CREEP BEHAVIOUR OF ROUND Al AND AlSi7Mg PLATES IN THE TEMPERATURE RANGE 633-903 K

Liljana STOJANOVA* and Krassimir RUSSEW*

Creep behaviour of round Al and AlSi7Mg plates is quantitatively studied. Empirical relations between load, temperature and deflection rate are derived. A possibility is shown to calculate, from the experimentally determined deflection rate of Al and AlSi7Mg cover plates of artificial blisters, the hydrogen pressure in annealing blisters of Al-alloys during heat treatment in moist atmosphere.

INTRODUCTION

In a previous paper (1) we have shown that the kinetic of hydrogen agglomeration in surface blisters in Al and Al-alloys during heat treatment in moist atmosphere could be quantitatively studied with the aid of artificial blisters, shown in Fig.1a. In order to calculate the pressure and the ammount of H_2 in these hollow defects the creep behaviour parameters of the metallic cover plates have to be known. The aim of this study was to derive empirical relations between the hydrogen pressure causing the blow up of artificial blisters and the experimentally determined deflection rate of the cover plates.

EXPERIMENTAL RESULTS AND DISCUSSION

Round plates of Al or AlSi7Mg alloy with a thickness of 0.43 and 0.50 mm respectively, were bonded between two rings of the same material with the aid of diffusion welding - Fig.1b. The bending creep of these plates (as well as the blow up of the artificial blisters) was studied with the aid of a PERKIN ELMER Thermomechanical analyzer TMS 2 (1,2). The values of deflection ω in the middle of the metallic plates, caused by different point loads P applied in the geometric centre of the plates, were monitored as

*Institute for Metal Science and Technology,
Bulgarian Academy of Sciences

a function of temperature (continuous heating conditions, heating rate 20 K/min) or time (isothermal conditions, heat treatments at several constant temperatures).

Fig.2 represents the temperature dependence of deflection ω of Al plates, caused by different applied loads under nonisothermal conditions. From these curves the deflection rate $\dot{\omega}$ was determined as a function of temperature. Fig.3 shows an example of creep curve of round Al plate under isothermal conditions as directly obtained by TMS 2. Similar curves were used to determine the deflection rate $\dot{\omega}_{iso}$ by steady state creep of the metallic plates heat treated at different constant temperatures and different applied loads.

As duscussed in (2) the dependence of steady state creep (deflection) rate $\dot{\omega}$ vs. the applied load P can be represented as:

low P values: $$\dot{\omega} = C_1 P^{1/m} \exp(-Q/RT) \qquad (1)$$

high P values: $$\dot{\omega} = C_2 \exp(BP) \exp(-Q/RT) \qquad (2)$$

where m, B, C_1 and C_2 are empirical constants, and Q is the activation energy for high temperature steady state creep. The values of these constants were determined experimentally.

Some of the experimental results for pure Al plates and their interpretation are already published elsewhere (2). By using eq.(1) and the experimentally determined deflection rates under isothermal and nonisothermal conditions the relations $P = P(T, \dot{\omega})$ were derived. According to (3) the relation between load P applied in the middle point of a round plate, and load Δp, uniformly distributed over the whole plate surface (e.g. gas or hydrostatic pressure), both applied at the same temperature and causing deflection with one and the same steady state deflection rate $\dot{\omega}$ of plates with equal dimensions, could be represented as:

$$\Delta p = 0.63 \ 13^{m/2} P \qquad (3)$$

For Al plates m = 0.492, and m = 0.561 in the temperature ranges 723-813 K and 813-903 K respectively. The relation Δp vs. $\dot{\omega}$ for Al cover plates of artificial blisters is as follows:

723-813 K: $$\ln \Delta p = -8.191 + 4220/T + 0.492 \ln \dot{\omega} \qquad (4)$$

813-903 K: $$\ln \Delta p = -14.902 + 9750/J + 0.561 \ln \dot{\omega} \qquad (5)$$

Due to the more complex multiphase structure of AlSi7Mg alloy its creep behaviour as compared with pure Al is more complex too. The experimental results for this alloy are given in Table 1. According to (3) the Δp vs. P-relation in this case is given by:

$$\Delta p = 0.38\ 13^{\,m/2}\ P \tag{6}$$

The values of m are given in Table 1.

TABLE I - Experimental results for AlSi7Mg alloy

T, K \ P, N	0.5	1.0	1.5
	$\dot{\omega}$ x10^6, m/min		
633	0.2	0.4	0.7
673	0.4	0.6	0.9
713	0.6	1.0	1.3
553	0.8	1.2	1.9

T, K \ P, N	0.5	1.0	1.5
	$\dot{\omega}$ x10^6, m/min		
773	0.9	1.6	2.2
813	1.0	1.8	2.8
853	1.2	2.5	3.6
m	1.15 for all temperatures		

T, K \ P, N	0.5	1.0	1.5	m	e	f	h	k
	$\dot{\omega}_{iso}$ x10^6, m/min							
783	0.1	0.4	0.8	0.68	-1.64	0.68	0.17	0.06
802	0.2	0.5	1.0	0.78	-1.63	0.78	0.18	0.09
817	0.3	0.6	1.1	0.81	-1.68	0.81	0.18	0.09
837	1.2	1.9	3.8	0.90	-2.68	0.90	0.06	0.12

Under nonisothermal conditions the dependence of H_2 pressure Δp in AlSi7Mg blisters on the temperature T and deflection rate $\dot{\omega}$ could be represented as:

$$T < 773\ K: \quad \ln \Delta p = -8.404 + 4840/T + 1.15 \ln \dot{\omega} \tag{7}$$

$$T > 773\ K: \quad \Delta p = -1.019 + 860/T + 0.164 \ln \dot{\omega} \tag{8}$$

Under isothermal conditions the following relations between Δp and $\dot{\omega}$ were derived:

$$T < 813\ K: \quad \ln \Delta p = e + f \ln \dot{\omega} \tag{9}$$

$$T > 813\ K: \quad \Delta p = h + k \ln \dot{\omega} \tag{10}$$

The values of the empirical constants e, f, h and k are diven in Table 1.

Fig.4. represents the time dependence of deflection ω , deflection rate $\dot{\omega}$ and the hydrogen pressure Δp in artificial AlSi7Mg blister during its heat treatment in moist atmosphere. The pressure Δp was calculated with the aid of eqns. (7) - (10). The blister was heated in the TMS 2 oven with 20 K/min up to 818 K followed by isothermal arrest until vanishing of any further deflection of cover plates.

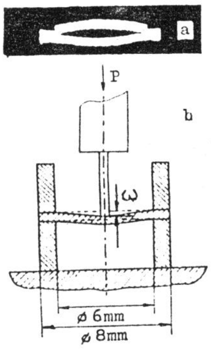

Fig.1. Experimental scheme

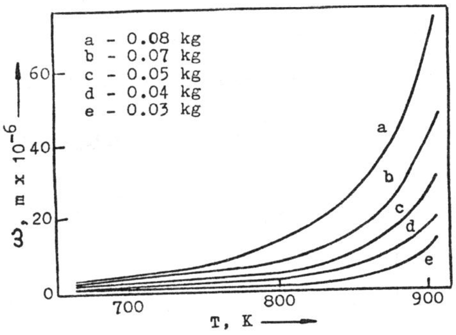

Fig.2. Temperature dependence of ω for pure Al plates.

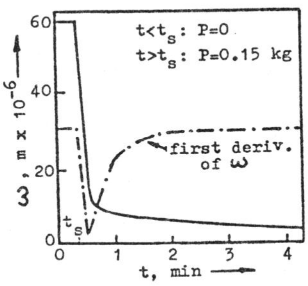

Fig.3. Creep curve under isothermal conditions.

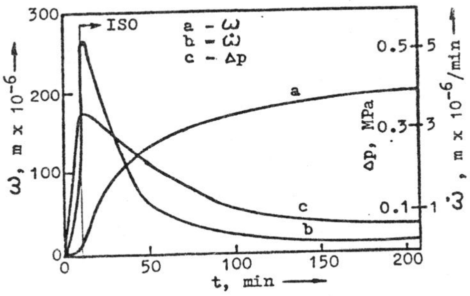

Fig.4. Data for hydrogen blow-up of AlSi7Mg artificial blisters.

REFERENCES

(1) Stojanova, L., Yaneva, S. and Stojchev, N., Z.Metallkde., V.78, 1987, p.452.

(2) Russew, K. and Stojanova L., Z.Metallkde., V.78, 1987, p.447.

(3) Birger, I.A. and Panovko, J., Prochnost-Ustojchivost-Kolebania, Vol.1, Publ. House „Mashinostroenie", Moskow, 1968 (in Russian).