Proceedings of the 12th International Conference on
Aluminium Alloys, September 5-9, 2010, Yokohama, Japan

pp. 1113-1116


# An Effect of Deformation After Quenching and Heat Treatment on Mechanical and Corrosion Properties of Al-Mg-Si-Cu-Zn Alloy

Kolobnev Nikolay, Makhsidov Vladimir, Samokhvalov Sergei, Sbitneva Svetlana, Popov Valeriy and Kurs Mariya

FSUE "All-Russian Scientific-Research Institute of Aviation Materials", 17, Radio street, 105005, Moscow Russia

An influence of type of deformation and ageing conditions on the structure, mechanical properties and intergranular corrosion resistance in plate of 1370 Al-Mg-Si-Cu-Zn alloy was investigated in the present work. The deformation applied between quenching and ageing was carried out by rolling, stretching and combined rolling and stretching. Susceptibility to intergranular corrosion of the alloys of this system can be decrease by applying artificial ageing at the stage of overageing. However, in this case mechanical properties decrease significantly and pitting corrosion is 0.16-0.28 mm deep. Applying of low-temperature thermo-mechanical treatment results in a decrease of intergranular corrosion depth (≤ 0.10 mm) and provides a high level of mechanical properties of 1370 alloy plates.

***Keywords:*** *Al-Mg-Si-Cu-Zn, LTTMT, ageing regime, IGC.*

## 1. Introduction

6013 and 6056 Al-Mg-Si alloys with an increased Cu content (0.5-1.1 %) are used for production of fuselage skin components and airframe primary structures the same way as the Russian alloy 1370 with chemical composition similar to that of 6056 alloy.

However, artificially aged Al-Mg-Si-Cu alloys are susceptible to intergranular corrosion (IGC). There are two well-known methods to decrease their susceptibility to IGC: additional alloying and overageing [1, 2].

In order to decrease IGC, 6056 alloy was additionally alloyed with Zn (0.1 – 0.7 %wt.) and two-stage ageing accomplished with overageing (T78) was used for its heat treatment [1-4]. As a result, susceptibility of this alloy to IGC has been eliminated. But this treatment caused a significant reduction in strength properties and occurrence of pitting corrosion up to 0.16 mm in depth (Table 1).

Table 1. An effect of ageing conditions on mechanical and corrosion properties of 6056 alloy [3, 4].

| Ageing regime | UTS, MPa | 0.2% YS, MPa | El., % | Type and depth of corrosion, mm |
|---|---|---|---|---|
| 180 °C, 8-10 h (T6) | 387 | 355 | 7.5 | IGC 0.13 |
| 175 °C, 6 h + 190 °C, 13 h (T78) | 364 | 337 | 10.5 | Pitting 0.16 |

In some cases, applying of a deformation stage between quenching and ageing stages can lead not only to an increase in strength properties, but also to an improvement of corrosion characteristics of semiproducts [5]. Application of the deformation stage between quenching and ageing stages in the course of manufacturing of semiproducts can be considered as one of the methods of low-temperature thermo-mechanical treatment (LTTMT).

## 2. Experimental procedure

12 mm and 20 mm thick plates made of 1370 aluminium alloy were used for studies. LTTMT of plates was carried out under the following conditions: quenching + deformation + ageing. A part of hot-rolled plates was subjected to a typical heat treatment: quenching, stretching with residual strain degree (ε = 1.5-2.0 %) followed by artificial ageing at 180 °C, 10 h (T1) [6]. After quenching the

other part of hot-rolled plates was subjected to deformation by rolling or stretching with ε = 15 % or to a sequential combination of rolling and stretching with ε = 20 % followed by one-, two- and three-stage artificial ageing carried out under various conditions (Table 2).

Table 2. Ageing regimes of plates.

| Ageing regime | Ageing temperature, °C | | |
|---|---|---|---|
| | Stage 1 | Stage 2 | Stage 3 |
| T1: 180 °C, 10 h | 180 | - | - |
| B1: 180 °C + $T_2$ ($T_2$<180 °C) | 180 | $T_2$ | - |
| C1: $T_1$ + 180 °C + $T_3$ ($T_1$<180 °C, $T_3$<180 °C) | $T_1$ | 180 | $T_3$ |

The grain structure of plates was studied by optical microscopy on the specimens in the longitudinal direction («L») after anodic oxidation with estimation grain's length («L») and width («W»). The specimens cut out from rolled surface of plate. Mechanical properties of plates were evaluated with the use of specimens cut out in TL direction. Analysis of penetration depth was carried out in the course of IGC tests of the rolled plate surface.

## 3. Results

Peak-aged 1370 alloy (T1) has demonstrated IGC penetration depth within 0.14-0.20 mm (Table 3). Overageing provides a reduction in susceptibility of this alloy to IGC down to 0.10mm in depth or eliminates it completely. However it results in a decrease of strength characteristics. LTTMT of 1370 alloy plates allows to keep strength characteristics and to reduce susceptibility to IGC.

Table 3. An effect of type of deformation applied between quenching and ageing (T1) stages on mechanical properties and IGC of 1370 alloy plates.

| Properties | Ageing regimes | | | | |
|---|---|---|---|---|---|
| | T1 | | | | B1 |
| | Initial state | Stretching, ε = 15 % | Rolling, ε = 15 % | Rolling, ε = 15 % + Stretching, ε = 5 % | |
| UTS, MPa | 435 | 425 | 430 | 440 | 440 |
| 0.2%YS, MPa | 400 | 395 | 410 | 420 | 420 |
| El, δ, % | 13 | 11 | 11 | 8 | 7 |
| IGC maximum depth, mm | 0.20 | 0.10 | 0.10 | 0.10 | 0.07 |

The grain structure of the plate is recrystallized, grains are stretched in rolling direction and there are sleep bands in the microstructure of the plates with LTTMT. The average grain size in plates without LTTMT (initial state) is (LxW) (105-125)x(35-40) µm (fig. 1a). There is increasing average length of grain in case of LTTMT with stretching by ε = 15 % in comparison with plates without LTTMT, average width stay about the same and the average grain size is (140-160)x(35-40) µm (fig. 1b). There is also increasing average length of grain, but in smaller extent as compared to deformation by stretching, the average width is decreasing in case of LTTMT with rolling by ε = 15 % in comparison with initial state and the average grain size is (125-145)x(30-35) µm (fig. 1c). In case of LTTMT with sequential combination of rolling with ε = 15 % and stretching with ε = 5 % in comparison with initial state there are also increasing average length, decreasing average width of grain and the average grain size is (120-140)x(20-25) µm (fig. 1d).

In case of rolling, LTTMT ensures higher values of strength properties and IGC depth = 0.10mm. However, deformation made by rolling should be accomplished by the subsequent straightening of plates. Application of the two-stage ageing (B1) allows to keep a high level of strength properties and to reduce susceptibility to IGC to some extent as compared with LTTMT with one-stage ageing T1.

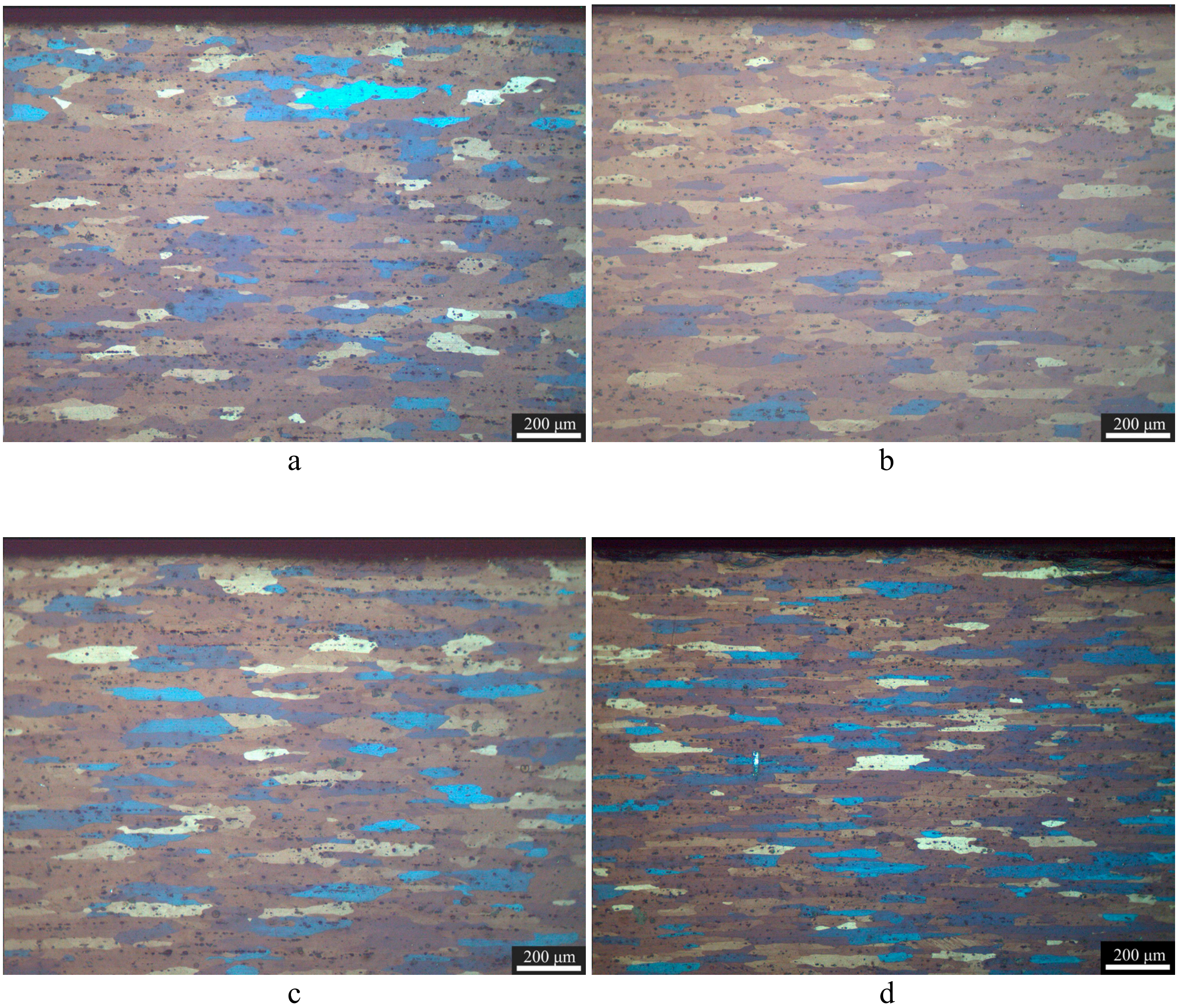


Fig. 1. Microstructure of 1370 plate with LTTMT:
a – initial state (without LTTMT);
b – deformation by stretching with ε = 15 %;
c – deformation by rolling with ε = 15 %;
d – deformation by rolling with ε = 15 % + deformation by stretching with ε = 5 %.

Application of the three-stage ageing C1 in case of LTTMT with stretch deformation stage (ε = 15 %) carried out after quenching provides keeping strength properties and some reduction in IGC level down to 0.07mm (Table 4).

Table 4. An effect of three-stage ageing on mechanical and corrosion properties of plates in case of LTTMT with stretch deformation stage.

| Ageing regime | UTS, MPa | 0.2% YS, MPa | El, % | IGC, mm |
|---|---|---|---|---|
| C1 | 440 | 420 | 8.0 | 0.07 |

As compared with one-stage ageing (T1), the three-stage ageing (C1) applied in the course of LTTMT with the stretch deformation solely (ε = 15 %) results in an increase in ultimate strength and yield strength by 15 and 25 MPa respectively at IGC level ≤ 0.10 mm (Table 4).

## 4. Conclusions

Applying of LTTMT for plate lead to changing of grain size, which is depending on schema and value of the applying forces during rolling or stretching of plate.

The usage of LTTMT in case of the stretch deformation solely ($\varepsilon = 15$ %) accomplished with three-stage ageing ($T_1 + 180°C + T_3$) for heat treatment of 1370 alloy plates allows one to ensure IGC level $\leq 0.10$ mm and to keep high strength properties.

A reduction in susceptibility to IGC provided by application of LTTMT can be referred to a change in the difference of electric potentials between grain and its sub-boundary zone as a result of a deformation-caused change in precipitation morphology throughout the grain body and on the grain boundaries.

## References

[1] Keitarou Yamaguchi, Ken Tohma: *Effect of Zn addition on intergranular corrosion resistance of Al-Mg-Si-Cu alloys,* (Proceedings of 6-th International Conference on Aluminium Alloys, Toyohashi, Japan, 1998), The Japan Institute of Light Metals, 1998, vol.3 pp 1657-1662.
[2] Ronan Dif, Denis Bechet, Tim Warner, Herve Ribes: *6056T78: a corrosion resistant copper-rich 6XXX alloy for aerospace application,* (Proceedings of 6-th International Conference on Aluminium Alloys, Toyohashi, Japan, 1998), The Japan Institute of Light Metals, 1998, vol.3 pp 1991-1996.
[3] R. Dif, B. Bès, J. C. Ehrström, C Sigli, T. J. Warner, Ph. Lassince, H. Ribes: *Understanding and modelling the mechanical and corrosion properties of 6056 for aerospace applications,* (Proceedings of 7-th International Conference on Aluminium Alloys, Charlottesville, Virginia, 2000), Trans Tech Publications Ltd, 2000, vol.1 pp 1613-1618.
[4] D. Bakavos, P. B. Prangnell, R. Dif: *A Comparison of the Effects of Age forming on the Precipitation Behaviour in 2xxx, 6xxx and 7xxx Aerospace Alloys,* (Proceedings of 9-th International Conference on Aluminium Alloys, Brisbane, Australia, 2004), Institute of Materials Engineering Australasia Ltd, 2004, pp 124-131.
[5] M.L. Bernstein: *Thermo-Mechanical Treatment of Metals and Alloys*, “Metallurgiya Publishers”, Moscow, 1968, vol. 1 pp. 329-343.
[6] V.V. Maskhidov, S.V. Samokhvalov, N.I. Kolobnev, V.I. Popov, M.G. Savenok: *An Effect of Ageing Conditions and Deformation Applied After Quenching on Susceptibility to IGC of Al-Mg-Si-Cu Alloys,* (Proceedings of International Scientific-Technical Conference «State-of-Art in Metal Science of Non-Ferrous Metals», Moscow, Russia, 2009), MISiS, 2009, pp 133-137.