Physical Sciences Section

QUESTION OF SECONDARY PEAK IN HARDNESS VERSUS RETROGRESSION TIME CURVE OF AA-7075 ALUMINIUM ALLOYS

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In 1974 Cina reported a new heat treatment process called retrogression and reaging for AA-7075 aluminium alloys to improve its resistance to stress corrosion cracking while maintaining its peak strength. Retrogression at a particular temperature, as a function of time, yields a secondary peak for hardness and strength. Present investigations indicate that the secondary peak is only a fluctuation in hardness values and has no physical existence. This has been confirmed by electrical resistivity measurements. Microstructural changes responsible for decrease in hardness during retrogression process have also been investigated by transmission electron microscope (TEM).

Key words : Hardness, Retrogression, AA-7075.

INTRODUCTION

Among the existing aluminium alloys, the AA-7075 aluminum alloys provide highest strength and good creep properties in T6 condition [1]. To improve its resistence to stress corrosion cracking (SCC) a heat treatment process called T73 is adopted which results in 10-15% lower strength than T6-temper. In 1974 Cina [2] reported a new heat treatment process known as retrogression and reaging (RRA) which claimed to give strength level equivalent to that of T6-temper, and SCC comparable to that of T73-temper. Heat treatment conditions for the standard T6 and T73 tempers are given in Table 1. RRA is applied to

Table 1. Heat treatment conditons for AA-7075

Solution anneal (W-Temper)	460°/3hrs/water quenched.
T6 - Temper	Solution anneal, age at 120°/ 24 hrs.
T73 - Temper	Solution anneal, two stage over-age; 110°/8hrs + 177°/8hrs.

AA-7075 in T6-temper and consists of heating for a short time called "retrogression" in the range of 200 to 280°. This is followed by reaging using T6 conditions.

Schematic representation of changes in hardness [2, 3] and yield strength [4, 5] during RRA are shown in Fig. 1. In retrogression process hardness/yield strength falls very sharply to a minimum value before increasing to a secondary peak, and then decreases as the material is overaged. In reaging after short retrogression treatment, hardness/yield strength is increased by 10-15% as compared to the original T6-levels, while longer retrogression times lead to a gradual loss of hardness/yield strength during reaging (Fig. 1).

Danh *et. al.* [4] have concluded that the retrogression process can be divided into three stages (Fig. 1). Stage I
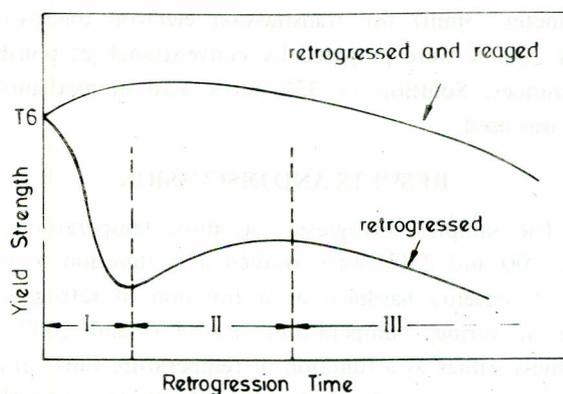
Fig. 1. Schematic representation of the changes in hardness/ yield strength during retrogression and reaging treatments [5].

corresponds to the partial dissolution of Guinier-Petterson, (G.P) Zones whereas formation and growth of precipitates can be correlated to stage II, and stage III results due to the coarsening of $MgZn_2$ precipitates. Islam and Wallace [6] have observed the dependence of retrogression temperature on the secondary peak. Farther wallace *et. al.* [7] have shown longer time may be needed to reach the minima at given temperature which is contrary to the results reported in literature [2, 6] and also that initial minimum in the retrogression does not necessarily correspond to the time required for the optimum combination of strength and SCC-resistance.

The aim of this work was to study hardness and electrical resistivity as a function of retrogression time and temperature and to investigate the reasons for the appearance of secondary peak (stage II) by TEM studies. Results obtained are reported here.

MATERIAL AND METHOD

Samples (15mm x 15mm x 1mm) from AA-7075 aluminium alloy extruded tubes were used. The chemical composition of the alloy is given in Table 2. Hardness was

Table 2. Chemical composition of AA-7075 aluminium alloy.

Element	Wt.%	Element	Wt.%	Element	Wt.%
Zn	5.49	Fe	0.13	Cr	0.21
Mg	2.15	Si	0.10	Ti	0.01
Cu	1.75	Mn	0.01	Al	Balance

determined on a Vickers Hardness Tester using a load of 5 kg. Each hardness value is a mean of 5 values. Electrical resistivity was measured on strips of 30.00mm x 2.75mm x 0.10mm using standard four probe method (8). Specimen (diameter; 3mm) for transmission electron microscope, JEM 200CX were prepared by conventional jet polishing techniques. Solution of 33% nitric acid in methanol at 40° was used.

RESULTS AND DISCUSSION

The samples retrogressed at three temperatures, viz 170, 200 and 230° were studied as a function of time. Fig. 2 presents hardness as a function of retrogression time at various temperatures. For 170 and 200°, the hardness values as a function of temperature runs parallel, and a minimum is obtained around 9 minutes and a slight increase is noted around 12 minutes but it is not significant and can also be interpretted as mere fluctuation in the
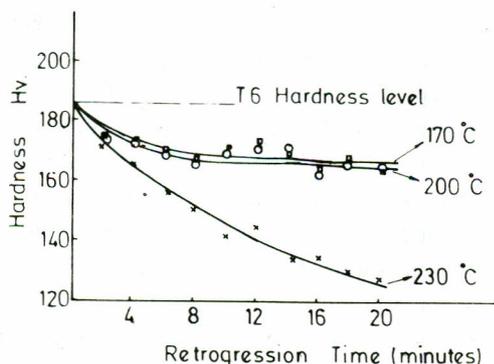
Fig. 2. Vickers hardness as a function of retrogression time at various retrogression temperatures.

hardness values (+3 HV). This is incontradiction to the work of Cina [2] and Park and Ardell [3]. The results of 230° retrogression are similar except that continuous decrease in hardness is registered upto 20 minutes.

The retrogression temperature, 230°, was selected for further studies due to the reasons that Islam and Wallace [6] registered a secondary peak at 220° after 5 minutes whereas at 180 and 200° for upto 10 minutes no secondary peak was noted. Secondly, a larger decrease in hardness at constant retrogression time is noted. At 230° 25 samples were studied as a function of time upto 100 minutes (Fig. 3) but no secondary peak was observed which is incontradiction to the work of Cina [2], Park and Ardell [3] Islam and Wallace [6]. Reaging of these samples
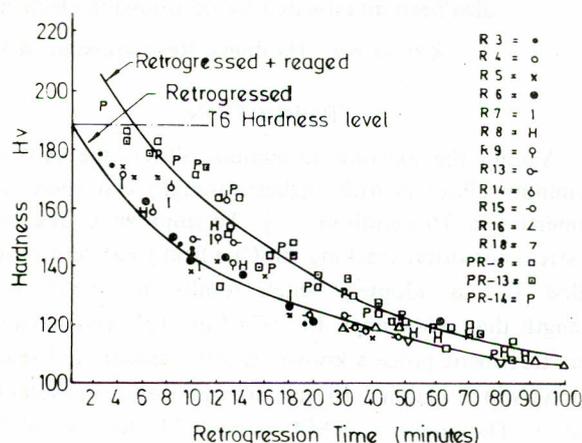
Fig. 3. Vickers hardness as a function of retrogression time and subsequent reaging.

showed that upto 6 minutes of retrogression, an increase in hardness was observed as compared to T6-temper. Lower retrogression time (say 2 minutes) resulted in an increase of about 11% in hardness which decreased as retrogression time was increased, and at five minutes no change was noted. Further increase in retrogression time resulted in a decrease in hardness as compared to T6 and longer retrogression time i.e. above 80 minutes made no improvement in hardness on reaging.

Electrical resistivity is a sensitive parameter and any change in phase transformaton or precipitation causes a change in its value . Furthermore there exists a definite correlation between electrical resistivity and hardness values of Al-alloys [9, 10]. Therefore, its was studied as a function of retrogression time and temperature. Change in electrical resistivity, (between un-retrogressed i.e. in T6-state and after relevant retrogression time) as a function of retrogression time is shown in (Fig. 4). It increases rapidly as retrogression time is increased and seems to saturate
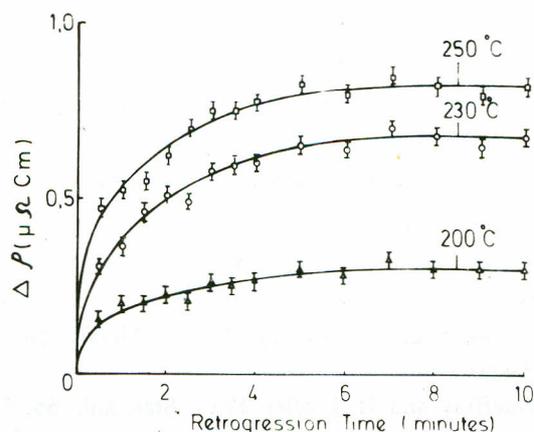
Fig. 4. Change in electrical resistivity as a function of retrogression time.

above 3 minutes. Higher retrogression temperature gave larger changes in resistivity values and saturation time appears to be temperature dependent. Here again nothing like secondary peak is registered. This is in agreement with the work of Islam *et. al* [6] and Shamim *et. al* [11].

The yield strength or hardness (Fig. 1) at the secondary peak, however, is not same as that of the original T6 starting materials, suggesting that there exist a different microstructural component contributing to the strengthening or hardening compared to the T6 temper. Therefore transmission electron microscope was used to compare the retrogressed structure after retrogression at 230° for various time intervals.

T6 material showed a typical microstructure with a homogeneous distribution of fine $MgZn_2$ precipitates in the matrix (Fig. 5a). It may be added that G.P. Zones would also be expected in the starting condition [7]. Micrographs of the T6 material retrogressed at 230° for 1, 2, 4, 5, 10, 20 and 30 minutes, respectively, are shown in (Fig. 5b) through 5h. There is almost no change in precipitate size upto one minute and above this a continuous growth of precipitates is observed. This is in agreement with the work of Danh *et. al* [4] and also in agreement with the small angle X-ray scattering (SAXS) data of Gueffery and Loffler [14]. Further Ungar *et. al* [15] have found that the dissolution of particles did not take place at temperatures below 250° and coarsening of would contirbute to a decrease in strength [16]. Thus it may be concluded that a continuous decrease in strength/hardness during retrogression can be explained on the basis of the coarsening of and − precipitates. These precipitates are composed of $MgZn_2$ and have hexagonal structure. The difference between the two is of lattice parameters only are coherent with the matrix [17]. Further, no special structural change during retrogression (Fig. 5b, 5h) is noted which may be held responsi-
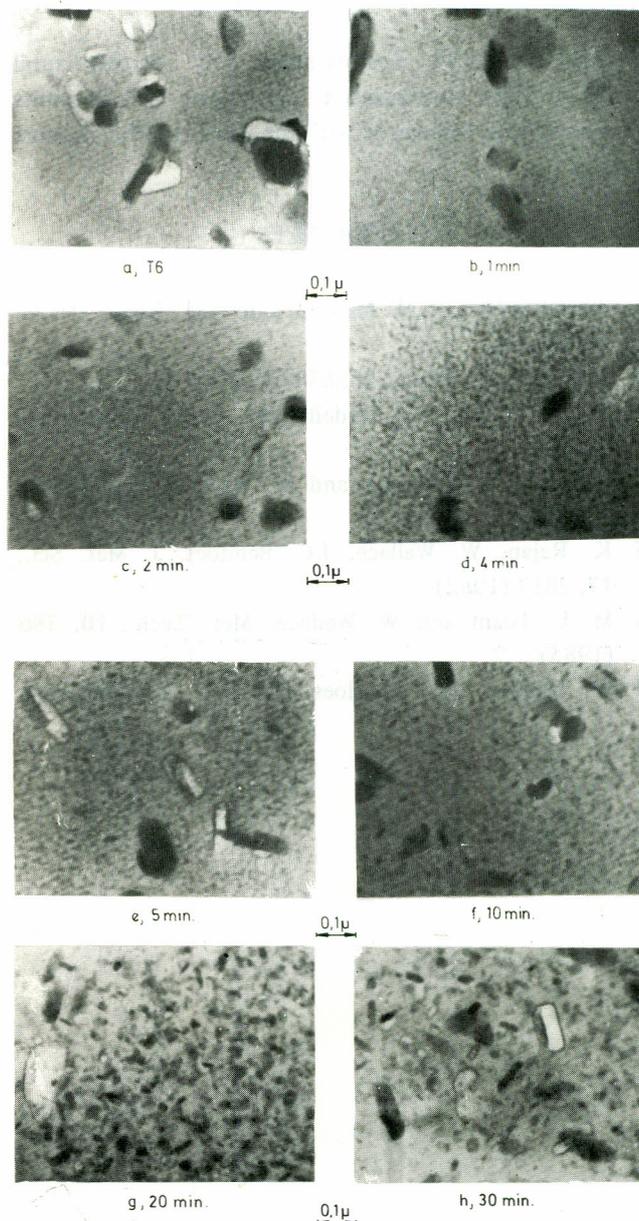
Fig. 5. Electron micrographs showing T6 (a) and coarsening of $MgZn_2$ (fine) precipitates during retrogression at 230° as a function of time (b to h).

ble for secondary peak. Thus existence of secondary peak was not proved by hardness and electrical resistivity measurements as well as TEM studies.

However, it is interesting to mention that in one minute retrogression (Fig. 5b) no increase in precipitate size is observed but hardness has decreased as compared to T6. This leads to the conclusion that this may be due to the partial dissolution of G.P. Zones [4].

CONCLUSION

Hardness measurements as a function of retrogression time revealed no secondary peak. This is confirmed by

electrical resistivity measurements and microstructural studies in TEM. Retrogression and reaging (RRA) results are, however, in agreement with the work of other authors [2-7].

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