Microstructure Evolution, Mechanical Properties, and Mechanism Analysis of AZ31 Magnesium Alloy by Electroplastic Rolling
電致塑性軋制 AZ31 鎂合金的變形機制及其組織與性能研究

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GUAN Lei
官磊

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MICROSTRUCTURE EVOLUTION, MECHANICAL PROPERTIES, AND MECHANISM ANALYSIS OF AZ31 MAGNESIUM ALLOY BY ELECTROPLASTIC ROLLING

GUAN LEI

DOCTOR OF PHILOSOPHY
CITY UNIVERSITY OF HONG KONG
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ABSTRACT

On account of the hcp structure and inactiveness of the non-basal slip systems, it is difficult to process magnesium alloys at low temperature (< 473 K). Magnesium alloy sheets are usually fabricated by hot or warm rolling. During this process, a multiple-pass operation incorporating small rolling reduction, intermediate annealing, and maintaining rolls at 423-473 K is employed to suppress edge cracks and fracture of the alloys and to maintain the workability. The complex process and high energy consumption lead to a high production cost, thereby hampering commercial applications of magnesium alloys. Hence, there is a need for a new fabricating process for magnesium alloy sheets.

Electroplastic manufacturing processing (EPMP) is one of the most effective ways to simplify the manufacturing processes while enhancing the properties of the final products. However, the EPR mechanism is still unclear. The objectives of the research work described in this thesis are: (1) to analyze the mechanism of the microstructural evolution in cold rolled AZ31 magnesium alloy during electropulsing treatment (EPT) by texture analysis, (2) to investigate the microstructure and texture development during electroplastic rolling (EPR), and (3) to explore the microstructure and texture evolution in EPR AZ31 magnesium alloy sheets during EPT.

The thesis is organized into three parts as described in the following. Firstly, the microstructural evolution in cold rolled AZ31 magnesium alloy during electropulsing treatment (EPT) is analyzed by texture analysis. The recrystallization mechanism during electropulsing is found to depend on the previous amount of reduction. The recrystallized grains give rise to the tilted basal texture by a rotation of 45°~60° from the rolling direction (RD) towards the normal direction (ND). The mechanism of the
microstructural evolution during electropulsing is discussed from the point of view of grain boundary motion.

Secondly, single large pass draught rolling by electroplastic rolling is conducted on AZ31 magnesium alloy sheets below 473K without heating rolls. The synergistic thermal and athermal effects during EPR are responsible for the low temperature dynamic recrystallization (DRX) within twins and shear bands. The inclination angle of the basal pole stems from the counterbalance between the inclination direction of the basal pole of the DRX grains and coarse-deformed grains.

Thirdly, after low temperature EPR, a large amount of stored plastic deformation preserves within grain boundaries and shear bands, thereby constituting the driving force for consequent recrystallization by subsequent EPT. The microstructure and texture evolution in EPR AZ31 magnesium alloy sheets during EPT are investigated and correlated with the mechanical properties.
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# LIST OF SYMBOLS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Symbol</th>
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<tbody>
<tr>
<td>AZ31</td>
<td>Mg-3Al-1Al</td>
</tr>
<tr>
<td>CDRX</td>
<td>Continuous dynamic recrystallization</td>
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<tr>
<td>CR</td>
<td>Cold rolling</td>
</tr>
<tr>
<td>DRX</td>
<td>Dynamic recrystallization</td>
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<tr>
<td>EBSD</td>
<td>Electron backscattered diffraction method</td>
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<tr>
<td>EL</td>
<td>Elongation to failure</td>
</tr>
<tr>
<td>EP</td>
<td>Electroplastic</td>
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<td>EPD</td>
<td>Electroplastic drawing</td>
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<td>Electropulsing treatment</td>
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<tr>
<td>HABM</td>
<td>High angle boundary</td>
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<td>HCP</td>
<td>Hexagonal close packed</td>
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<td>HEPRS</td>
<td>High electroplastic rolling speed</td>
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<td>LABM</td>
<td>Low angle boundary migration</td>
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<td>LEPRS</td>
<td>Low electroplastic rolling speed</td>
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<td>LTDRX</td>
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<tr>
<td>RMS</td>
<td>Root-mean-square current</td>
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<td>SEM</td>
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<td>Strain induced grain boundary migration</td>
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<td>Transverse direction</td>
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<tr>
<td>TEM</td>
<td>Transmission electron microscopy</td>
</tr>
<tr>
<td>UTS</td>
<td>Ultimate tensile strength</td>
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