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Improvement of Copper Alloy Springs. III
Secular Change in Spring Materials of Brass Series*

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Synopsis

One of the most unfavorable defects of a spring sheet of brass is that the spring properties change with time even at room temperature after final cold-working or low-temperature annealing. An investigation was made into the possibility to suppress the so-called secular change after low-temperature annealing. The change after low-temperature annealing was considered to be related to that after final cold-rolling. The secular change after cold-rolling showed a tendency to stabilize the spring properties and, when a rolled brass plate was annealed at low-temperature after it was allowed to remain at room temperature for a time long enough for stabilization, the change after low-temperature annealing became less. The secular change in two-phase brass, namely, 60/40 brass could be considered as a combined effect of α- and β-brass, though β-brass showed more complicated change than α-brass. All the experiments were carried out at room temperature and at the constant temperatures of 25° and 40°C.

I. Introduction

The spring materials of brass usually become inferior in the spring properties with time at room temperature, even after cold-rolling and low-temperature annealing, which is called "secular change". According to Murakawa(1), such a change after annealing is observable only in the alloys containing zinc, and scarcely in other metals and alloys. This phenomenon, especially the change after annealing, will be detected more clearly and precisely by the Murakawa's static or the present authors' dynamic residual deflection measurement in the spring test than by the usual hardness test, because the change in hardness after annealing is not remarkable. On the other hand, according to Mishima(2),(3), the hardness change after cold-rolling is observable at room temperature in most metals and alloys. Therefore, this change also will be detectable by the above-mentioned spring test.

As described above, brass cannot be considered as a high class spring material because of its secular change compared with other alloys, for instance, phosphor bronze, in which the change after low-temperature annealing is hardly observable,

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(1) K. Murakawa, Rep. Inst. Sci. Tech., Univ. Tokyo, **3** (1949), 10; 82.

(2) Y. Mishima et al., J. Japan Inst. Metals, **18** (1954). 543.

(3) Y. Mishima, J. Japan Inst. Metals, **19** (1955), 241.

though some changes may be expected especially after cold-working. Furthermore, as reported in the previous work, the spring property of 60/40 brass is greatly improved by adding various third elements, except the secular change. Therefore, some possibilities adequate to overcome this defect should be considered. However, scarcely any research has been made for such a purpose.

It was from the above point of view that the present authors studied the phenomenon and found it possible to suppress the change after low-temperature annealing.

II. Experimental procedures

1. Specimen

The specimens used were plain 70/30 brass, plain 60/40 brass, special 60/40 brass containing iron, manganese or tin, and plain β-brass properly annealed and cold-rolled to the thickness of 0.5 mm. Among them, plain β-brass would be necessary in investigating the behaviour of the secular change in 60/40 brass. The β-brass was cold-rolled to the thickness of 1 mm by repeating the rolling of 20 per cent reduction and the intermediate annealing at 200°C, and then subjected to the ready-to-finish annealing at 430°C for 30 min and the final cold-rolling of proper reductions. The brass was used only for the measurement of hardness, because the alloy could not be used in the spring tests. Other procedures will be described in detail in the following sections.

2. Experimental method

All experiments were carried out with the spring fatigue testing machine used in the previous work, excepting the hardness test which was performed on the specimen of β-brass. In the spring fatigue test, the residual deflection was precisely measured after repeating the bending of 2000 cycles under constant maximum surface stresses (σ_{max}). Though the specimens were kept at room or higher constant temperature for the ageing, each measurement was made at room temperature. At least, a day was required for preparing the specimens, such as cutting or machining operations, etc. after final rolling before their first measurements.

III. Experimental results and considerations

1. Secular change in 60/40 brass

The change in spring properties of 60/40 brass after low-temperature annealing is shown in Fig. 1, in which the results obtained from other alloys, namely, 70/30 brass, phosphor bronze and nickel silver are also shown for comparison. Each specimen was cut from the cold-rolled sheets in transverse to the rolling direction, and subjected to low-temperature annealing after being allowed to remain at room temperature for about two months after the final cold-rolling of 60 per cent reduction. The changes both in vacuum and in air were all examined at room temperature. Similar to the previous work[1], it was concluded from the comparison that the change was maximum in 60/40 brass, less in 70/30 brass and screcely observable in two other alloys. However, the tendency of the change showed itself differently, when the 60/40 brass was annealed at low-temperature after it was allowed to remain for a longer duration after its final cold-rolling than the case shown in Fig. 1. An example of such a case is shown in Fig. 2, in which the same plain 60/40 brass as the above was annealed at 150°, 225° and 250°C after it was allowed to remain at room temperature for about 14 months after its final cold-rolling, and the brass containing iron was annealed at 225°C after it was allowed to remain for about 10 months. The ageing was done at room temperature for the former, and at 30±1°C for the latter. As shown in the figure, the changes remarkably decreased in both cases, compared with the case in Fig. 1. Especially, it should be noted that the brass containing iron showed little change, even though the final rolling reduction was of comparatively small amount of 30 per cent.

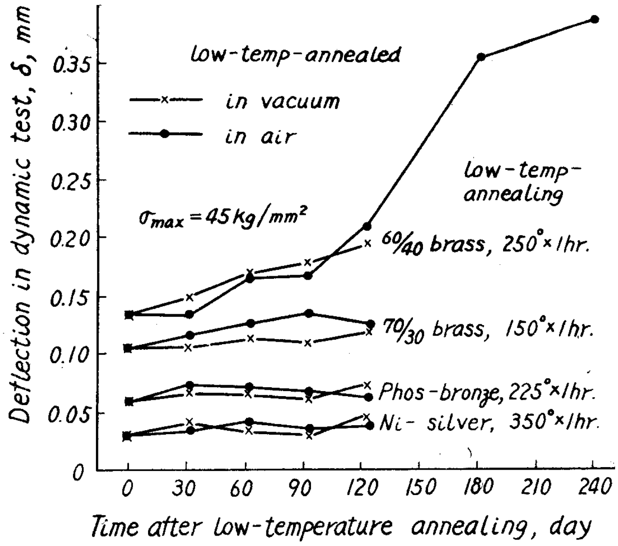


Fig. 1 Secular change in spring properties after low-temperature annealing of various copper alloys, specimen: 60% reduction, transverse to rolling direction, low-temp.-annealed after 2 months after final cold-rolling.

Therefore, it may be considered that the change is affected by the time kept between the final cold-working and the low-temperature annealing, that is, the longer the time, the less the change.

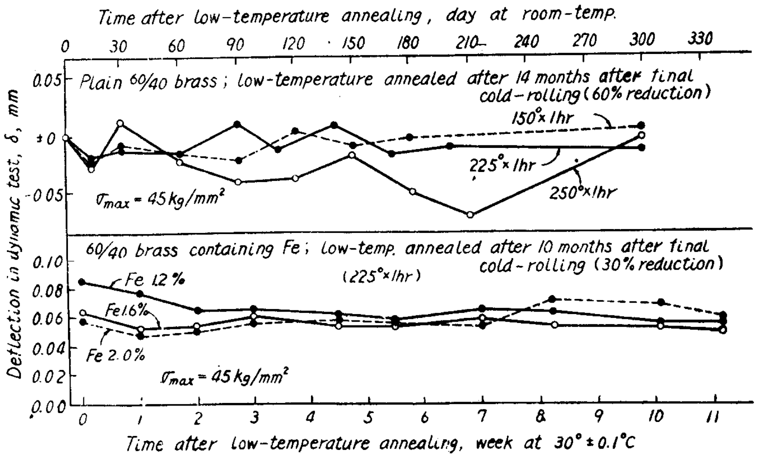


Fig. 2. Secular change in 60/40 brass, low-temperature annealed after more then 10 months at room temperature after final cold-rolling

2. Secular change after cold-rolling

It was necessary, from the results described above, to examine how the spring properties of the brass were changed after final cold-rolling at room temperature. Hence, a series of experiments was carried out on the several cold-rolled brass sheets prepared under different conditions. Fig. 3 shows an example of the results. In the figure, the specimen marked "BR" was cold-rolled to 0.5 mm in thickness

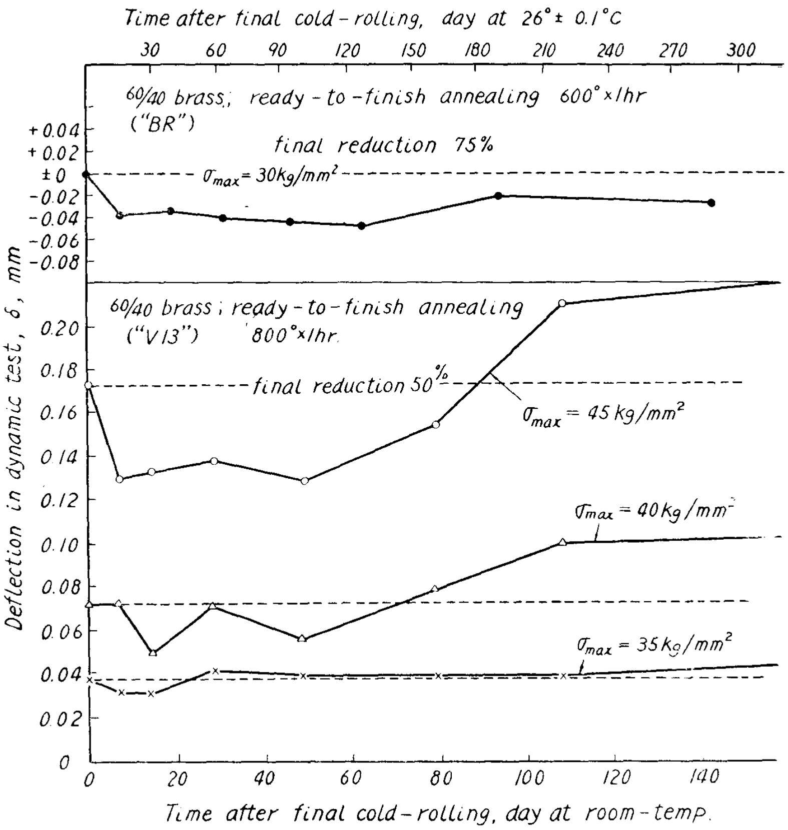
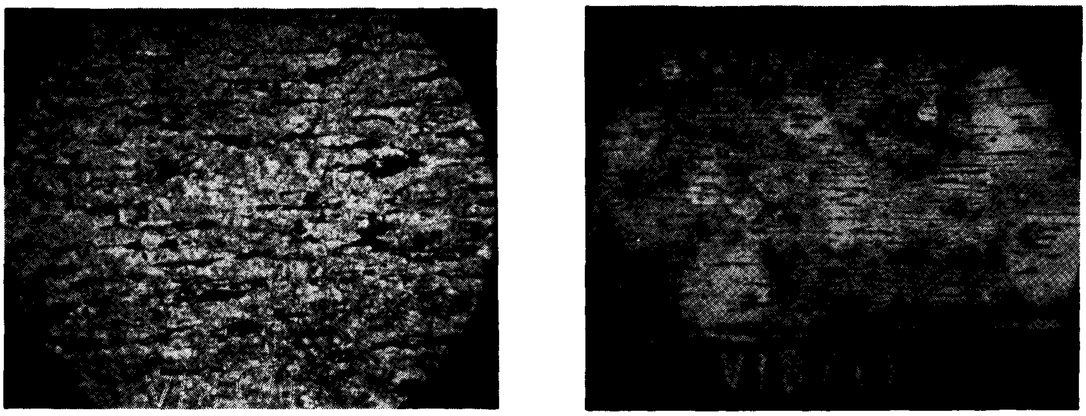


Fig. 3. Secular change in spring properties after final cold-rolling of 60/40 brass.

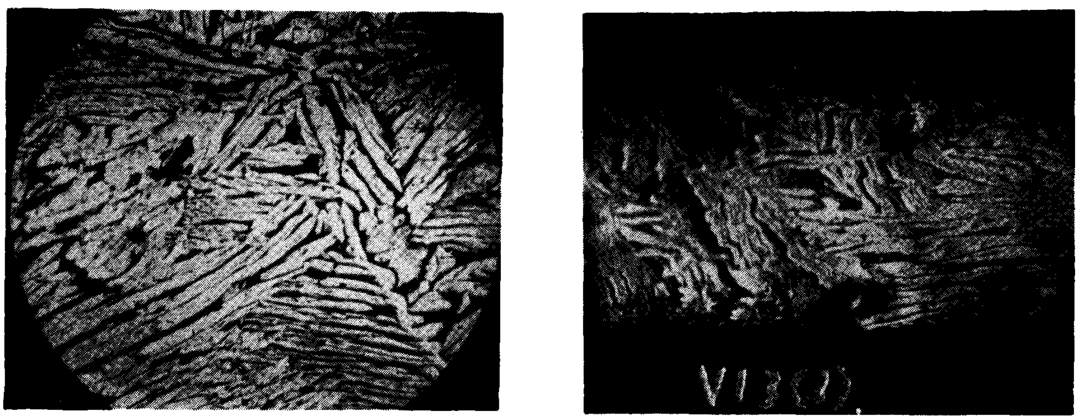
by the reduction of 75 per cent after annealing at 600°C for 1 hr, and kept at 26±0.1°C. As shown in the figure, the residual deflection in dynamic test decreased at first with time after cold-rolling and then increased after about 200 days to somewhat higher value thought to be saturated. The specimen marked "V 13" was the 60/40 brass cold-rolled to 0.5 mm in thickness by the reduction of 50 per cent after annealing at 800°C for 1 hr, being different from an ordinal one in the structure of α-β phase distribution, as shown in Photos. 1 and 2. Though the change was measured under higher constant stress than in the case of "BR", the tendency of the change was considerably different, that is, the deterioration of spring properties seemed to be more remarkable with increasing amount of β-phase. In fact, the change in the alloy "V 13" showed a tendency similar to that of "BR", when it had been cold-rolled 50 per cent after annealing at 500° for 1 hr.

Therefore, it was considered that the characteristics of the change in 60/40 brass might be affected by those of both α- and β-phases. Therefore, it was necessary to examine separately the changes in α and β brass. Fig. 4 (a) shows the results obtained from the changes at 40°C of two kinds of 70/30 brass, which were cold-rolled 50 per cent after annealing at 700° and 500°C, resulting in the different ready-to-finish grain sizes of 0.13 and 0.03 mm respectively. It was a fundamental tendency that the residual deflection of each specimen finally reached some lower values than initial ones, though, in the earlier stage of the change, some deviations were seen among them with the different grain sizes. Therefore, it was recognized that such a change as observed in the specimen of "BR" in



(a) ×75 (b) ×75

Photo. 1. Structure of 60/40 brass cold-rolled,
Ready-to-finish anneal : 500°C Final reduction : 50 per cent
Rolling direction : horizontal
(a) Pararell to strip surface (b) Longitudinal section



(a) ×75 (b) ×75

Photo. 2. Structure of 60/40 brass cold-rolled,
Ready-to-finish anneal : 800°C Final reduction : 50 per cent
Rolling direction : horizontal
(a) Pararell to strip surface (b) Longitudinal section

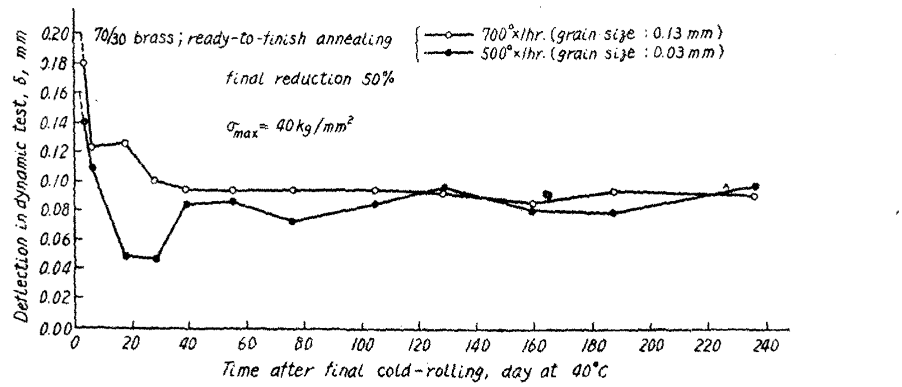


Fig. 4 (a). Secular change in spring property of 70/30 brass having different grain sizes, specimen : as rolled.

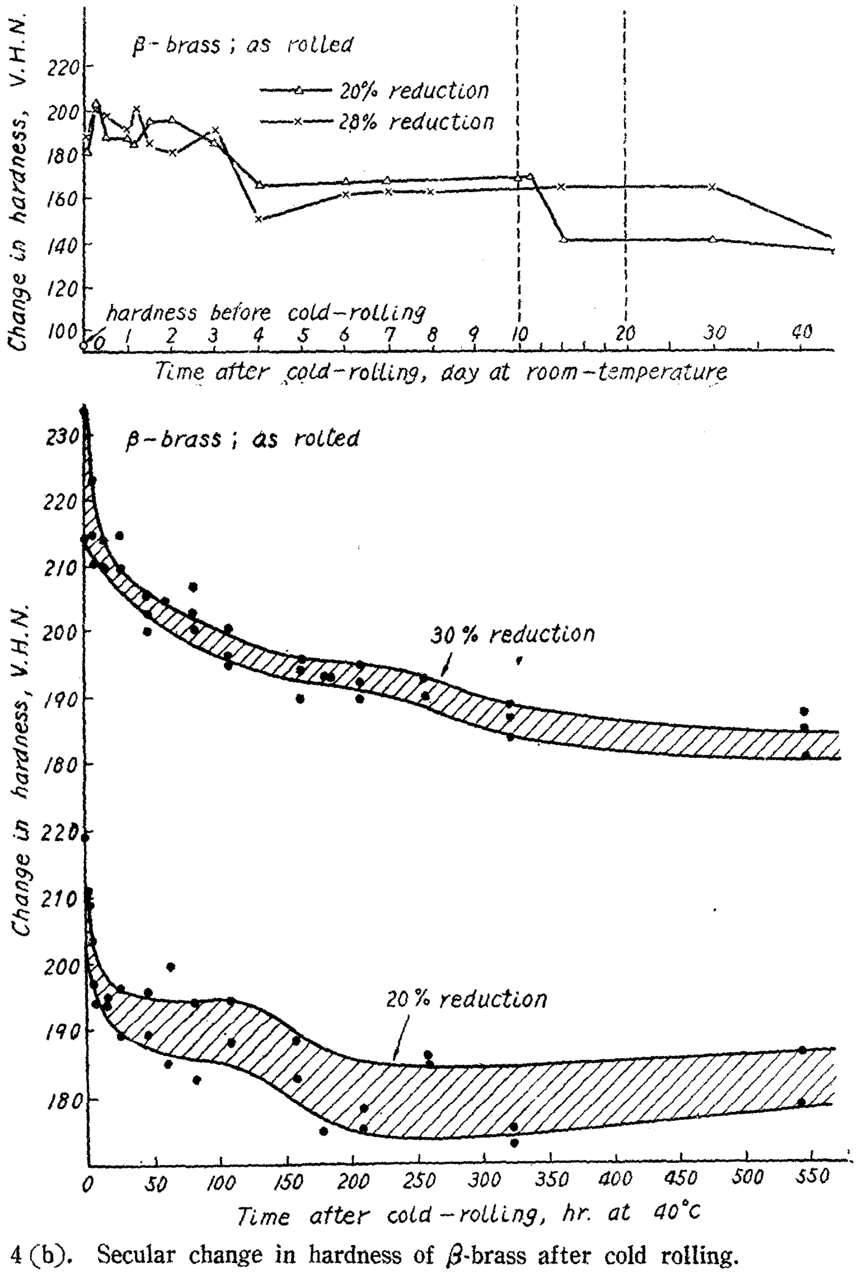


Fig. 4 (b). Secular change in hardness of β-brass after cold rolling.

Fig. 3 might be due almost to the characteristics of α-phase. On the other hand, the change in β-brass was estimated by measuring its hardness, because the spring test is inapplicable to the characteristics of plasticity. The specimens were prepared by comparatively low rolling reduction. The results are shown in Fig. 4 (b). The handness change in β-brass was considerably rapid at room temperature or 40°C, a remarkable softening taking place. Therefore, the change in spring properties of β-brass after cold-working was considered to be a deterioration, which is contrary to that of α-brass. From the results shown in Fig. 4, the behaviour of the change observed in cold-rolled 60/40 brass ("BR" and "V 13" in Fig. 3) might qualitatively be interpreted as the combined effect of α- and β-brass.

3. Secular change after low-temperature annealing in relation to ageing time after final cold-rolling

As seen in Fig. 2, the brass containing iron does not show any secular change after low-temperature annealing, when the alloy is kept at room temperature for more than 10 months after the final cold-rolling. It follows, therefore, from the curve of "BR" in Fig. 3 that the duration of 10 months will be sufficient for the stabilization. It will then be interesting to examine whether the duration may

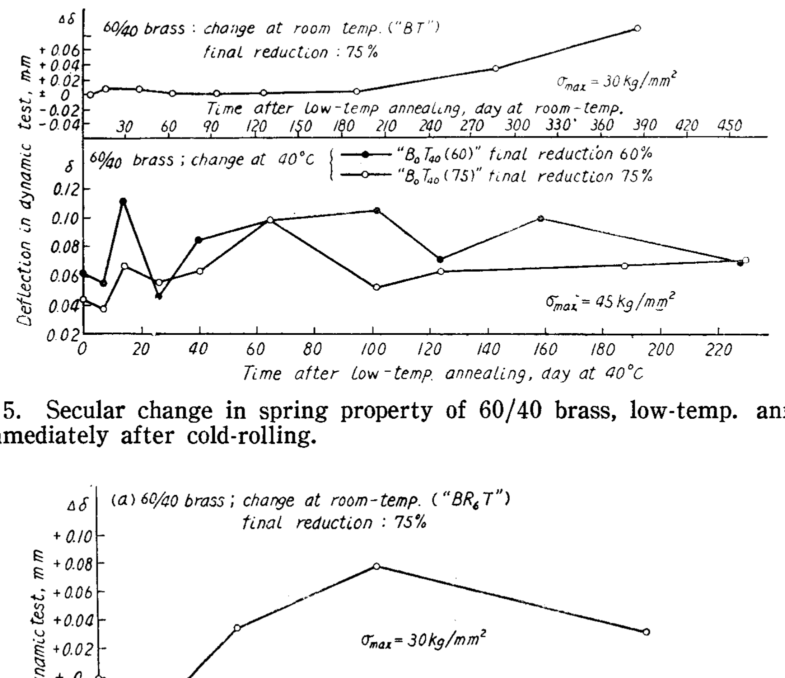


Fig. 5. Secular change in spring property of 60/40 brass, low-temp. annealed immediately after cold-rolling.

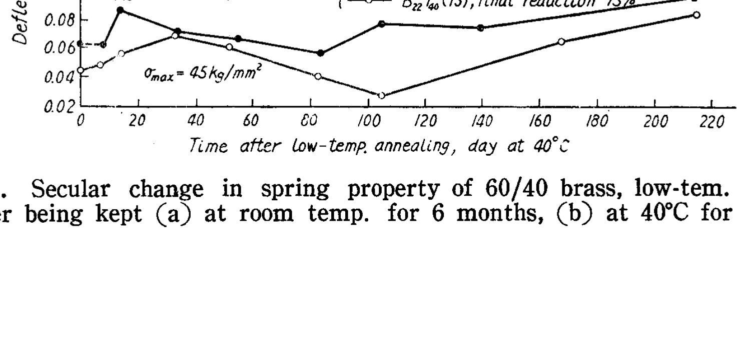


Fig. 6. Secular change in spring property of 60/40 brass, low-tem. annealed after being kept (a) at room temp. for 6 months, (b) at 40°C for 22 days.

affect the change after low-temperature annealing or not.

From the above point of view, the secular changes at room temperature and 40°C after low-temperature annealing of 60/40 brass, which had been kept at 40°C for various durations after its final cold-rolling, were investigated, the results of which are shown in Figs. 5 and 6. The change in the specimen "BT" shown in Fig. 5, which was the same as "BR" in Fig. 2 but annealed at 250°C for 1 hr immediately after cold-rolling, showed the deterioration of the spring property after being kept for about 190 days, and it was not saturated even after 390 days. The changes at the interval between 60 and 100 days of the specimens "B_0T_{40} (60)" and "B_0T_{40} (75)", which were annealed at 250°C immediately after final cold-rolling of 60 and 75 per cent reductions and kept at 40°C, seemed to correspond to the change in the deterioration of the specimen "BT". Therefore, it might be impossible to suppress the change, even though the annealing was done at the initial stage of ageing, during which the change after cold-working would not develop so much.

Fig. 6 shows the changes in the specimens annealed after they were kept at room temperature or at 40°C for various durations after the final cold-working. The duration of 6 months at room temperature was not sufficient to stabilize the change after the cold-working, as shown in Fig. 3. Therefore, the change in "BR_6T" could not be suppressed, as observed in the cases of Figs. 1 and 5. On the other hand, the changes in the specimens "$B'_{22}T_{40}$ (60)" and "$B'_{22}T_{40}$ (75)", which were the same rolled sheets as "B_0T_{40} (60)" and "B_0T_{40} (75)" but annealed after they were kept for 22 days at 40°C after the final cold-rolling, were less than the others. The ageing at 40°C for 22 days could correspond to that at room temperature for about 230 days, provided that the activation energy of the diffusion of zinc in 60/40 brass was about 30,000 cal/mol, at the room temperature of 25°C. Therefore, it will be reasonable that the tendency of the change in this case corresponds to that shown in Fig. 2.

From the results shown in Figs. 1~6, it will be clear that the secular change in spring properties after low-temperature annealing has some relation with the change after cold-working. According to the hardness test by Mishima[(2),(3)], however, the change after annealing is related only with the phenomenon of hardening in low-temperature annealing, and is independent of the change after cold-working. Therefore, the relationship should be investigated more precisely. Of course, some relationships can be recognized between the anneal-hardening and the change after the annealing. Though the mechanisms of those phenomena are not clear yet, it will be considered as one of the processes of suppressing the change that the change after cold-working should be brought in the final stabilized condition. The ageing time necessary for the stabilization will be more than about 200 days at room temperature, but the change can be accerelated by keeping the alloy at higher temperatures.

Summary

(1) The secular change in the spring' properties of 60/40 brass might be suppressed.

(2) The secular change after low-temperature annealing of cold-rolled 60/40 brass was affected by the ageing time after final cold-rolling. When the brass was annealed after being kept at room temperature for the time shorter than about 200 days after the final cold-rolling, the change could not be suppressed. The change might be caused by some complexities in the initial stage of ageing after cold-rolling.

(3) The ageing after cold-rolling for more than about 200 days at room temperature or for suitable time at higher temperature, at which the anneal-hardening would not occur, could decrease or suppress the secular change after low-temperature annealing essentially. The phenomena would be one of the possibilities of suppressing the change.

(4) A tendency of the change in the spring property after cold-working was contrary to that after low-temperature annealing. The change in 60/40 brass could be considered as the combined effect of α- and β-phases.

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