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INITIAL SOFTENING IN SOME ALUMINIUM BASE PRECIPITATION HARDENING ALLOYS (*)

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It has been reported by previous workers that some extent of softening is observed before setting in of the usual hardening process when ageing is carried out on the Al-Cu and Al-Mg precipitation hardening alloys. The possible reason for the initial softening has been suggested as relief of thermal strain.

Present work was undertaken to make systematic study of initial softening in certain Al-Cu and Al-Mg alloys. The phenomenon of initial softening was studied as a function of solute concentration, quenching medium, and temperature of ageing. Hardness measurements were carried out to follow the process of softening and relief of thermal strain was studied by analysing X-ray line profile.

Experimental Procedure

Preparation of Alloys:

Binary Al-Cu and Al-Mg alloys were prepared from super purity Aluminium and high purity copper and Magnesium. The cast alloys were forged, annealed and machined into disc shaped specimens 20 mm dia x 8 mm thick. The nominal compositions of the binary Al-Cu alloys were from Al-2% Cu to Al-4.5% Cu at intervals

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of 0.5% Cu. The Al-Mg alloys, that were cast, had the nominal compositions of Al-6% Mg, Al-8% Mg and Al-10% Mg.

Heat Treatment:

The alloys were solution treated at appropriate temperatures and then quenched in (1) water at (30 ± 1)°C or (2) Brine water at 0°C. The specimens were then aged at 110°C, 130°C, 170°C, 190°C and 210°C for the binary Al-Cu alloys and 200°C, 250°C and 300°C for the Al-Mg alloys.

Hardness Measurement:

Hardness values were determined by a Vickers Hardness tester with 5 Kg load. 4 specimens were taken out at the end of each ageing period and 3 hardness values were determined on each specimen. Average of a set of 12 readings was taken for determining each hardness value on ageing.

X-ray diffraction studies:

For the purpose of X-ray studies the specimens were mounted on perspex sheet after being polished. The target used in the X-ray tube was Iron. Manganese filter was used to cut off K_β radiation. Bragg angle Vs intensity graphs were plotted with automatic strip chart potentiometer. The half width (β) of the diffracted line was evaluated by dividing the area under the curve by the peak height above the background.

Results & Discussions

Quenched Hardness:

It was observed that the quenched hardness values of both Al-Cu and Al-Mg alloys increase with (a) Severity of quench and (b) Solute concentration. Each of this is attributable to increased lattice strain. Part of quenched hardness is also corelated to possible creation of dislocation loops as a result of collapse of vacancy clusters.

Extent of Softening:

The results show that extent of softening that is observed before the setting in of the hardening process is a function of both solute concentration and severity of quench. The simple explanation lies in the process of relief of lattice strain developed during quenching. Further it was also evident that whereas the extent of softening steadily increases with increasing temperature of ageing for Al-Cu alloys, the case is just the opposite for Al-Mg alloys. The possible reason for this type of behaviour is suggested in terms of the discontinuous and continuous precipitation and consequent grain boundary and intergranular precipitation that takes place in the Al-Mg system.

Time to reach minimum hardness:

The two systems viz Al-Cu and Al-Mg showed distinct difference in behaviour with respect to time required to reach minimum hardness in the range of temperatures under study. In case of Al-Mg alloys, it was found that time taken to reach minimum hardness decreased steadily with increase in the temperature of ageing. This result can be explained as due to the acceleration of the processes of relief of thermal strain and precipitation hardening with increase in ageing temprature. On the other hand, for Al-Cu alloys, there was a reversal in the trend of relationship between the time-to-minimum hardness and ageing temperature. First, the time increased with decrease in ageing temperature and then suddenly the value dropped down on decreasing the ageing temperature below a particular value. The possible explanation lies in corelation between the time-to-minimum hardness and the precipitating entity responsible for hardening. In the particular range of ageing temperatures, there is change over from precipitation of (a) Zones to (b) θ', with increase in ageing temperature. The difference in kinetics of precipitation of zones and θ' explains the anamoly that is observed.

For both the alloys, it was observed that at a given temperature of ageing, higher is the solute concentration, lower is the time-to-minimum hardness. The obvious explanation is the faster rate of hardening due to higher degree of supersaturation.

Range of Softening:

For the Al-Cu alloys under study, it was noted that softening could be observed only over a definite range of temperature. This range gets reduced with increase in solute concentration. It is suggested that the lower and upper limit of temperature of ageing within which softening can be observed is fixed by (a) Complete masking of strain relief by zone formation due to slow rate of strain relief and (b) Extremely fast process of strain relief followed by precipitation such that initial softening is not observable.

X-ray line width:

The values of half line width (β) (obtained after suitable corrections for nonhomogeneity of K_α radiation due to the presence of doublet and assuming Gaussian distribution for line profile) are found to be in accordance with hardness values. Initially the value of β is large and there is sharpening when the hardness value attains a minimum, followed by broadening on further ageing. The plausible explanation is that the initial width is due to distorted lattice produced as a result of quenching. Subsequent broadening can be attributed to coherency strains developed between the matrix and precipitating zones or precipitating phases.

Conclusion

The study of initial ageing indicates that

1. There is initial softening followed by usual hardening.

2. Only within a definite range of temperature of ageing, initial softening can be observed. With increase in solute concentration the range narrows down.

3. The extent of softening increases with (a) severity of quench and (b) solute concentration.

4. For Al-Cu alloys, the extent of softening increases with increase in ageing temperature

in contrast to Al-Mg alloys where the reverse is found to be true.

5. Time to reach minimum hardness increases with decreases in temperature and there is reversal in this trend for many Al-Cu alloys.

6. X-ray line profile analysis reveals an initial sharpening followed by the broadening of the lines.