Effect of Zirconium and Lanthanides on the Recovery in 2618 Base Aluminum Alloys

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Influence of zirconium and lanthanides on structure and properties of 2618 base aluminum alloys, used at elevated temperatures, are presented in this work. The recovery was determined through the change in the microhardness with time and temperature on different zirconium and lanthanides contents. It was used for evaluation of creep-resistance of the alloys. It is possible to predict the optimal chemical composition of alloy to provide good mechanical properties at elevated temperatures.

Zirconium exhibited to retard the recovery at lower temperature, 150–250°C, whereas lanthanides do higher temperature 300–350°C.

KEY WORDS: 2618 alloy; heat-resistant aluminum alloys; recovery; zirconium; lanthanides.

1. Introduction

The modern development of aluminum alloys implies the production of sophisticated aluminum alloys to achieve the better combination of demanding characteristics. The effects of chemical composition on behavior of heat-resistant aluminum alloys that are presently of commercial importance especially in aircraft industry are studied in this work.

It is known that the transition metals with relatively low solid solubility (manganese, chrome, zirconium, cerium, lanthanum etc.) could be precipitated in the form of fine dispersed particles and used for strengthening of grains and sub-grains.1–5) Hence, they increase the recovery resistance, contribute to avoid recrystallization and improve the strength, toughness and the resistance to stress-corrosion cracking.

It is also known that one of the heat-resistance criteria is yield creep.6) Since the difficulties in development of the recovery process means at the same time the difficulties in the creep process, the accent was put on the investigation of recovery process. The basic idea was to find a method, which would enable obtaining of optimal alloy composition. The chemical composition and structure of alloy defined on that way would provide good mechanical properties at room temperature and also efficiently increase the recovery resistance. In that way, the high strength parameters at elevated temperatures could be approached and thereby the creep velocity decreased.

In this work, the change in micro-hardness of aluminum alloys containing zirconium and lanthanides in different ranges was monitored with time during annealing at different temperatures. The determined values of activation energy7) as well as relative degree of recovery values indicate the difficulty of recovery process development, i.e. the influence of zirconium and lanthanides on creep resistance. In this paper, only the investigation results referred to the relative degree of recovery as measure of creep resistance are presented.

2. Experimental

Six aluminum alloys with the nominal composition given in Table 1 were prepared by melting AA 2618 (RR 58) alloy, Al–Zr5 master alloy and misch metal (50% Ce and 50% other elements) in a resistance-heated furnace with the graphite crucible. The 2618 alloys were produced by standard melting procedure. Pre-alloy AlZr5 was added to melts in order to achieve the certain zirconium content.

The cast specimens with thickness of 9–10 mm were subjected to the homogenizing heat treatment for 22 h at the temperature of 510–515°C and cooled together with the furnace. The homogenized specimens were hot forged and then cold rolled to a final thickness of 0.5–0.6 mm. The recovery process was performed on the all alloys at five selected temperatures, in the range 150 to 350°C, and for nine different time periods (1–320 min).

3. Results and Discussion

The recovery resistance of the alloys was determined by Eq. (1) on the basis of relative degree of recovery, factor $R$,}

| Table 1. Chemical composition of the alloys. [mass%] |
|-----------------|----------|----------|----------|----------|----------|----------|
|                | Cu      | Fe       | Ni       | Mg       | Si       | Zr       | Lanthanides |
| Alloy 1        | 2.10    | 0.96     | 1.21     | 1.28     | 0.30     | -        | -         |
| Alloy 2        | 2.15    | 0.91     | 1.20     | 1.26     | 0.29     | 0.08     | -         |
| Alloy 3        | 2.10    | 0.93     | 1.20     | 1.25     | 0.28     | 0.18     | -         |
| Alloy 4        | 2.10    | 0.91     | 1.18     | 1.24     | 0.28     | 0.24     | -         |
| Alloy 5        | 2.12    | 0.94     | 1.21     | 1.24     | 0.29     | -        | 0.15       |
| Alloy 6        | 2.13    | 0.93     | 1.19     | 1.26     | 0.27     | -        | 0.25       |
was defined as:

\[ R = \frac{H_d - H}{H_d - H_0} \]  \hspace{1cm} (1)

Where \( H_0 \): micro-hardness of specimens before deformed
\( H_d \): micro-hardness of specimens after deformed
\( H \): micro-hardness of specimens after recovered.

The value of relative degree of recovery equal to 1 is referred to as rolled alloys.
The relative degree of recovery were retarded by increase of zirconium content, as shown in Figs. 1–4.

The zirconium impeded the recovery process and consequently caused the increase in creep resistance, that was confirmed by determinations of apparent activation energies for the examined alloys during recovery process.\(^7\) The lanthanides also increased the recovery resistance of the alloys, as shown in Figs. 5–8.

It was found that recovery process in all examined alloys finished for times up to 40 min, so the present experimental results related to that period. After 40 min, the changes were relatively slow.

The influence of zirconium as well as lanthanides on the relative degree of recovery at all investigation temperatures...
The thinner lines showed the alloys containing lanthanides. It is obvious that at low temperatures 150–250°C, zirconium strongly suppressed the recovery process than lanthanides did. At higher temperatures the alloys containing lanthanides possess higher values of the relative degree of recovery. Hence, these alloys exhibited smaller susceptibility to the recovery process i.e. higher recovery resistance than alloys containing zirconium.

It is known that the solute atoms of alloying elements could increase the activation energy for the formation and moving of the vacancies\(^8\) and hence influence on the decrease in diffusion rate. The decrease in diffusion rate consequently impeded the movement of dislocations by cross-slip mechanism, dislocation climb mechanism as well as the mechanism of dislocation intersection. Therefore, the recovery rate was decreased i.e. the creep resistance was increased. During the recovery process, the annihilation of vacancies is a dominant process at low temperatures, but the movement of dislocations without activation of climb process is operative at moderate temperatures. At the higher temperatures the dislocation climb is a dominant process.\(^9\)\(^–\)\(^11\) So, it could be supposed that lanthanides obstructed the dislocation climb more efficient than zirconium. Therefore, the alloys containing lanthanides have higher values for the relative degree of recovery i.e. higher recovery resistance at high temperature compared to alloys with zirconium.

### 4. Conclusions

- Zirconium increases the relative degree of recovery of produced alloys.
- Lanthanides increase also the relative degree of recovery according to their contents in the alloy.
- At low temperatures, 150–250°C, zirconium exhibited stronger effects on the recovery process than lanthanides.
- At higher temperatures, 300–350°C, the alloys containing the lanthanides possess greater relative degree of recovery. Hence, these alloys are exhibited greater recovery resistance at higher temperatures than alloys with zirconium.
- The heat-resistant aluminum alloys RR58 additionally alloyed with zirconium and lanthanides would have good mechanical properties.

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