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Grain Behaviour in 70/30 Brass Plate Heat-Treated Rapidly at High Temperatures*

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Synopsis

The grain behaviour in 70/30 brass plate at high temperatures was investigated by means of the rapid-heating method, and its applicability to controlling the grain size was also considered. It was observed that the effects of impurities, rolling reduction and ready-to-finish grain size were much reduced than in the case of the ordinary batch-annealing method at lower temperatures. The non-uniform mixed grain size observable sometimes at lower temperatures could be avoided, and the scale formation by oxidation was comparatively slight. However, it should be noted that the material slightly cold-rolled showed a grain growth although no recrystallization could be observed.

I. Introduction

With the improvement in quality of wrought copper alloys in recent years, the grain size has become so important that it has been designated in JIS (Japanese Industrial Standard). Since the behaviour of grain during heat-treatment is affected by many factors, it is difficult to take widely applicable technical measure for the grain size control. One of the present authors previously examined the measures for the grain size control with commercial brasses in Japan by studying systematically the influence which the intermediate working process and impurities would have on the grain size.[1] In these investigations the heat-treatment was done only by an ordinary method of bach-annealing. However, the continuous-annealing or the rapid-heating method has recently come to be used,[2],[3] and naturally, the grain behaviour depends upon the condition of heating and the dimension of specimen. In the present case, only the commercial 70/30 brass was examined in the laboratory scale.

II. Experimental procedures

1. Specimen

'Every specimen was a sheet of 70/30 brass of commercial purity, 0.5 mm in thickness, finished by final rolling. To examine the influence of impurities, four

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* The 933rd report of the Research Institute for Iron, Steel and Other Metals. Reported in Japanese in the J. Japan Inst. Met., **22** (1958), 155.

(1) Y. Toba and O. Izumi, Shindo-Geppo (J. Japan Wrought Copper Alloys Assoc.), (1956), Nos. 3∼6.

(2) H. Burghoff, Grain Control in Industrial Metallurgy, ASM (1949).

(3) C.A. Turner and S.P. Banno, Met. Progr., **70** (1955), 96.

kinds of material containing different amounts of Fe, P and Pb within the range of the commercial purity as shown in Table 1 were chosen. Passing through the intermediate working process under the same condition (annealing at 500°C and

Table 1. Chemical composition of specimens.

	Zn	Fe	Pb	P	Cu
3NO	30.47	0.001	—	0.0006	Rest
K	29.34	0.019	0.029	0.001	"
3 O	30.03	0.0015	0.002	0.0032	"
3 W	29.33	0.003	—	0.007	"

rolling of 50 per cent reduction), the rolled sheet of about 4 mm in thickness was finally finished as the specimens of 0.5 mm in thickness. Further, to examine the influences of the final rolling and the temperature of ready-to-finish annealing (ready-to finish grain size), other material (Zn 31.36, Fe 0.003, P 0.002, Pb 0.007, Cu balance) was used. The material was rolled down through the same intermediate process as the above, and after ready-to-finish annealings at 750 and 500°C they were made into coarse-grained (0.2~0.3 mm) and fine-grained (0.03 mm) materials as shown in Table 2. Each of them was finished as a plate of 0.5 mm in thickness by the final rolling of 10, 30, 50 and 90 per cent reduction.

Table 2. Working procedures

50% Cold rolling ——→ Ready-to-finish annealing {750°C × 3hr., 500°C × 3hr.}

——→ Cold rolling {10%, 30%, 50%, 90%} reduction ——→ Heating at 850°C (for various times)

——→ {Water quenching, Air cooling}

2. Method of experiment

The specimen, $10 \times 15\,mm^2$, was cut off from the above-mentioned rolled material. Each specimen was annealed at 850°C for 5 sec~5 min, and then water-quenched and air-cooled. In this case, the real temperature of the specimen at the time when it was put into the furnace naturally comes into question, but the specimen was so small as compared with the capacity of the furnace that it was almost impossible to detect the change in the furnace temperature when the specimen was really put into the furnace. Therefore, though it was probale that it might take some time to reach the temperature of 850°C, the time for which the specimen was kept in the furnace was adopted as the standard of comparison. The surface of the specimen after heat-treatment was first polished with emery paper to remove dezincificated or oxidized layers, then, electrolytically polished and etched in the orthophosphoric acid solution, and further, re-etched chemically in ferric chloride solution, in order to show the grain boundaries clearly. The grain size was determined by comparing microscopic photographs of these specimens with the standard pictures of the grain size of ASTM.

III. Experimental results and considerations

1. Influence of impurities

The result obtained with the above-mentioned four kinds of specimen is shown in Fig. 1, in which two dotted lines parallel to the adscissa show the range of the practical use of grain size. In 10~15 sec of heating it began to recrystallize and soon afterwards a rapid grain growth took place. The materials containing Fe and P began to recrystallize rapidly but the grain growth was somewhat slow, and when the time of annealing was prolonged their grain sizes showed a tendency to become somewhat coarser than others (30, 3W in the figure). In the material of high purity (3 NO), the grain growth was comparatively fast. The influence of Fe alone or containing Pb was not so striking (K). The grain size in the range of practical use might be obtained for about 30~45 sec under the annealing at 850°C in the present experiment, but even in the range of the commercial purity the influence of impurities was observable to some extent, though it might be diminished as compared with the case of batch-annealing.(1) Therefore, it may be necessary to take good care of the composition of the material

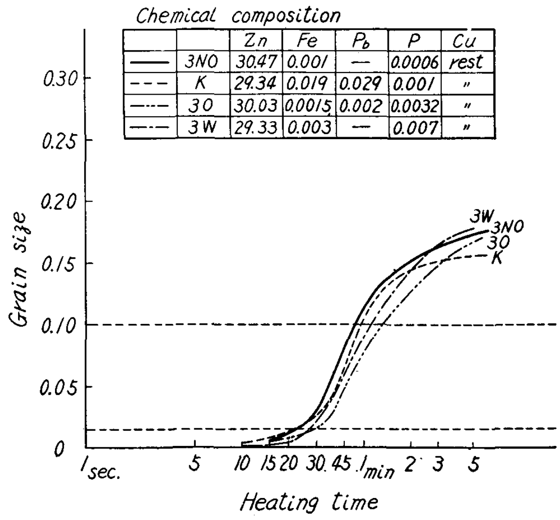
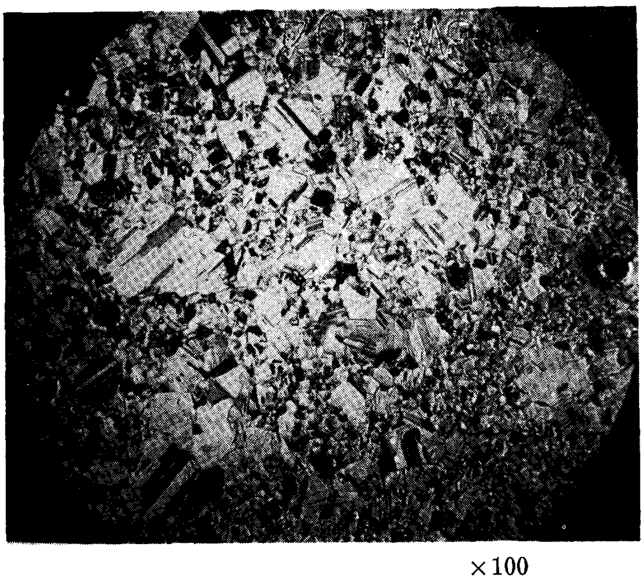


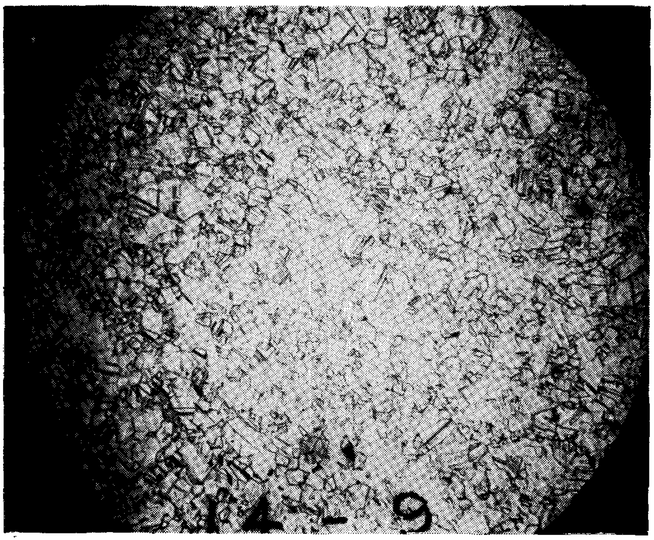
Fig. 1. Effect of impurities on grain growth at 850°C of 70/30 brass sheets, cold-rolled 50 per cent, 0.5 mm in thickness.



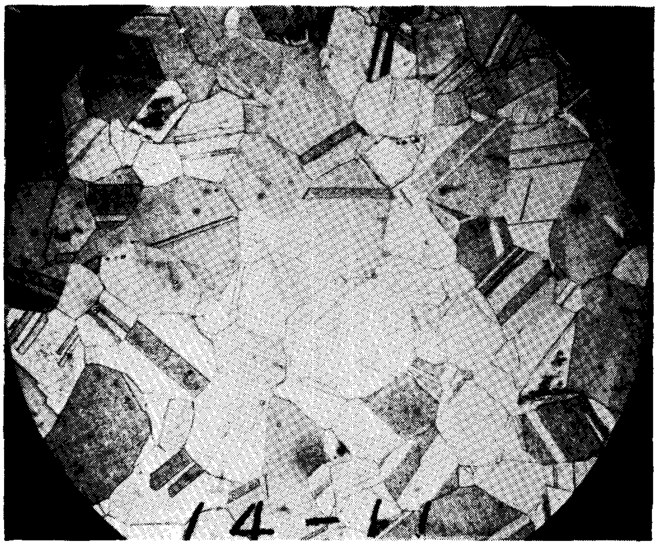
×100

Photo. 1. Mixed grain size observed at 500° annealing, Specimen : 3W.

even when the grain size control is carried out by the rapid-heating method. There was no difference between the grain size obtained by water-quenching after heat-treatment and that by air-cooling, but the hardness was a little higher in the former case. Oxidized scales were less than the ordinary case of batch-annealing, because of the short time of annealing. Furthermore, it is noteworthy that rapid-heating can prevent a mixed grain size from occurring. When the material (3W) containing a comparatively large amount of Fe and P as impurities was treated with the ordinary batch-annealing method, large and small grains mixed together as shown in Photo. 1, and made it hard to control the grain size. However, when the same material was heated rapidly at high temperatures, such tendency could be almost eradicated as shown in Photo. 2. From the above results it seems that



(a) ×100
850°×30 sec



(b) ×100
850°×45 sec

Photo. 2. Uniform grain size observed at 850° annealing, Specimen : same as shown in Photo. 1.

this rapid-heating treatment has many advantages for the grain size control, though some difficulties exist for adjusting the heating time and the temperature.

2. Effects of the working reduction and ready-to-finish grain size

The results obtained with the specimens treated as assigned in Table 2 are shown in Figs. 2 and 3. In this case, the materials of high reduction and with

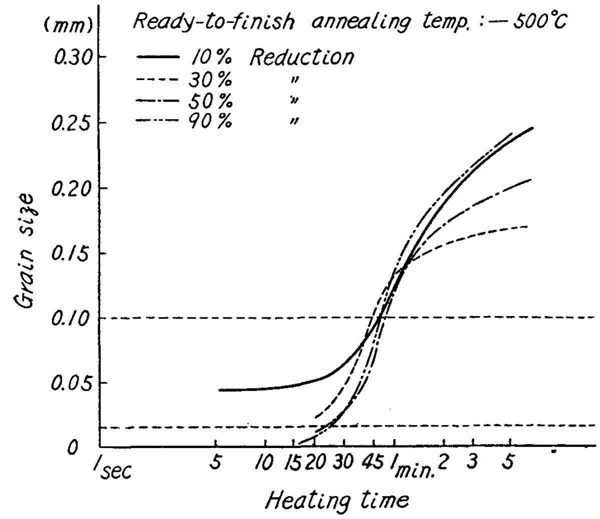


Fig. 2. Effect of final reduction on grain growth at 850°C of 70/30 brass sheets. Ready-to-finish grain size : Fine.

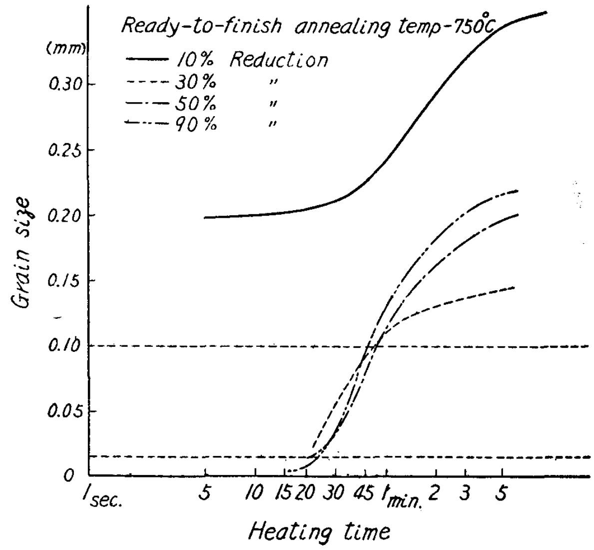


Fig. 3. Effect of final reduction on grain growth at 850°C of 70/30 brass sheets. Ready-to-finish grain size : Coarse.

small ready-to-finish grain size begin to recrystallize earlier. As for the grain size on the way to grain growth, there is little difference between the grain sizes of the specimens of 50 per cent and 90 per cent in reduction, but that of 30 per cent reduction is larger than the former two. When the time of annealing is prolonged, on the contrary, the grain size of the coarse-grained material tends to be larger in the highly reduced material. It is noteworthy that the material of low reduction of 10 per cent allows the old deformed grains to grow without the nucleation of newly oriented grains through rapid heating at 850°C. In the supplementary experiment on the same specimen annealed at 750°C, however, the recrystallization could clearly been observed. The phenomena similar to the former had been reported by Maddigan and Blank,[4] who pointed out that the grain growth without any nucleation could be recognized in the slightly reduced 70/30 brass after long-annealing at the temperature of recovery range. It is, however, uncertain whether those two kinds of grain growth can be attributed to the same mechanism, or not. Yet, it is a phenomenon worthy of attention in the practice of grain size control.

On the other hand. little or no influence of the relative size of ready-to-finish grains could be observed, so long as the working reduction was high enough to bring about recrystallization (except the above-mentioned case where the grain growed without any nucleation, even if the reduction was beyond the so-called

(4) S. E. Maddigan and A. I. Blank, Met. Tech., **7** (1940), 1166.

critical reduction for recrystallization). Fig. 4 shows the grain sizes obtained by annealing rolled sheets having different ready-to-finish grain sizes at 750, 850 and 900°C for 40 sec. It can be observed only that the coarser ready-to-finish grains

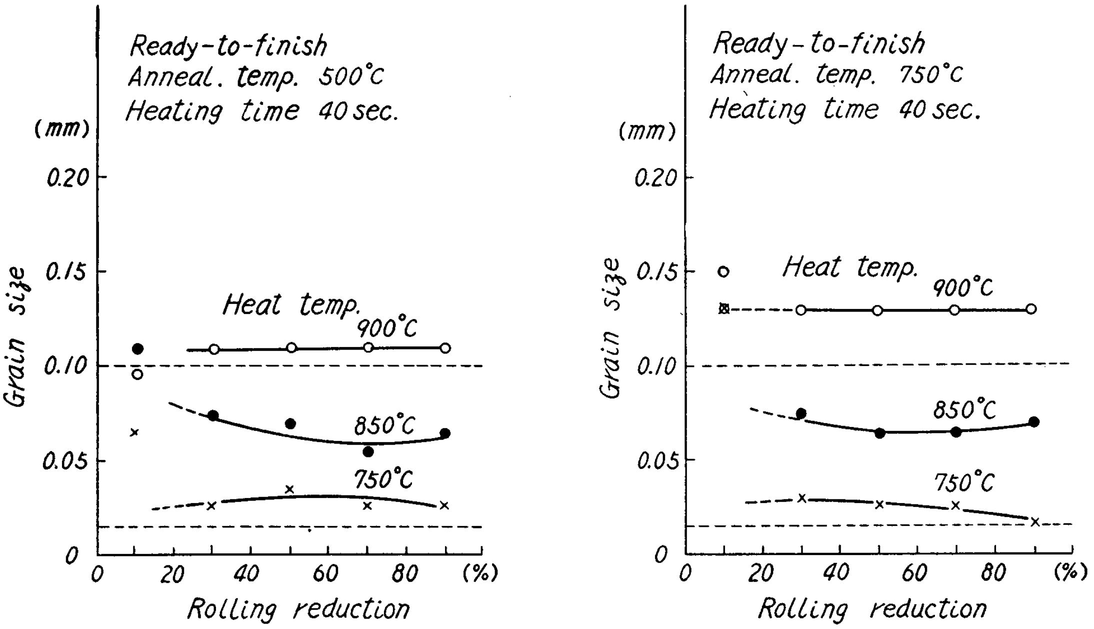


Fig. 4. Grain sizes obtained by annealings at 750, 850, 900°C for 40 sec. Ready-to-finish grain size: Fine (left), Coarse (right).

tend to become a little larger in size after heat-treatment. As a matter of fact, it is thought that this will prove no serious hindrance to rapid-heating, which may be an advantage over the case of batch-annealing.

Thus, a series of experiments was examined on the grain behaviour of 70/30 brass plate heat-treated rapidly at high temperatures, and as a result it was seen that the rapid heat-treatment was certainly applicable to the grain size control, that is, the influences of impurities, working reduction and ready-to-finish grain size can be reduced considerably as compared with the case of batch-annealing, and in the case of heating at 850°C in air, the grain size in the rang of practical use can be obtained by heating for within 1 min. It should be noted, however, that at the low reductions the grain growth takes place without nucleation due to recrystallization. If the heating velocity varies with the thickness of the plate and the metood of heating (for example, the type of the furnace or fuel), the grain behaviour will be different from the present results. Yet, the tendency of the influence of the factors may roughly be inferred from what has been stated above.

Summary

The grain behaviour of 70/30 brass plate rapidly heated at high temperatures was investigated, and the applicability of rapid heating to the grain size control was also examined. The influence of impurities, working reduction and ready-to-finish grain size could be considerably reduced as compared with the case of

ordinary batch-annealing. The occurrence of mixed grain sizes could be avoided by this method, and scales fromed by oxidation were comparatively scarce. It was noteworthy, however, that a low-reduced material showed grain growth without recrystallization.

Acknowledgments

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