POWDER METALLURGY MATERIALS

STRUCTURE AND PROPERTIES OF RAPIDLY CRYSTALLIZED
Al–Li ALLOY AFTER COMPACTING AND AGING

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The processes of aging of P/M semifinished products of Al–Li alloy obtained
by two different production methods were investigated. The possibility of
compacting by extrusion without preliminary heating of the blanks was eval-
uated.

At present the number of works devoted to study of P/M materials obtained by methods
of rapid hardening from the molten state and in a nonequilibrium condition has increased.
Depending upon the method of production the powder particles may have the form of strips,
spheres, etc. [1, 2]. The processes of production of parts from powders include the stage
of compacting of them. The structure and properties of semifinished products and parts
of powders are determined by their production conditions and subsequent thermoplastic work-
ing. In particular, the compacting conditions, including high-temperature heating for sin-
tering and working, may lead to acceleration of processes of decomposition of the super-
saturated solid solutions obtained in rapid hardening or crystallization of the materials
in the amorphous state. In a number of cases this makes it necessary to introduce an addi-
tional operation of hardening with subsequent aging. In addition preservation in compact-
ing of the nonequilibrium structure may make possible a strengthening heat treatment in
a production-wise convenient stage of production of semifinished products. In a number
of cases the strength properties of an alloy may be increased, for example by having com-
bined strain hardening and dispersion hardening. The statements made above refer in full
degree to alloys of the Al–Li system. In [3] P/M Al–Li alloys containing up to 4% Li were
investigated. Production of such alloys with cooling rates of the molten material of
vcool ~ 10^4 °C/sec makes it possible to significantly increase the alloy element content
in the solid solution, to refine the grain, and to provide uniform distribution of the inter-
metallic phases formed in aging. However, heating to temperatures normally used in produc-
tion of semifinished products and parts from powder leads to precipitation of phases from
solution even in the stage of treatment of it and makes it necessary to harden before aging.
Hardening from 540°C [3] causes development of recrystallization processes in the material,
as the result of which, the basic advantages of rapid crystallization in production of pow-
ders are lost to a significant degree. At the same time works are known [4] in which alu-
minum alloys were successfully deformed without preliminary heating, as the result of which,
the original structure of rapidly crystallized powders is probably preserved to a certain
degree.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>τ_{ag} (h)</th>
<th>τ_0 (N/mm^2)</th>
<th>τ (N/mm^2)</th>
<th>α (%)</th>
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<td>High-temperature extrusion</td>
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<td>135</td>
<td>260</td>
<td>15.2</td>
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<td>and hardening</td>
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<td>190</td>
<td>375</td>
<td>13.6</td>
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<td></td>
<td>10</td>
<td>330</td>
<td>400</td>
<td>4.4</td>
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<td></td>
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<td>240</td>
<td>300</td>
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<tr>
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<td>255</td>
<td>14.6</td>
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<tr>
<td></td>
<td>3</td>
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<td></td>
<td>24</td>
<td>335</td>
<td>410</td>
<td>6.4</td>
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Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 11, pp. 30-32,
Fig. 1. The structure (a) (10,000×) and electron diffraction pattern (b) of Al-2.6% Li alloy without preheating.

Fig. 2. Structure of Al-2.6% Li alloy: a) compacted at 400°C, 11,000×; b, c) compacted without preheating and aged at 160°C for 18 h, 36,000×; a, b) bright field; c) dark field.

In this work an attempt is made to study the evolution of the structure of a rapidly crystallized Al-Li system P/M alloy in compacting and heat treatment and also to reveal the possibility of use of cold compacting in production of the material.

Al-2.6% Li alloy, the compacting processes of which by the traditional method are best known, was investigated. The powder of the alloy was obtained by gas spraying in argon, and the cooling rate was $v_{\text{cool}} = 10^4 \, ^\circ\text{C/sec}$ (determined according to the data of [2]). The particle size of the powder in the form of spheres did not exceed 300 μm. The compacting was done using the method described in [5] with heating of the briquettes to 400°C or without preheating. In the latter case the temperature of the alloy taking into consideration heating of it in deformation did not exceed 200°C. A press with a force of 6 MN was used. The extrusion was done with similar reductions. The specimens compacted at 400°C were water-hardened from 540°C and aged at 150-200°C. The specimens compacted without preheating were aged at the same temperatures without preliminary hardening. After each operation in production of the P/M alloy and heat treatment of it the structure of the specimens was investigated by transmission electron microscopy using the method of [6]. The microhardnesses of the specimens were measured in the chamber of an NM-100 high-temperature microscope with an 0.2 N load on the indentor. The tensile tests were made on an Instron machine with a strain rate of $10^{-3} \, \text{sec}^{-1}$. A Winston double bridge circuit was used to measure the electrical resistance.

An analysis of the structure of the powder in the original condition showed that with $v_{\text{cool}} = 10^4 \, ^\circ\text{C/sec}$ a second phase is precipitated in the alloy. In the transmission electron microscopic investigations, the δ'-phase (Al₆Li) was not detected, apparently as the result of the too small size of the precipitates. However, on the electron diffraction patterns there are observed superstructural reflexes corresponding to it, which agrees with the data of [7]. Similar results were obtained in electron microscopic investigation of specimens compacted without preheating (Fig. 1). For these specimens nonuniaxiality of the grains, which have a form close to cylindrical, is characteristic while in the longitudinal cross section these grains have the form of rectangles with a size of (3-5) x (1-2) mm. The average dislocation density in the alloy is about $10^{10} \, \text{cm}^{-2}$. The alloy has a microhardness of 65 H, $\sigma_y = 10 \, \text{N/mm}^2$, $\sigma_t = 255 \, \text{N/mm}^2$, and $\delta = 14.6\%$. 

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