Mg alloys production and research of Aluminum Corporation of China Limited

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Preface

Contents

1. Contents

1. Production and Research of Magnesium Alloys of Zhengzhou Light Metal Research Institute

Zhengzhou Light Metal Research Institute is the unique large-scale research institutes in China's light metal field. It is a research center of CHALCO, making a great contribution to the rapid development of China's aluminum and magnesium industry. Its research and development of silicon thermal reduction magnesium method ensure China primacy for decades.

- China's light metal professional field only large-scale scientific research institutions
- China Light Metal Academic Committee Secretary - General unit
- International Magnesium Standards Association (IMA) Secretary General
- National Light Metal Quality Supervision and Inspection Center
- National Aluminum Smelting Engineering Technology Research Center
- China Aluminum Industry Co., Ltd. Postdoctoral Research Station
- International Organization for Standardization (ISO) in China technical standards focal point
- Non-ferrous metal standard sample of fixed - point development
Advantages of Mg-Li alloys

- Ultra light, high specific strength, high specific modulus
- Excellent rigidity
- Conductive, heat conduction
- High damping capacity
- Excellent electromagnetic shielding performance
- Can be welded, good machining and cold formability

Research

- Casting: Low vacuum induction melting and gas protection melting
- Alloying: Aluminum, zinc, rare earth elements (including mixed rare earth, Y, La, etc.); alkali metals (Ca, Sr, etc.) and Sn, Pb, etc.
- Deformation: Extrusion, forging
- Heat treatment: Annealing, solid solution, homogenization
- Surface treatment: Micro-arc oxidation, anodizing, plating
- Security: Flammable and explosive, lithium toxicity protection
1.1 Ultra-light Mg-Li alloy

Production (research and development) of the Mg-Li alloy grades and performance

<table>
<thead>
<tr>
<th>Grade</th>
<th>Density g/cm³</th>
<th>Hardness HB</th>
<th>Tensile Strength MPa</th>
<th>Yield Strength MPa</th>
<th>Elongation %</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA91</td>
<td>1.45</td>
<td>45-75</td>
<td>180-240</td>
<td>120-190</td>
<td>10-30</td>
</tr>
<tr>
<td>LA141</td>
<td>1.35</td>
<td>40-70</td>
<td>160-230</td>
<td>100-170</td>
<td>20-40</td>
</tr>
<tr>
<td>LZ91</td>
<td>1.48</td>
<td>45-75</td>
<td>180-240</td>
<td>140-180</td>
<td>15-35</td>
</tr>
<tr>
<td>MA21</td>
<td>1.6</td>
<td>50-80</td>
<td>200-260</td>
<td>150-220</td>
<td>6-25</td>
</tr>
<tr>
<td>MA18</td>
<td>1.48</td>
<td>45-65</td>
<td>140-210</td>
<td>90-180</td>
<td>10-30</td>
</tr>
</tbody>
</table>

Including the standard grade alloy and special composition of Mg-Li alloy, its mechanical properties meet or better than the United States or the former Soviet Union production of magnesium alloy.

1.1 Ultra-light Mg-Li alloy

Typical products and applications

Zhengzhou Light Metal Research Institute produces high-quality large-scale magnesium alloys ingots. The ingots would be forged, extruded or rolled, to produce magnesium alloys forging slabs, bars and sheets or plates. It has developed a variety of Mg-Li alloys parts, including many military and civilian customers, widely used in aerospace, transportation and 3C products.

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Part name</th>
<th>Application areas</th>
<th>Customer category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Single combat with communications radar</td>
<td>Communication</td>
<td>Military</td>
</tr>
<tr>
<td>2</td>
<td>UAV parts</td>
<td>Aviation</td>
<td>Military, Civil</td>
</tr>
<tr>
<td>3</td>
<td>Fighter antenna bearing</td>
<td>Aviation</td>
<td>Military</td>
</tr>
<tr>
<td>4</td>
<td>Satellite grating shell</td>
<td>Aviation</td>
<td>Military, Civil</td>
</tr>
<tr>
<td>5</td>
<td>Aeronautical equipment housing parts</td>
<td>Aviation</td>
<td>Military</td>
</tr>
<tr>
<td>6</td>
<td>Waveguide</td>
<td>Communication</td>
<td>Military</td>
</tr>
<tr>
<td>7</td>
<td>Other</td>
<td>Transportation, 3C</td>
<td>Civil</td>
</tr>
</tbody>
</table>

1.1 Ultra-light Mg-Li alloy

1) Ingot casting

At present, a large size of Mg-Li alloy ingot has been successfully produced. The diameter of ingot can reach 350mm. In addition, a 200 * 800 mm flat ingot mold is made, and the trial is preparing.

Mg-Li alloy ingot with a diameter of 350mm

Mg-Li alloy ingot with a diameter of 240mm

1.1 Ultra-light Mg-Li alloy

2) Plate (foil)

The successful production of Mg-Li alloy sheet and foil, the product size is accurate, good shape, smooth surface, excellent performance, has completed the supply of spare parts for aerospace parts.

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness /mm</th>
<th>Width /mm</th>
<th>Length /mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate</td>
<td>0.5~45</td>
<td>≤1000</td>
<td>≤2000</td>
</tr>
<tr>
<td>Foil</td>
<td>0.05~0.5</td>
<td>≤300</td>
<td>L</td>
</tr>
</tbody>
</table>

1.1 Ultra-light Mg-Li alloy

3) Forging Slab and Bar

Mg-Li alloy forged slab

Slab thickness of up to 110mm, width up to 350mm, length up to 4000mm, weight up to 50kg.

Mg-Li alloy forged bar

Forging bar diameter 30 – 150mm, length 1000 – 2000mm, weight up to 50kg.

1.1 Ultra-light Mg-Li alloy

4) communications radar

A total of hundreds of parts, all the use of Mg-Li and made of surface corrosion treatment, played a significant weight loss effect.

Aluminum Alloy 60Kg

Weight 41.5%

Mg-Li Alloy 35Kg
1.1 Ultra-light Mg-Li alloy

5) UAV Parts

6) Fighter Antenna Bearing
A Mg-Li alloy was prepared by vacuum melting furnace and processed to prepare high performance magnesium and lithium alloy material and processed into the base of the fighter antenna.

1.1 Ultra-light Mg-Li alloy

7) Satellite Grating Shell

Satellite grating cover housing parts

8) Aeronautical Equipment Shell Parts
Avionics equipment shell parts (micro-arc oxidation treatment)

1.1 Ultra-light Mg-Li alloy

9) Waveguide

Mg-Li alloy waveguide

1.1 Ultra-light Mg-Li alloy

10) Some other Applications
Sound vibration film, Bike frame and Notebook shell
1.2 High strength and heat resistant Mg-RE alloys

High Temperature Performance and Application of High Strength- Heat resistant- Mg-RE Alloy

High strength and heat resistant Mg-RE alloy products

Properties of high strength and heat resistant Mg-RE alloy products

<table>
<thead>
<tr>
<th>Alloys</th>
<th>Properties</th>
<th>Tensile Temperature/°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Mg-Gd-Zr</td>
<td>σ /MPa</td>
<td>298.0</td>
</tr>
<tr>
<td></td>
<td>δ /%</td>
<td>17.1</td>
</tr>
<tr>
<td>Mg-Gd-Y-Zr</td>
<td>σ /MPa</td>
<td>370.0</td>
</tr>
<tr>
<td></td>
<td>δ /%</td>
<td>4.0</td>
</tr>
<tr>
<td>Mg-Gd-Y-Mn</td>
<td>σ /MPa</td>
<td>341.0</td>
</tr>
<tr>
<td></td>
<td>δ /%</td>
<td>6.3</td>
</tr>
<tr>
<td>Mg-Gd-Y-Nd-Zr</td>
<td>σ /MPa</td>
<td>490.4</td>
</tr>
<tr>
<td></td>
<td>δ /%</td>
<td>148.8</td>
</tr>
<tr>
<td>Mg-Gd-Y-Nd-Zr</td>
<td>σ /MPa</td>
<td>375.3</td>
</tr>
<tr>
<td></td>
<td>δ /%</td>
<td>7.1</td>
</tr>
</tbody>
</table>

The tensile properties of Mg-Gd-Y-Zr alloy at different temperatures

Progress in study on fine-grain strengthening of Mg-Gd-Y-Zr alloy

The extrusion temperature of Mg-Gd-Y-Zr alloy decreased from 500°C to 400°C:
- Grain size decreased from 126 μm to 7.4 μm;
- Tensile strength increased from 200MPa to 312MPa; improved 112MPa, an increase of 56%;
- Elongation increased from 2.9% to 5.6%

Gain refinement of magnesium alloy has the following characteristics:
①Effective; ② Do not reduce the plasticity of the material; ③ There are many ways to refine grains and easy to implement in production

Progress in study on precipitation strengthening of Mg-Gd-Y-Zr alloy

High strength(UTS: 400MPa) Mg alloys was fabricated in 2004
1.3 The wrought magnesium alloy of MB15 (ZK61M)

**MB15 (ZK61M) wrought magnesium alloy**

To improve the microstructure uniformity and explore the potential of mechanical properties of MB15, we carried out four aspects in the study:

1. MB15 Quality control of casting ingot
2. MB15 Processing Map
3. MB15 Finite Element Simulation and Analysis of the forging process
4. In progress (MB15 Isothermal Forging)

**Isothermal Forging**: Developing a high uniformity of microstructure, high performance and low anisotropy of MB15 forged magnesium alloy. Microstructure uniform increased more than 30%, tensile strength and yield strength increased more than 30MPa, inclusion and porosity decreased more than 5%, the property of anisotropy decreased more than 30MPa.

1.4 Fluxless melting

**The development of fluxless melting**

In order to obtain good toughness and improve the fatigue property of magnesium alloy, it is necessary to reduce the content of metal impurity elements and the amount of nonmetallic inclusions by the appropriate casting process. Impurity elements have a very negative effect on corrosion resistance and toughness of magnesium alloy. Non-metallic inclusions would also reduce the toughness of magnesium alloys.

The biggest problem with the existence of magnesium alloy production in China is that the original magnesium quality is unstable, high content of impurities and the amount of inclusions. Smelting process behind, the use of flux, low level of workers and other reasons caused by the performance of domestic magnesium alloy products are not up to standard.

Zhengzhou Light Metal Research Institute selected the best high-purity magnesium alloy raw materials, as well as military grade low sodium and low potassium high purity lithium ingots. Magnesium-lithium alloy produced by melt-free vacuum casting process is characterized by high plasticity and good corrosion resistance compared with ordinary magnesium alloy.
2.2 Twin-roll continuous casting and rolling process

Development

Magnesium alloy continuous casting and rolling technology was used as early as 1980 by the United States House Chemical Company Finite Engineering Company for the first time, followed by Germany, France, Australia, South Korea, China and other research. The process simplifies the sheet production process, shortening the production cycle, equipment investment is also reduced.

Luoyang Copper Co. Ltd. used this technology in 2005 and produced AZ31B magnesium sheet successfully produced specifications for 6.7mm × 600mm AZ31B. The newly established Luoyang Tengxi Magnesium company continues the experimental study of the technology. From equipment research and development to process testing, trying to break through the bottleneck of industrial production, after several years of testing, and achieved initial results, successfully produced specifications for 6.7mm × 600mm AZ31B. AZ61 magnesium alloy casting and rolling roll, the maximum weight is 500Kg.

Luoyang Copper Co. Ltd. and Taiyuan University of Science and Technology to strengthen cooperation in the magnesium casting equipment, intelligent upgrade, the temperature, flow, level, speed and other technical parameters to build "s_cycle feedback correction, close-loop program control" the whole process of man-machine dialogue intelligence Control System , and strive to achieve from the smelting, liquid, liquid level control, release, rolling and final return and other full precise quantitative control, to achieve the copper-copper alloy casting process from qualitative to quantitative, from experience to intellectual control of the change.

Note:

1. Thickness > 3mm or length > 1000mm
2. Sheet length more than 500
3. Weight is 500Kg

## Cold rolling alloy type and specifications

<table>
<thead>
<tr>
<th>Type</th>
<th>Coating</th>
<th>State</th>
<th>Standard</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ31B</td>
<td>GB/T</td>
<td>H112</td>
<td>T5154-2003</td>
<td>Automatic rolling, strip rolling, aluminum, chemical machinery</td>
</tr>
<tr>
<td>AZ61M</td>
<td>GB/T</td>
<td>H112</td>
<td>T5154-2003</td>
<td>Automatic rolling, strip rolling, aluminum, chemical machinery</td>
</tr>
</tbody>
</table>

## Twin-roll continuous casting and rolling process

### Properties of products

<table>
<thead>
<tr>
<th>Type</th>
<th>Coating</th>
<th>Width</th>
<th>Thickness</th>
<th>Rm/N/mm²</th>
<th>Rp0.2/N/mm²</th>
<th>A/50mm %</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ31B</td>
<td>H112</td>
<td>800-1200</td>
<td>0.6-1.0</td>
<td>285</td>
<td>200</td>
<td>20</td>
</tr>
<tr>
<td>AZ61M</td>
<td>H112</td>
<td>100-250</td>
<td>2.0-8.0</td>
<td>295</td>
<td>220</td>
<td>20</td>
</tr>
</tbody>
</table>

## Performance comparison of twin-roll continuous casting and rolling and conventional rolling

<table>
<thead>
<tr>
<th>Type</th>
<th>Coating</th>
<th>Width</th>
<th>Length</th>
<th>TYS/N/mm²</th>
<th>YS/N/mm²</th>
<th>El/.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ31B</td>
<td>H112</td>
<td>800-1200</td>
<td>200-2500</td>
<td>210</td>
<td>170</td>
<td>40</td>
</tr>
<tr>
<td>AZ61M</td>
<td>H112</td>
<td>100-250</td>
<td>200-2500</td>
<td>220</td>
<td>180</td>
<td>30</td>
</tr>
</tbody>
</table>

## Notes

1. The mechanical properties of the AZ31B sheet are closer to that of the target, which is lower than that of the hot rolled sheet.
2. Respectively, young and sheet metal and rolled sheet for high-temperature rolling, the performance from the requirements of GB/T 5154-2010.
3. The use of twin-roll continuous casting process to produce AZ61 magnesium alloy sheet can achieve the minimal content.
3. Northeast Light Alloy Co. Ltd

Northeast Light Alloy Co. Ltd is China's first company to produce wrought magnesium alloy. It cast China's first qualified wrought magnesium alloy ingot in 1958 and then began to produce magnesium alloy sheet. The company not only provided much-needed magnesium alloy tube, rod, profiles, but also provided the production of small-size squeeze plate, strip for the national defense and military departments in past 50 years.

- National Enterprise Technology Center
- The National high Technology Enterprise
- National Innovation Enterprise
- National Enterprises and Institutions of Intellectual Property pilot units

3.1 Products of magnesium alloy

### Products and Applications

Northeast Light Alloy Co. Ltd products

<table>
<thead>
<tr>
<th>Type</th>
<th>Alloy Profiles</th>
<th>State</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MB2 (AZ108M)</td>
<td>R, F</td>
<td>aircraft</td>
</tr>
<tr>
<td>2</td>
<td>MB8 (ME20M)</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>3</td>
<td>MB15 (ZK61M)</td>
<td>R, F</td>
<td>engine</td>
</tr>
</tbody>
</table>

In addition, Northeast Light Alloy Co. Ltd also carried out a small amount of magnesium alloy ingot production and trial production. The company adopted advanced semi-continuous casting method and successfully prepared ultra-high toughness Mg-Gd-Y-Zr alloy ingots (diameter of 500mm). It is the largest size of rare earth magnesium alloy ingots in the recent reports at home and abroad.

3.2 Research of magnesium alloy

A. Low cost and ultra high strength flame retardant magnesium alloy

Aiming at the civil transportation tools, the company developed a low-cost ultra-high strength flame retardant and corrosion resistant magnesium alloy without rare earth. Its yield strength is similar to that of ultra-high strength rare earth magnesium alloy with a large amount of expensive rare earth. It has a wide range of application prospect in the rail transport.

#### Tensile properties at room temperature

<table>
<thead>
<tr>
<th>Alloy</th>
<th>condition</th>
<th>YS (MPa)</th>
<th>UTS (MPa)</th>
<th>ε (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg-Al-Ca-1</td>
<td>As-extruded</td>
<td>423</td>
<td>440</td>
<td>4.6</td>
</tr>
<tr>
<td>Mg-Al-Ca-2</td>
<td>As-extruded</td>
<td>350</td>
<td>350</td>
<td>15</td>
</tr>
<tr>
<td>Mg-Zn-Ca</td>
<td>As-extruded</td>
<td>325</td>
<td>340</td>
<td>16</td>
</tr>
</tbody>
</table>
3.2 Research of magnesium alloy

B. High damping and high strength magnesium alloy

Based on the deep research on the damping mechanism of magnesium alloy, different series of high damping high strength magnesium alloys were developed.

<table>
<thead>
<tr>
<th>Alloys</th>
<th>As-extruded</th>
<th>RT</th>
<th>220</th>
<th>250</th>
<th>15</th>
<th>&gt; 0.01</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg-Cu-Mn-X</td>
<td>As-extruded</td>
<td>RT</td>
<td>250</td>
<td>320</td>
<td>8</td>
<td>&gt; 0.01</td>
</tr>
<tr>
<td>Mg-Si-Sc-X</td>
<td>As-extruded</td>
<td>RT</td>
<td>270</td>
<td>340</td>
<td>9</td>
<td>&gt; 0.01</td>
</tr>
<tr>
<td>Mg-Zn-Ca-X</td>
<td>As-extruded</td>
<td>RT</td>
<td>200</td>
<td>280</td>
<td>20</td>
<td>&gt; 0.01</td>
</tr>
</tbody>
</table>

C. New type of high thermal conductivity of magnesium alloys

Suitable for die-casting of high thermal conductivity and high strength magnesium alloy

- Good die-casting performance (Comparable to AZ91)
- High thermal conductivity (>150W/mK)
- Strength (Better than AZ91)
- Low cost
  - Mg-Zn-X
  - Mg-Al-X
  - Mg-La-X

Easy forming of high conductivity high-strength magnesium alloys

- High-speed extrusion, low temperature extrusion, stamping
- High thermal conductivity (>125W/mK)
- Strength (Comparable to ZK60)
- Corrosion resistance
- Low cost
  - Mg-Zn-X
  - Mg-Al-X