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High temperature creep property of silicon particles reinforced high Al Zn-based alloys①

Zhang Liming(张利明)[1,2]; Ding Zhimin(丁志敏)[2], Lao Bin(劳 彬)[3]

1. *Department of Materials Engineering, Dalian University of Technology, Dalian 116028, P. R. China*

2. *Department of Materials Science and Engineering, Dalian Railway Instiute, Dalian 116024, P. R. China*

3. *Shanghai Automobils Industry Group, Shanghai 200006, P. R. China*

Abstract: The deformation creep characteristics of as-cast silicon particles reinforced zinc-based alloys (Si/ZA27) were determined by high temperature creep experiments at 453 K and 61.1 MPa condition. The experimental results indicated that the minimum creep rate of the silicon-containing alloys are about three fifth of that of the matrix alloy(ZA27). The deformation process is mainly controlled by grain boundary sliding mechanism. Both dislocation climb and disperse silicon phase are also contributed to it. Micro-structural changes were investigated during the deformation experiments.

Key words: particle; reinforcing ZA27; creep property **Document code: A**

1 INTRODUCTION

Zinc-based cast alloys containing a high concentration of aluminum and some copper have been found to be economical-and-effective for substitutes for bronze in a variety of general engineering with their excellent comprehensive mechanical properties and wear resistance[1]. However, there are some practical demerits such as poor impact property, low creep resistance and dimensional instability for most zinc-based cast alloys[2], which have restricted their use to slow-moving tribological application ($V_{max} < 7.1$ m/s) at operating temperature beyond 150 ℃. Therefore, improving the elevated temperature property of zinc-based alloys, which in turn could widen the range of their utility and working capability. Some achievements have been reached by ways of microstructural and compositional modifications such as zinc-matrix composites have high strength and stiffness at the room temperature, moreover, the reinforced particles can effectively improve their high temperature creep resistance and elastic modulus[8]. However, the study on the high temperature creep behavior of particles phase reinforced zinc-based cast alloy has seldom been reported by now. This investigation focused on the creep behavior of silicon particles reinforced zinc-based cast alloys at high temperature and high deformation stress, compared with those of the similarly processed conventional zinc-based alloy (ZA27). The creep mechanism of these alloys also discussed under the experimental condition.

2 EXPERIMENTAL

2.1 Sample Preparation

Two silicon particles (5 % and 8 %) (mass fraction) respctively reinforced zinc-based cast alloys modified by 2 %($(NaPO_3)_6$ and one conventional zinc-based alloy (ZA27) were produced by casting into permanent mould. Microstructural studies were carried out on metallographically prepared samples after etching them with 0.05 % HF(hydrofluorine acid). A Neuphot-21 optical microscope and Rigaku D/Max X-ray diffractometer using Cu radiation were used for

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carrying out the microstructural investigation.

2.2 Determination of hardness and thermal expansion coefficient

Hardness of specimens were determined with a Brinell hardness tester while density was measured by water displacement technique using an analytical balance, simiearly, thermal expansion coefficient was found with help of a thermal expansion tester. The data points represent an average of at least three observations.

2.3 Deformation creep test

The deformation creep test was carried out under stress of 61.1 MPa on a constant load creep machine. The schematic diagram is shown in Fig.1. The temperature of creep test was controlled at 180 ±2 ℃. Strain was measured by a CWB-2 model digital recorder being accurate to 1 μm, the specimens subjected to creep tests were 3 mm × 3 mm × 6 mm.

Fig.1 Scheme of creep experiment device

3 RESULTS AND DISCUSSION

3.1 Properties and microstructure

Table 1 shows the composition, density and thermal expansion coefficients of the samples. The present of silicon particles led to increase the hardness of samples while the density and thermal expansion coefficients were decreased. As revealed by the X-ray diffraction pattern shown in Fig.2, the sample A mainly contains α, β and ε phases. Compared with sample A, sample B also contains Si phase besides the above three phases. Fig.3 ~ 5 represent the microstructural features of ZA27 and two modified zinc-based alloys (5Si/ZA27 and 8Si/ZA27, respectively). The ZA27 showed primarily α dendrites along with eutectoid β and metastable ε phase (regions marked a, b and c, respectively). Addition of silicon element led to the features of primarily silicon particles (regions marked Si), rest of the features of silicon containing alloys remained identical to those of the silicon free specimen. After modification of $(NaPO_3)_6$, the primary silicon particles become more fine and blunt. The microstructural characteristics of these alloys system have been discussed elsewhere[9,10].

3.2 Deformation creep characteristics

Fig.6 shows the relationship between the strains of three samples and the times under the stress of 61.1 MPa and 453 K experimental condition. The stable creep rates of silicon-containing alloys are lower than that of the silicon-free sample. Fig.7 reveals the creep rates of samples during the experiment. The minimum creep rates of samples A, B and C are approximately 50×10^{-5}, 42×10^{-5} and 30×10^{-5} min^{-1} respectively. The creep resistance of the three samples at this high temperature are the

Table 1 Chemical compositions and properties of samples

No	Composition/ %					HB	Density /($g·cm^{-3}$)	Melting point/ ℃	Thermal expansion coefficient × 10^{-6}				
	Al	Cu	Mg	Si	Zn				50 ℃	100 ℃	150 ℃	200 ℃	250 ℃
A	27	2.5	0.04	—	Bal	123	4.96	484	25.8	28.9	29.29	34.16	36.37
B	27	2.5	0.04	5	Bal	138	4.68	470	23.81	25.66	26.23	28.23	29.64
C	27	2.5	0.04	8	Bal	138	4.57	456	8.84	16.87	20.79	25.93	28.92

Fig.2 X-ray diffraction patterns of samples
A—ZA27; B—5Si/ZA27

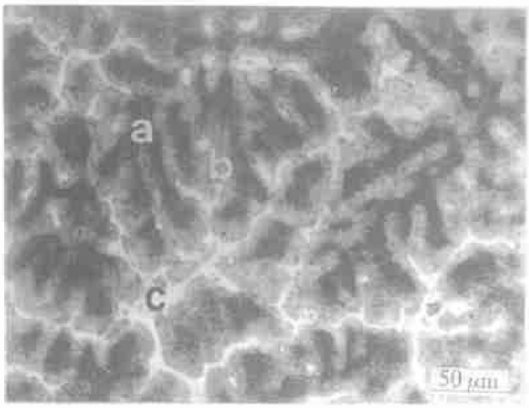

Fig.3 Microstructure of as-cast ZA17 alloy

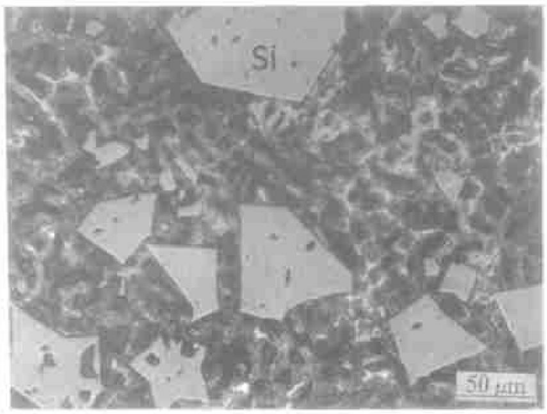

Fig.4 Microstructure of as-cast 5Si/ZA27 alloy (Before modification)

following order: A < B < C.

3.3 Simulation graph of minimum creep rates

Fig.8 shows the simulation graph of the minmum creep rates of the three samples. The results indicated that the slopes of the silicon-containing alloys are lower than that of the silicon-free sample, moreover, the slopes of higher silicon-containing alloys is the lowst among the three materials.

3.4 Microstructural analysis

Fig.9 shows the cross section morphology of the samples after the creep deformation, there are some structures with special orientation, but no similar phenomenon on the vertical section of the samples. Zhu Y H[11] has discussed these structures with some special orientation induced by creep stress. Fig.10 reveals the morphology

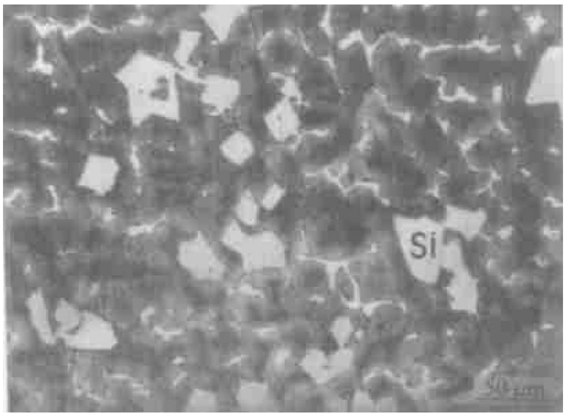

Fig.5 Microstructure of as-cast 5Si/ZA27 alloy (After modification)

Fig.6 Curves of strain vs time of three samples

Fig.7 Curves of the strain rate vs time of three samples

Fig.8 Simulation graph of the minimal creep rates

of some fragmented silicon particles at the edge of the samples, because the stresses easily concentrate on the edge of the sample and the matrix (ZA27) has an excellent plasticity at the high temperature. On the other hand, the silicon particles are so brittle as not to afford the high stress and then led to break down.

3.5 Creep mechanism

As a result, the creep resistance of the zinc-based alloy containing silicon particle phase performed better than that of the conventional ZA27 alloy. The creep mechanism of the zinc based alloy containing silicon particle should be developed from the traditional creep mechanism, because the existence of fine silicon particles effected the movement of dislocation and grain boundary sliding behavior, and finally led to decrease the minmum creep rate.

4 CONCLUSIONS

(1) The silicon particles reinforced exhibit higher hardness, lower density and lower

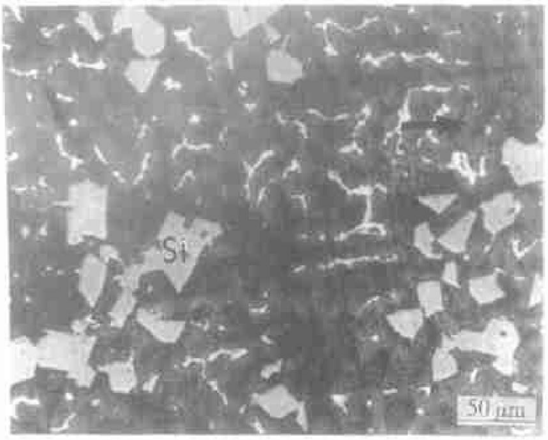

Fig.9 Structural orientation after creep deformation

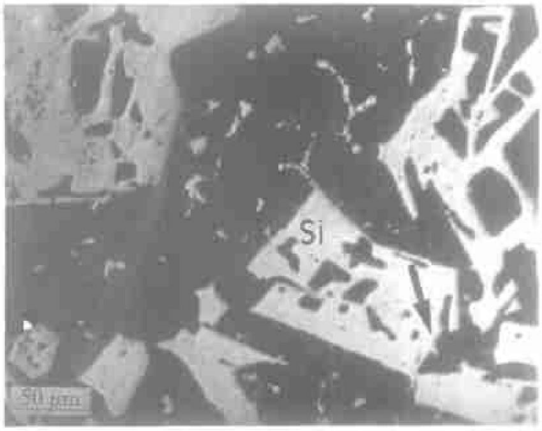

Fig.10 Damage morphology of silicon particle

zinc-based cast alloys modified by $(NaPO_3)_6$ thermal expansion coefficients than those of the conventional zinc-based alloy(ZA27).

(2) The creep resistances of the modified zinc-based alloys containing silicon particle were significantly better than that of ZA27 alloy at the same experimental condition. Moreover, the alloys with higher concentration of silicon element have better creep resistance.

(3) The modified zinc-based alloys containing silicon phase with improved elevated temperature property could be developed through microstructural and compositional alterations, this would greatly widen the application of zinc-based alloy.

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