Key Engineering Materials *Online: 2007-08-15*
ISSN: 1662-9795, Vols. 345-346, pp 33-36
doi:10.4028/www.scientific.net/KEM.345-346.33

Effects of Heating Rate and Temperature Holding Time on Mechanical Behaviors of Aluminum Alloys

Chenguang Huang[1,a], Siying Chen[2,b] and Chunkui Wang[1,c]

[1]Institute of mechanics, Chinese Academy of Sciences, Beijing, 100080, China

[2]Department of Optoelectronic Engineering, Beijing Institute of Technology, 100081, China

[a]huangcg@imech.ac.cn, [b]csy@bit.edu.cn, [c]ckwang@imech.ac.cn

Keywords: Aluminum alloy, Mechanical Properties, Heating rate, High temperature

Abstract. In this paper, the mechanical properties of several aluminum alloys are obtained experimentally at different temperatures, from room temperature to about 400^0C by using the Gleeble 1500 thermomechanical system. Besides, the thermal softening characteristics, effects of heating rate and temperature holding time are discussed in details. It is found that the strength of LF6, a kind of antirust aluminum alloy, is not sensitive to the heating rate (0.1-1000*K/s*) and temperature holding time (0-1*h*). However, the mechanical behaviors of other alloys depend on these factors very obviously. At last, these phenomena are discussed in the viewpoint of the microstructures and techniques of ageing strengthening of these alloys.

Introduction

Aluminum alloys are used widely in engineering structures and vehicles, such as aircraft, space crafts, etc. because of its lightweight and high specific strength. The determination of the mechanical behaviors of these materials at different temperatures has important practical value, and has been investigated by many researchers. [1-2]

However, the studies on high temperature behaviors and their dependences on the heating rate, temperature holding time of aluminum alloys seem to be neglected, both experimental and theoretical ones, though it plays a key role in some fields, such as hot working, structural failure induced by high energy beams and laser processing, *etc*. [3-5].

In this paper, an antirust aluminum alloy LF6, a super duralumin alloy LC4, a reflectal alloy LD10 and a duralumin alloy LY12 are selected as materials investigated. First, their macroscopic mechanical behaviors are obtained with a Gleeble 1500 testing machine under different loading conditions. Then, during 4 magnitudes of heating rate (0.1-1000*K/s*), the effect of heating rate on the mechanical properties of these alloys, are detected, which are heated to the same final temperature. After that, the effect of temperature holding time on mechanical properties of aluminum alloys is acquired. At last, the relative mechanism of these effects are discussed and explained.

Experiments

In this paper, the element constituents of aluminum alloys LF6, LC4, LD10 and LY12 are listed in Tables 1-4. And, these alloys are heat treated in different ways, as followings,

1. LF6 alloy, is heated up to 310^0C and dry quenching.
2. LC4 alloy, solid-solution heat treated at 470^0C and artificial aging at 140^0C during 10 hours.
3. For LD10 alloy, solid-solution temperature is 500^0C and aging temperature is 155^0C.

4. For LF12 alloy, solid-solution temperature is 500^0C, and with a natural aging.

Table 1 Element constituents of LF6 (except Al)

Element	*Mg*	*Mn*	*Ti*	*Be*	*Cu*	*Zn*	*Fe*	*Si*
Content (%)	6.30	0.75	0.08	0.005	0.05	0.22	0.35	0.30

Table 2 Element constituents of LC4 (except Al)

Element	*Zn*	*Mg*	*Cu*	*Mn*	*Cr*	*Fe*	*Si*
Content (%)	6.30	2.65	1.65	0.52	0.18	0.45	0.16

Table 3 Element constituents of LD10 (except Al)

Element	*Cu*	*Mg*	*Mn*	*Si*	*Fe*	*Zn*	*Ni*	*Ti*
Content (%)	4.40	0.76	0.60	0.85	0.63	0.20	0.08	0.09

Table 4 Element constituents of LY12 (except Al)

Element	*Cu*	*Mg*	*Mn*	*Fe*	*Si*	*Zn*	*Ni*	*Ti*
Content (%)	4.25	1.55	0.67	0.41	0.42	0.28	0.05	0.12

All experiments are implemented on standard specimens by using a Gleeble 1500 materials testing machine, as shown in Fig. 1. The temperature of specimens is detected by a fast-response thermocouple, and controlled by a feedback system, while the mechanical loading and the deformation are measured respectively with a force sensor and a quartz displacement sensor.

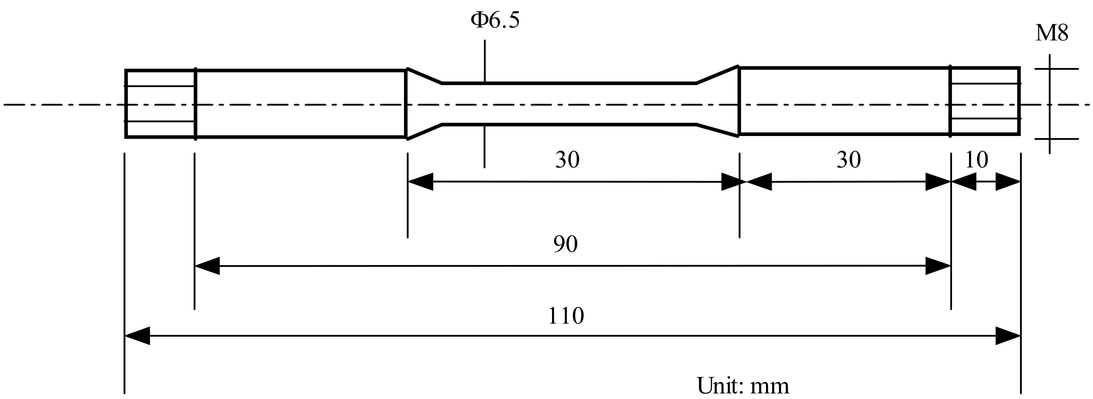

Fig. 1 Dimensions of aluminum alloys specimens

Uniform heating is achieved by a low voltage 50Hz AC current passing directly through the specimen, and the heating rate can be up to 10,000 *K/s* while the specimen temperature varies from room temperature to about 400^0C.

All the testing can be divided into 3 sections,

Section 1. The heating rate and strain rate of specimens are fixed at 1000*K/s* and $10^{-3}s^{-1}$, the final temperatures of different specimens are changed from room temperature to about 400^0C, in order to evaluate the thermal softening of these alloys.

Section 2. The specimen temperature and strain rate are fixed, the heating rate is varied from 0.1*K/s* to 1000*K/s*, to check the effect of heating rate on mechanical behaviors of alloys.

Section 3. When the specimen temperatures, heating rate and strain rate all are fixed, we change the temperature-holding time to explore the effect of this factor.

Experimental Results

Fig. 2 shows strain *vs.* stress curves of aluminum alloys at different temperatures at a heating rate of 1000*K/s* and a strain rate of $10^{-3}s^{-1}$.

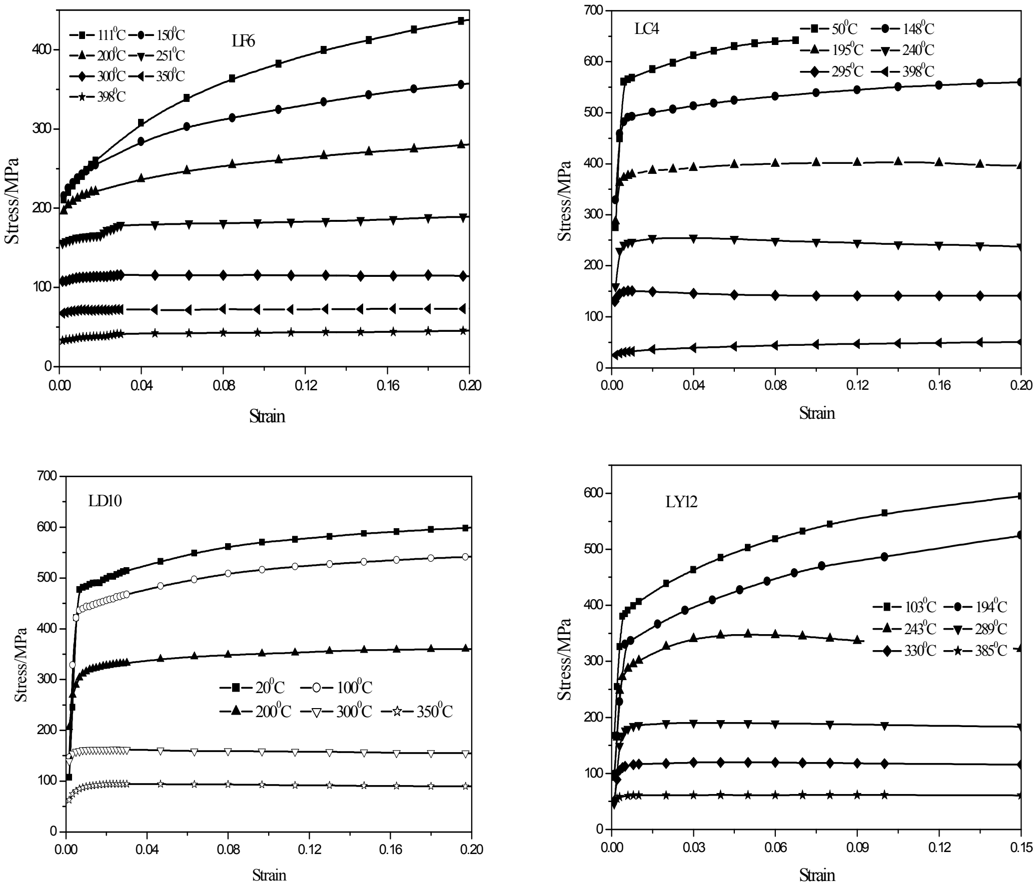

Fig. 2 Mechanical properties of several aluminum alloys

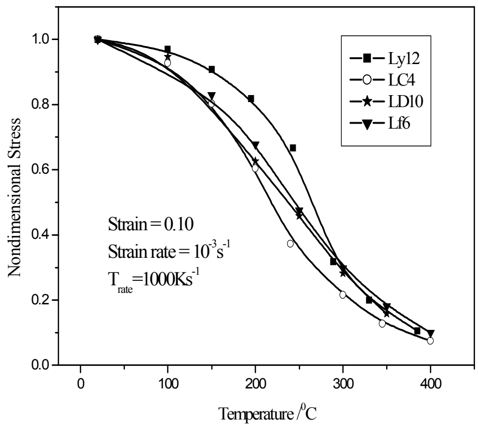

Fig.3 Thermal softening of aluminum alloys

Fig. 3 shows the thermal softening characteristics of these materials. Where, the vertical axis represents the nondimensional flow stresses of materials deformed with a strain of 10%, and the horizontal axis shows specimen temperatures. From Fig. 3, we can find that the thermal softening characteristics of these alloys are similar. However, LY12 shows a better elevated temperature property, because there are some strengthening phases in this alloy, which are insoluble under high temperature.

Then, the effects of heating rate and temperature holding time on the mechanical properties of these alloys are acquired. We find that LF6 alloy is insensitive to these factors in all the experiments. So, only the mechanical properties of other there kinds of alloys are included in following text and figures.

Fig. 4 shows the effect of heating rate on the ultimate tensile strength of LC4, LD10 and LY12 alloys. Form this figure, it can be found that this effect gets more obvious when the heating rate is lower than 1*K/s*, and is increased with a higher specimen final temperature.

Fig. 5 Shows the relationship between alloys strength and temperature holding time. From this figure, we can deduce that alloys, which are subjected to a longer holding time before they are tested, show a lower strength. However, this trend becomes more obvious with a higher final specimen temperature, and there is a saturation time existed in relative curves.

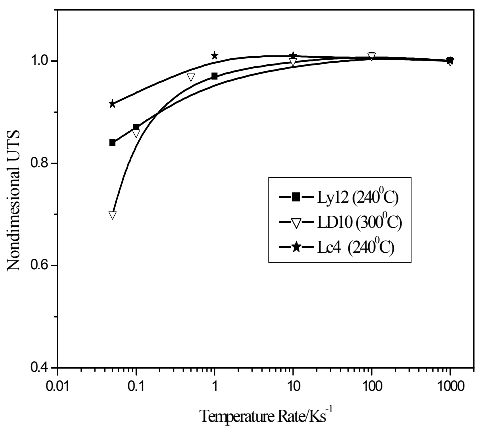

Fig. 4 Effect of heating rates

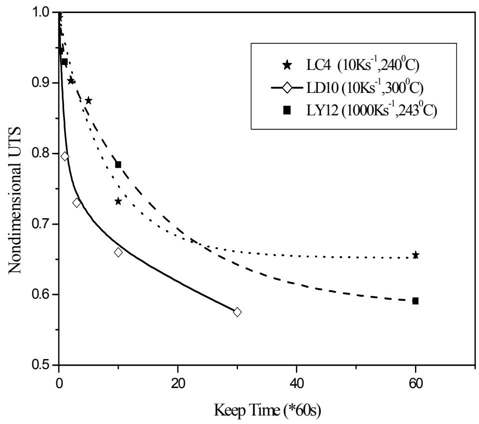

Fig. 5 Effect of temperature holding time

Discussions and Conclusions

In the above sections, the macroscopic mechanical properties of various alloys and the effects of heating rate and temperature holding time have been shown. We will give a physical explanation in this section.

LD10 and LC4 alloys are heat treated by solid-solution strengthening and artificial aging. When these alloys have been soaked in a high temperature above 200^0C for a long time, overaging will occur. Overaging will induce the precipitate of the strengthening phase from the solid solution, and the recovery of lattice distortion, and the dispersion strengthening effect will disappear. Indeed, when the soaking time is long enough, the precipitated phase will continue to gather and growth, and to become a source of failure.

LY12 alloy is natural aging strengthened. When the specimen temperature is above 200^0C, the regression will occur. Enrichment zones, which are formed in aging treatment, with large quantity and small scale, will disappear, that will reduce the mechanical properties of this alloy.

In Fig.4, we find that the effect of heating rate is obvious under a heating rate of 1*K/s*, and is aggravated with an increase of specimen final temperature. The key mechanism is, only when the heating time is longer than the characteristic time of overaging and regression process, the effect of heating rate can be emerged. The same mechanism hold true for the effect of temperature holding time, shown in Fig. 5.

For the saturation of temperature holding time effect, the main reason is that the overaging and regression phase transformations decelerate, and are completed, when the soaking time is above 10 minutes.

Acknowledgement. Authors thank the National Natural Science Foundation of China (10602009) and Chinese National High Technology Planning for financial support.

References

[1] B. Raeisinia, W.J. Poole and X. Wang, et al: Metallurgical and Materials Transaction A, 4,37A ,(2006), p. 1183-1190
[2] P. Juijerm and I. Altenberger: Scrita Materialia, 10, 55, (2006), p. 943-946
[3] W.P. Latham, J.E. Beraun: Proceedings of SPIE, 4376(2001), p. 5-14
[4] C.G. Huang: Ph. D. Dissertation, Chinese Academy of Sciences, 1996.
[5] C.G. Huang, Z.P. Duan: Acta Mechanica Solida Sinica, 13 (2000), p. 141-148

The Mechanical Behavior of Materials X
10.4028/www.scientific.net/KEM.345-346

Effects of Heating Rate and Temperature Holding Time on Mechanical Behaviors of Aluminum Alloy
10.4028/www.scientific.net/KEM.345-346.33