High-strength Al-Mg-Sc alloy with 0.1wt.%Sc content
In 2017, UC RUSAL set up the Light Materials and Technologies Institute (LMTI) in Moscow to develop new alloys and materials for customers requirements and to solve research and technology problems common to all the production facilities of the Company.

- LMTI staff - 32 employees, 6 of them have PhD degree, and 2 - Doctor of Sciences
- LMTI has its own testing centres to carry out general and specific tests (mechanical, corrosion, physical etc.) according to Russian and International methods
- Research directions LMTI:
  - alloys for die casting
  - alloys for high pressure die casting
  - wrought alloys
  - mathematical modeling in the development of new materials and processes
  - technologies for the production of pastes, pigments, gasifiers
  - metal matrix composite materials
  - additive technologies
ILMIT R&D center can perform various tests according to the specific methods, which are necessary for the customer. Some methods can be developed if necessary.
Sparingly alloyed high-strength Al-Mg-0.1%Sc alloy

MOTIVATION

- Resources for increasing of mechanical properties of the Al-Mg alloys are exhausted

- It is known, that Sc is the most effective hardener of the Al-Mg alloys

- At the same time, addition of Sc in concentrations, which correspond to commercial Al-Mg-Sc alloys, increase significantly the price of material

Sc-containing materials can be applied in case of their cost efficiency
The greatest strength properties growth of Al-Mg system alloys is observed at Sc concentrations up to 0.1%. With a further increase of Sc concentration strength growth rate decreases.

Concentrations >0.3wt.%Sc are not commonly used for traditional casting and rolling technology.

As a simple criterion for economical efficiency of Sc adding, the price of 1 MPa of the rolled products is taken.
Sparingly alloyed high-strength Al-Mg-0.1%Sc alloy

Existing commercial 5xxx series alloys containing Sc have lower cost efficiency (about 20%) in comparison with 5083 alloy, making it difficult to use them widely as an alternative to the latter.

From this perspective Al-Mg-0.1%Sc alloy can be used as an alternative to 5083 in marine constructions.

The advantages of 5xxx(0.1%Sc):

- material costs
- weight of constructions
- fuel consumption
- CO2 footprint
Sparingly alloyed high-strength Al-Mg-0.1%Sc alloy

Al-Mg-0.1%Sc alloy can be considered as an possible alternative to AA2024 for aerospace application through:
- High YS value, close to 2024
- 5% lower density
- High fatigue characteristics
- Excellent weldability
- Good corrosion resistance
- No need for heat treatment

Problems with 2024 alloy:
- Additional costs for heat treatment operation
- Prone to warping
- Low corrosion resistance
- Low weldability
RUSAL has developed a new Al-Mg-Sc alloy with 0.1wt% Sc content, combining:

- High strength properties comparable to commercial alloys with higher Sc content
- Lower price
- Good workability (as good as traditional 5xxx series alloys)

For serial production have been developed:

- Casting technology (slabs and billets)
- Rolling technology
- Forging technology

_No special equipment is required._
Mechanical properties of Al-Mg-0.1%Sc (Rusal) and other commercial wrought alloys

<table>
<thead>
<tr>
<th>Alloy</th>
<th>State</th>
<th>UTS, MPa</th>
<th>YS, MPa</th>
<th>Elongation, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>5083</td>
<td>O</td>
<td>315</td>
<td>145</td>
<td>15</td>
</tr>
<tr>
<td>1570 (Russia) 0.25%Sc</td>
<td>O</td>
<td>400</td>
<td>310</td>
<td>15</td>
</tr>
<tr>
<td>2024</td>
<td>T3</td>
<td>465</td>
<td>325</td>
<td>10-16</td>
</tr>
<tr>
<td>Al-Mg-0.1%Sc (Rusal)</td>
<td>O</td>
<td>380-410</td>
<td>280-320</td>
<td>14-19</td>
</tr>
</tbody>
</table>

RUSAL Al-Mg-0.1%Sc alloy in comparison with 5083:
+90% increase of YS
+20% increase of UTS of the weld joints
Promising fields of wide application for Al-Mg-Sc alloys

Aerospace

Shipbuilding

Source: Moss
Industrial production of the semi-finished products

MECHANICAL PROPERTIES of semi-products

<table>
<thead>
<tr>
<th>Semi-product</th>
<th>State</th>
<th>Yield stress Rp0.2, [MPa]</th>
<th>Ultimate tensile stress Rm, [MPa]</th>
<th>Elongation, %</th>
<th>Modulus of elasticity [GPa]</th>
<th>Density, g/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>sheets</td>
<td>annealed</td>
<td>280-320</td>
<td>380-410</td>
<td>14-19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>extrusions</td>
<td>after extrusion</td>
<td>330</td>
<td>400</td>
<td>10</td>
<td>70</td>
<td>2.66</td>
</tr>
<tr>
<td>forgings</td>
<td>annealed</td>
<td>255</td>
<td>380</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CORROSION RESISTANCE

<table>
<thead>
<tr>
<th>Test</th>
<th>Specification</th>
<th>Requirement</th>
<th>Typical values</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAMLT (Nitric Acid Mass Loss Test)</td>
<td>ASTM G67</td>
<td>&lt;15 mg/cm²</td>
<td>2 mg/cm²</td>
</tr>
<tr>
<td>ASSET (Assessment of Exfoliation Corrosion Test)</td>
<td>ASTM G66</td>
<td>Within PB</td>
<td>PB</td>
</tr>
</tbody>
</table>
Industrial testing

It was proofed that alloy has good workability in standard technological operations along with its high mechanical properties and good weldability in comparison with 5083-type and 2024-type alloys, what makes it reasonable substitution for traditional alloys in aerospace construction.

Weldability

Alloy has shown good weldability by using MIG and EBW methods. Welded joint efficiency (UTS_{base} / UTS_{weld}) of Al-Mg-0.1%Sc alloy is equal 0.9 and identical to 5083-type alloy.

![EBW (4.5mm sheet)](image)
Other properties

Fatigue

<table>
<thead>
<tr>
<th>Test</th>
<th>Typical value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue Strength</td>
<td>200 MPa</td>
</tr>
<tr>
<td>(200 000 000 cycles, stress ratio R = 0.1)</td>
<td></td>
</tr>
</tbody>
</table>

Tensile test at room temperature (after holding at 300 °C during 100 hours)

<table>
<thead>
<tr>
<th>State</th>
<th>Sample</th>
<th>$\sigma_{0.2}$, МПа</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>1.5mm sheet</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td>after holding at 300 °C during 100 hours</td>
<td>305</td>
</tr>
</tbody>
</table>

Charpy impact test (4.5mm sheet):

<table>
<thead>
<tr>
<th>State</th>
<th>Welding method</th>
<th>Impact strength, kJ/m²</th>
<th>Filler wire</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>-</td>
<td>371</td>
<td></td>
</tr>
<tr>
<td>welded joints</td>
<td>EBW</td>
<td>606</td>
<td>5083-type</td>
</tr>
<tr>
<td></td>
<td>MIG</td>
<td>580</td>
<td>1570 (0.25%Sc)</td>
</tr>
</tbody>
</table>
Available dimensions of slabs, billets and rolled products for delivery

### Slabs:

<table>
<thead>
<tr>
<th>Thickness, mm</th>
<th>Width, mm</th>
<th>Length, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 … 560</td>
<td>1310 … 2150*</td>
<td>up to 6000</td>
</tr>
</tbody>
</table>

* on request

### Billets:

<table>
<thead>
<tr>
<th>Diameter, mm</th>
<th>Length, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>ø 125 … 410</td>
<td>up to 6000</td>
</tr>
</tbody>
</table>

### Sheets:

<table>
<thead>
<tr>
<th>Thickness*, mm</th>
<th>1250x2500</th>
<th>1500x3000</th>
<th>2000x4000</th>
<th>2000x6000</th>
<th>2500x6000 **</th>
<th>2000x8000 **</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>4-12</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>&gt;12 ** (plates)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

* thickness tolerances according to EN 485-3 (for hot rolling) and EN 483-4 (for cold rolling);
** on request
Thank you for your attention!

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