KINETICS CHARACTERISTICS OF BAINITE FORMATION IN Cu-Zn-Al ALLOYS①

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ABSTRACT

TTT diagrams and kinetics curves of bainite formation through up quenching from martensitic state and cooling from high temperature parent phase in Cu-Zn-Al alloys are established by means of dilatometry and metallographic inspection. Experimental results show that the kinetics characteristics of bainite formation obey the Austin-Rickett Equation with $n = 2.25$ for up-quenched specimens and $n = 1.80$ for specimens cooled from high temperature, and the activation energy of bainite formation is about 110 kJ / mol; corresponding to that of the diffusion of solute atoms.

Key words: Cu-Zn-Al alloy, bainitic transformation, kinetics

1 INTRODUCTION

Takezawa and Sato[1] discovered that kinetics characteristics of bainite formation through up quenching from martensitic state in Cu-Zn-Al alloys under stress conforms to the Austin-Richett Equation for diffusional formation with its activation energy close to that for the diffusion of Zn. Lee and Kim[2] got the same results in Cu-Zn-Al alloys by monitoring the variation of electrical resistivity with time at aging temperatures for up quenched specimens from a martensitic state. In this paper, the isothermal transformation kinetics of bainite formation through up-quenching from a martensitic state and cooling from a high temperature parent phase in Cu-Zn-Al alloys are studied by means of dilatometry and metallographic inspection.

2 EXPERIMENT AND RESULTS

A Cu-25.34Zn-3.88Al (wt%) alloy is used for up-quenched specimens which are 12mm long and 2mm in diameter. After annealing at 500℃ for 2h, cooling down to 200℃ in furnace and then to room temperature in air, these specimens are held at 800℃ for 5 min, quenched into a 150℃ oil bath for 15 min, and then quenched into water to get 18R martensite (M_s = 72℃) and finally set in a LK-02 dilatometer and up-quenched to different temperatures in the range of 200–300℃ at a rate of 40℃ / s. The measured TTT diagram and change of fraction transformed vs time are shown in Fig.1 and Fig.2 respectively. The transformation product is plate like bainite

①Manuscript received June 6, 1991

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whose fraction transformed is corrected by metallography.

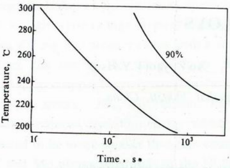

Fig.1 TTT diagram of specimen up quenched from martensitic state to various temperatures in a Cu-25.34Zn-3.88Al alloy

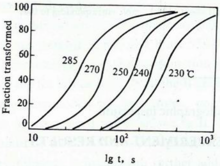

Fig.2 Fraction transformed vs time curve of bainite formation through up quenching from martensitic state in a Cu-27.27Zn-3.73Al alloy

A Cu-27.27Zn-3.73Al (wt%) alloy is prepared for $12\times 2\times 1mm^3$ specimens cooled down from a high temperature parent phase. After annealing at 550℃ for 1h, cooling down to 200℃ in furnace and then to room temperature in air, these specimens are set in a LK−02 dilatometer, heated to 800℃ at a rate of 10℃ / s and held for 10 min, and then quenched to different temperatures at a rate of 100−120℃ / s. The measured TTT diagram is shown in Fig.3.

The morphology of the transformed products after isothermal holding at above 370℃ is rod or needle, and below 370℃ it is a mixed structure of rod and plate, i. e. $B_s\approx$ 370℃. In the range of 300−325℃, the mainly product is plate-like bainite. The change of fraction transformed vs time is shown in Fig.4.

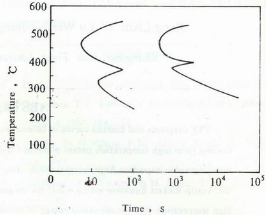

Fig.3 TTT diagram measured from parent phase cooling in a Cu-27.27 Zn-3.37Al alloy

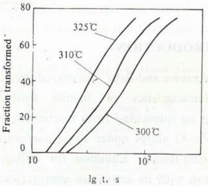

Fig4 Fraction transformed vs time curve of bainite formation in a Cu-27.27 Zn-3.73Al alloy

3 DISCUSSION

The dilation and X-ray diffraction analyses show that in up quenched specimen, the 18R martensite is firstly transformed into a DO_3 parent phase which is transformed into bainite during subsequent isothermal holding. In reference to the work of Singe *et al.*[3], the transition temperature of B_2-DO_3 in Cu-27.27 Zn-3.73Al alloys is about 290℃. Thus, the bainite forms from a B_2 parent phase for the

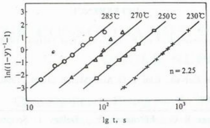

Fig.5 $\ln((1-y)^{-1}-1)$ vs lgt for bainite formation of the up-quenched specimen in a Cu-25.34Zn-3.88Al alloy

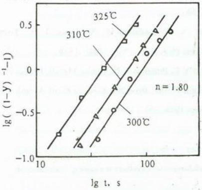

Fig.6 $\lg((1-y)^{-1}-1)_n$ vs lgt for bainite formation of the specimen quenched from a high temperature parent phase in a Cu-27.27Zn-3.73Al alloy

specimens quenched from high temperture in the range of 325–300℃.

The kinetics curves in Figs.2 and 4 obey the Austin-Rockett Equation for diffusional transformation[4]

$$dy / dt = kn(1-y)^2(kt)^{n-1}$$

Where, y is the fraction transformed, t is time and k is a coefficient connected with the activation energy. The value of n is 2.25 for up-quenched specimens (Fig. 5) and 1.80 for specimens quenched from high temperature (Fig.6). They are close to each other.

The kinetics do not conform to the Austin Rockett Equation for specimens quenched from high temperature to below 300℃ because B_2 and DO_3 are transformed into bainite at the same time. Figs.2 and 4 do not obey the Avrami Equation. It can be concluded that

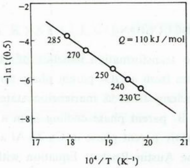

Fig.7 $-\ln t(y=0.5)$ vs T^{-1} for bainite formation of an up quenched specimen in a Cu-25.34Zn-3.88Al alloy

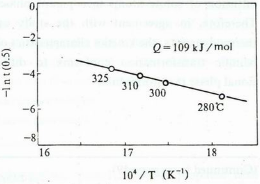

Fig.8 $-\ln t(y=0.5)$ vs T^{-1} for bainite formation of a specimen quenched from a high temperature parent phase in a Cu-27.7Zn-3.73Al alloy

both hard impingement and diffusion associated soft impingement coexist in the growth process of bainite in Cu-Zn-Al alloys.

From the Arrhenius Equation with y = 50%, it follows that the activation energies of bainite formation from DO_3 through up-quenching, and from B_2 through quenching from high temperature are 110kJ / mol (Fig.7) and 109kJ / mol (Fig.8) respectively, the former being consistent with the latter.

In reference to the reported activation energies of the diffusion of Zn in Cu-Zn alloys as 150 kJ / mol[5, 6] and 135 kJ / mol [7], it may be reasonably suggested that the 110 kJ / mol given in this work is the activation energy for the diffusion of solute atoms in Cu-Zn-Al alloys.

4 CONCLUSION

The transformation kinetics of bainite formation from a DO_3 parent phase through up-quenching from a martensitic state and from a B_2 parent phase cooling from a high temperature parent phase in Cu-Zn-Al alloys, obey the Austin Rockett Equation with the value of n close to 2. The activation energy of bainite formation corresponds to that of the diffusion of solute atoms in a parent phase. Therefore, in agreement with the study on thermodynamics, the kinetics characteristics of bainitic transformation conforms to diffusional phase transformation.

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