to investigate the influence of the operation on the microstructure and mechanical properties of these alloys. The shear punch test (SPT) and Vickers microhardness test were employed to evaluate the mechanical properties of the extruded and MDFed samples. Both the shear yield stress (SYS) and ultimate shear strength (USS) obtained from the shear punch test increased just after two passes but decreased with further pressing, although it was expected that the grains become finer with increasing the pass number. After two passes USS increased from 121.58 MPa to 142.42 MPa. This rise and fall indicates that texture softening overcame the strengthening effects of the grain refinement. The Vickers microhardness was measured across the cross sections of the extruded and MDFed samples, the results of this test also confirm this. The average microhardness of the extruded and MDFed samples were found to be respectively 73.50, 85.93, 82.26 and 77.83 HV for the extruded and 2.4 and 6 passes of MDFed, which confirms SPT results. Optical micrographs showed that processing by MDF reduces the grain size from 11.22 to 1.91 µm after 6 passes.

چکیده
در پژوهش حاضر، نخست از آیاز سایز مایع AM60-ها در یک گرده گرفته، است بدست آمده از آتی و نتایجی از آن فاز چندمطیعه که بزرگترین گرده و خروج از آن را در پژوهش حاضر می‌باشد. از تاثیر میکروسکوپی برای انرژی از آن فاز چندمطیعه که بزرگترین گرده و خروج از آن را در پژوهش حاضر می‌باشد. از تاثیر میکروسکوپی برای انرژی از آن فاز چندمطیعه که بزرگترین گرده و خروج از آن را در پژوهش حاضر می‌باشد. از تاثیر میکروسکوپی برای انرژی از آن فاز چندمطیعه که بزرگترین گرده و خروج از آن را در پژوهش حاضر می‌باشد.
The chemical composition (wt %) of AM60 alloy

<table>
<thead>
<tr>
<th></th>
<th>Aluminum (Al)</th>
<th>Zinc (Zn)</th>
<th>Magnesium (Mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM60</td>
<td>8.65</td>
<td>0.45</td>
<td>10.55</td>
</tr>
</tbody>
</table>

Fig. 1 A schematic representation of MDF

Table 1 The chemical composition (wt %) of AM60 alloy

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</tbody>
</table>

410
Fig. 2 Casting geometry and dimensions in millimeters

Fig. 3 Casting alloy sample after turning

Fig. 4 Extruded sample

Fig. 5 Prepared samples for the MDF process

1. Wire cut
2. Mechanical Test System
آزمون سیمبیرش

نتایج آزمون سیمبیرش به‌عکس مابلندی درجه 1000 به 0.7 میلی‌متر به هدف حفظ آرا برای نمایش در این اثر به رسمیت با استفاده از گراف میکروسکوپی نتایج در نتایج نهایی (ξ) و تاثیرات نتایج نهایی (γ) از هر پاس به‌عنوان نتایج نهایی چارش شد.

نمونه‌هایی با یکداخمه زیر 135 × 800 × 6000 میلی‌متر از سیمبده‌ها با استفاده از گراف میکروسکوپی نتایج نهایی (ξ) و تاثیرات نتایج نهایی (γ) از هر پاس به‌عنوان نتایج نهایی چارش شد.

2-4-1 تأثیر آزمون نسبی بر دیسپلاستیک

برای بررسی تأثیر نمایش چند‌گزینه‌ای و بررسی آزمون سیمبیرش به‌عنوان نمونه‌های با یکداخمه زیر 135 × 800 × 6000 میلی‌متر از سیمبده‌ها با استفاده از گراف میکروسکوپی نتایج نهایی (ξ) و تاثیرات نتایج نهایی (γ) از هر پاس به‌عنوان نتایج نهایی چارش شد.

3-نمونه‌هایی با یکداخمه زیر 135 × 800 × 6000 میلی‌متر از سیمبده‌ها با استفاده از گراف میکروسکوپی نتایج نهایی (ξ) و تاثیرات نتایج نهایی (γ) از هر پاس به‌عنوان نتایج نهایی چارش شد.

\[ P = \frac{2m + 1}{2m^2} \]

\[ \tau = \frac{m}{n + 1} \]

\[ \rho = \frac{m}{n + 1} \]

4-1 در این رابطه 2 رابطه 3 نمونه بررسی وزن، P نیروی وارد شده، 0.7 شرایط نمونه‌است.

برای بررسی تأثیر نمایش چند‌گزینه‌ای و بررسی آزمون سیمبیرش به‌عنوان نمونه‌های با یکداخمه زیر 135 × 800 × 6000 میلی‌متر از سیمبده‌ها با استفاده از گراف میکروسکوپی نتایج نهایی (ξ) و تاثیرات نتایج نهایی (γ) از هر پاس به‌عنوان نتایج نهایی چارش شد.

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Fig. 9 Shear stress plotted against the normalized punch displacement for the extruded and MDPEd specimens

Table 2 Variations of shear yield stress and ultimate shear strength after extrusion and MDF process

<table>
<thead>
<tr>
<th>Shear Stiffness (%)</th>
<th>Extruded (MPa)</th>
<th>2 Passed (MPa)</th>
<th>4 Passed (MPa)</th>
<th>6 Passed (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>99.81</td>
<td>121.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>133.74</td>
<td>142.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>123.34</td>
<td>139.92</td>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>116.29</td>
<td>5.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Shrink 3 Nibers of the diameter of the as-extruded (a) 2 passes of MDF (b) 4 passes of MDF (c) and 6 passes of MDF operation (d) of the AM60 alloy

Table 3 Grain size variation in micrometer after extrusion and MDF process

<table>
<thead>
<tr>
<th>Process</th>
<th>Average grain size (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extrusion</td>
<td>3.63</td>
</tr>
<tr>
<td>MDF 2 passes</td>
<td>1.2</td>
</tr>
<tr>
<td>MDF 4 passes</td>
<td>0.7</td>
</tr>
<tr>
<td>MDF 6 passes</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Fig. 11 Optical micrographs showing the grain sizes for the as-extruded (a), 2 passes of MDF (b), 4 passes of MDF (c) and 6 passes of MDF operation (d) of the AM60 alloy

<table>
<thead>
<tr>
<th>Grain size variation in micrometer after extrusion and MDF process</th>
<th>AM60</th>
</tr>
</thead>
<tbody>
<tr>
<td>as-extruded (a)</td>
<td>3.63</td>
</tr>
<tr>
<td>MDF 2 passes (b)</td>
<td>1.2</td>
</tr>
<tr>
<td>MDF 4 passes (c)</td>
<td>0.7</td>
</tr>
<tr>
<td>MDF 6 passes (d)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Critical grain size (d_c)

11.22 4.25  2.63  1.91

Downloaded from mme.modares.ac.ir at 9:45 IRDT on Tuesday July 13th 2021
Fig. 13 The ultimate shear strength and micro-hardness variations in terms of the number of MDF passes

<table>
<thead>
<tr>
<th>MDF Pass Number</th>
<th>USS (MPa)</th>
<th>Microhardness (HV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>125</td>
<td>65</td>
</tr>
<tr>
<td>4</td>
<td>130</td>
<td>70</td>
</tr>
<tr>
<td>8</td>
<td>140</td>
<td>75</td>
</tr>
</tbody>
</table>

Fig. 14 Dependence of the microhardness of the ECAPed samples on the number of passes [14]

<table>
<thead>
<tr>
<th>ECAP Pass Number</th>
<th>Microhardness (HV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>120</td>
</tr>
<tr>
<td>4</td>
<td>130</td>
</tr>
<tr>
<td>8</td>
<td>140</td>
</tr>
</tbody>
</table>

Fig. 12 Dependence of the microhardness of the MDFed samples on the number of passes

<table>
<thead>
<tr>
<th>MDF Pass Number</th>
<th>Microhardness (HV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>120</td>
</tr>
<tr>
<td>4</td>
<td>130</td>
</tr>
<tr>
<td>8</td>
<td>140</td>
</tr>
</tbody>
</table>

3-1 - The effect of ECAP on the microhardness of MDFed samples

3-2 - The effect of MDF on the microhardness of ECAPed samples

3-3 - The effect of ECAP and MDF on the microhardness of the samples

3-4 - The effect of MDF on the microhardness of ECAPed samples

3-5 - The effect of ECAP on the microhardness of MDFed samples

3-6 - The effect of ECAP and MDF on the microhardness of the samples

3-7 - The effect of MDF on the microhardness of ECAPed samples

3-8 - The effect of ECAP and MDF on the microhardness of the samples

3-9 - The effect of MDF on the microhardness of ECAPed samples

3-10 - The effect of ECAP and MDF on the microhardness of the samples

3-11 - The effect of MDF on the microhardness of ECAPed samples

3-12 - The effect of ECAP and MDF on the microhardness of the samples

3-13 - The effect of MDF on the microhardness of ECAPed samples

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3-16 - The effect of ECAP and MDF on the microhardness of the samples

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3-18 - The effect of ECAP and MDF on the microhardness of the samples

3-19 - The effect of MDF on the microhardness of ECAPed samples

3-20 - The effect of ECAP and MDF on the microhardness of the samples

3-21 - The effect of MDF on the microhardness of ECAPed samples

3-22 - The effect of ECAP and MDF on the microhardness of the samples

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3-46 - The effect of ECAP and MDF on the microhardness of the samples

3-47 - The effect of MDF on the microhardness of ECAPed samples

3-48 - The effect of ECAP and MDF on the microhardness of the samples

3-49 - The effect of MDF on the microhardness of ECAPed samples

3-50 - The effect of ECAP and MDF on the microhardness of the samples


