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Improvement of Copper Alloy Springs. II
60/40 Brass Series Containing Iron, Manganese and Tin*

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Synopsis

From the previous work, iron, manganese and tin were chosen as the third alloying elements in order to improve the spring property of plain 60/40 brass. The effects of the respective elements on spring properties and bending characteristics (formability) of 60/40 brass sheet were compared with each other. Those elements not only improved the spring properties remarkably, but also extended the suitable range of low-temperature annealing as compared with the case of plain 60/40 brass. The present results showed that manganese and tin would be the most favorable elements for practical purposes.

I. Introduction

The present authors have reported the results of a series of experiments concerning the improvement of spring properties of 60/40 brass by adding several third elements to the alloy.(1) Among those elements, iron, manganese, tin and aluminium were favorable to the purpose. Though further improvement would be expected by increasing their amounts, the effect of each element on other properties of the alloys, for instance, formability, should concurrently be examined.

The alloys containing iron (1.2~2.0 per cent), manganese (0.5~1.0 per cent), and tin (0.5~1.0 per cent) individually or containing tin and manganese together were examined in the present work.

II. Experimental procedures

1. Specimen

Each alloy was cast and rolled to the thickness of 0.5 mm at the Taihei Metals Co., Tokyo. The chemical compositions and the rolling schedules are listed in Table 1. All specimens were cut from each rolled sheet in the transverse direction of the rolling. After the cutting, each specimen was machined to the standard size of $0.5 \times 10 \times 130\ mm^3$. The low-temperature annealing was carried out in the range 125~300°C for 1 hr.

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* The 859th report of the Research Institute for Iron, Steel and Other Metals. Read at the Annual Meetings of Japan Institute of Metals at Tokyo, Apr. 1953 and 1954.

(1) M. Kawasaki and O. Izumi, Sci. Rep. RITU, **A8** (1956), 484

Table 1. Chemical analysis of samples and rolling schedules.

60/40 Brass containing	Fe (%)	Mn (%)	Sn (%)	Rolling schedule
Fe	1.2 1.6 2.0	— — —	— — —	Hot rolling; 22 mm→5mm. Intermediate annealing; 550°C. Cold rolling; 5 mm→0.5 mm. Ready-to-finish annealing; 450°. Final reduction; 30%, 50% & 70%.
Mn	— — —	0.56 0.84 1.00	— — —	Hot rolling; 26 mm→13 mm. Intermediate annealing; 500°. Cold rolling; 13 mm→0.5 mm. Ready-to-finish annealing; 600°. Final reduction; 50% & 70%.
Sn	— — —	— — —	0.53 0.77 0.99	
Mn + Sn	— —	0.14 0.69	0.31 0.53	

2. Measurement

The measurement of spring properties was carried out in the same way as described in the previous work[1], that is, the spring limit and the residual deflection in dynamic spring test were compared with each other. On the other hand, the formability was estimated by measuring the number of bending cycles up to the rupture (radius of bending = 5 mm; angle of bending = 180°). The scheme of the testing machine is shown in Fig. 1. Vickers hardness at the load of 10 kg or the microstructure were also examined, if necessary.

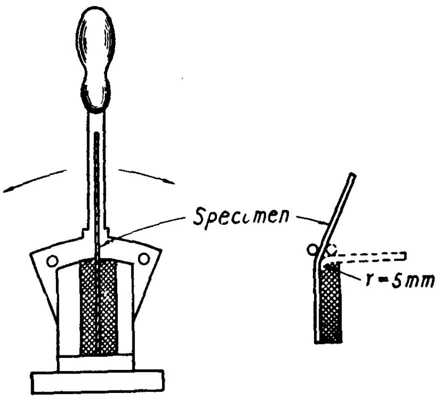

Fig. 1. Scheme of bending tester.

III. Experimental results and considerations

1. 60/40 brass series containing iron

Fig. 2 shows one of the results of the measurements of spring limit, residual deflection, bending cycles up to the rupture and hardness of 60/40 brass containing various amounts of iron. In the specimens as rolled, the amount of iron content had little effect on the spring limit. The improvement, however, could remarkably be attained by low-temperature annealing, that is, the spring limit was about 65 kg/mm^2 in the specimens containing 1.6 and 2.0 per cent of iron at the reduction of 50 and 70 per cent. The alloys would be hopeful of use, because the values of them were all about 55 kg/mm^2 even at the reduction of 30 per cent. The values of spring limit, however, were lowered temporarily at 175~200°C as shown in Fig. 2 and, therefore, the heat-treatment should carefully be done for each temperature. Such a behavior of the spring limit in relation to the annealing temperature was also observed in copper alloys with peritectic structure by Takahashi[2].

(2) S. Takahashi, private communication.

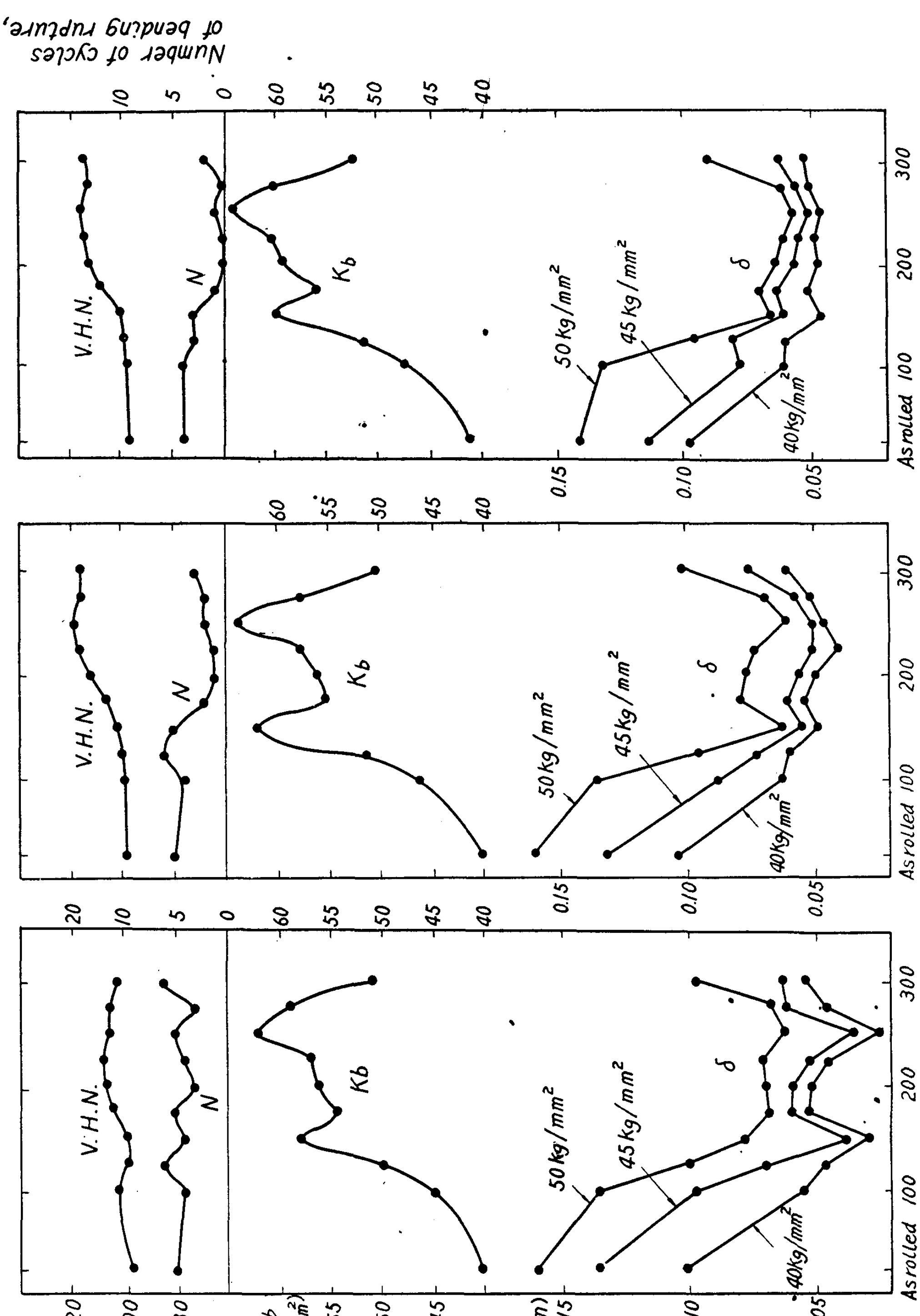

Fig. 2. Results of spring, hardness and bending test of 60/40 brass containing Fe (Reduction 50%).

From the bending-rupture test, it was shown that the bending characteristics were remarkably deteriorated by increasing rolling reduction from 50 to 70 per cent. Therefore, the critical rolling reduction of the alloy would be about 40 per cent. The effect of the amount of iron content on the bending properties was not so remarkable.

From the results shown above, it will be concluded that the alloy containing iron from 1.0 to 2.0 per cent is hopeful of practical use, provided that the rolling reduction is below about 40 per cent.

2. 60/40 brass series containing manganese and tin

As mentioned in the previous paper(1), 60/40 brass containing manganese or tin is considerably superior to the others in the spring property. In the present case, the bending characteristics of the alloys used in the previous work were compared with one another in the same way as described above. Fig. 3 shows the results obtained. Some improvements in the bending characteristics could be observed only in the alloy containing manganese, as shown in the figure. The alloy containing tin was comparable to plain brass, and the alloy containing iron was considerably inferior to plain brass at high reduction. It might be impossible to improve both spring and bending properties together, because those would be affected contrarily each other. From the results shown in Fig. 3, however, the alloys containing manganese or tin could be expected to show excellent spring properties without disturbing their bending characteristics.

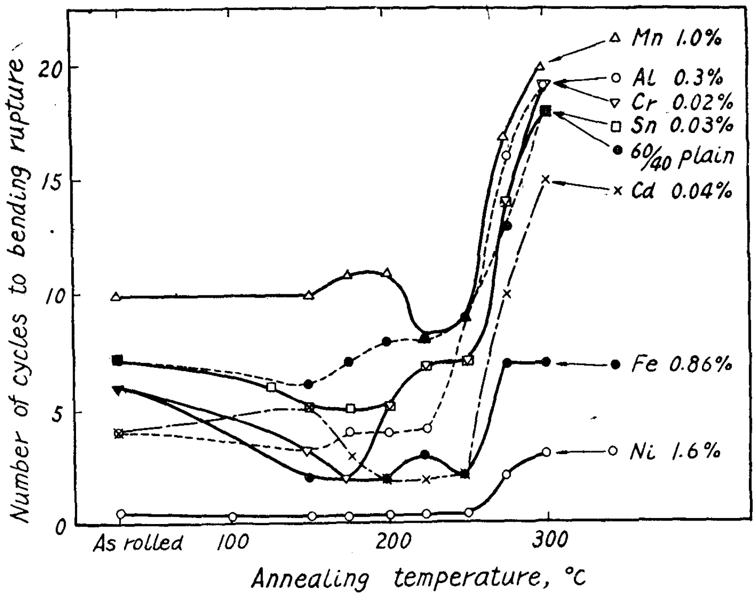

Fig. 3. Comparison of bending rupture characteristics of special brass containing various third elements: Specimens: 75 % reduction, transverse to rolling direction.

(i) 60/40 brass containing manganese

Fig. 4 shows the results of 60/40 brass containing three different amounts of manganese. The spring properties of the alloys, as rolled, rather seemed to

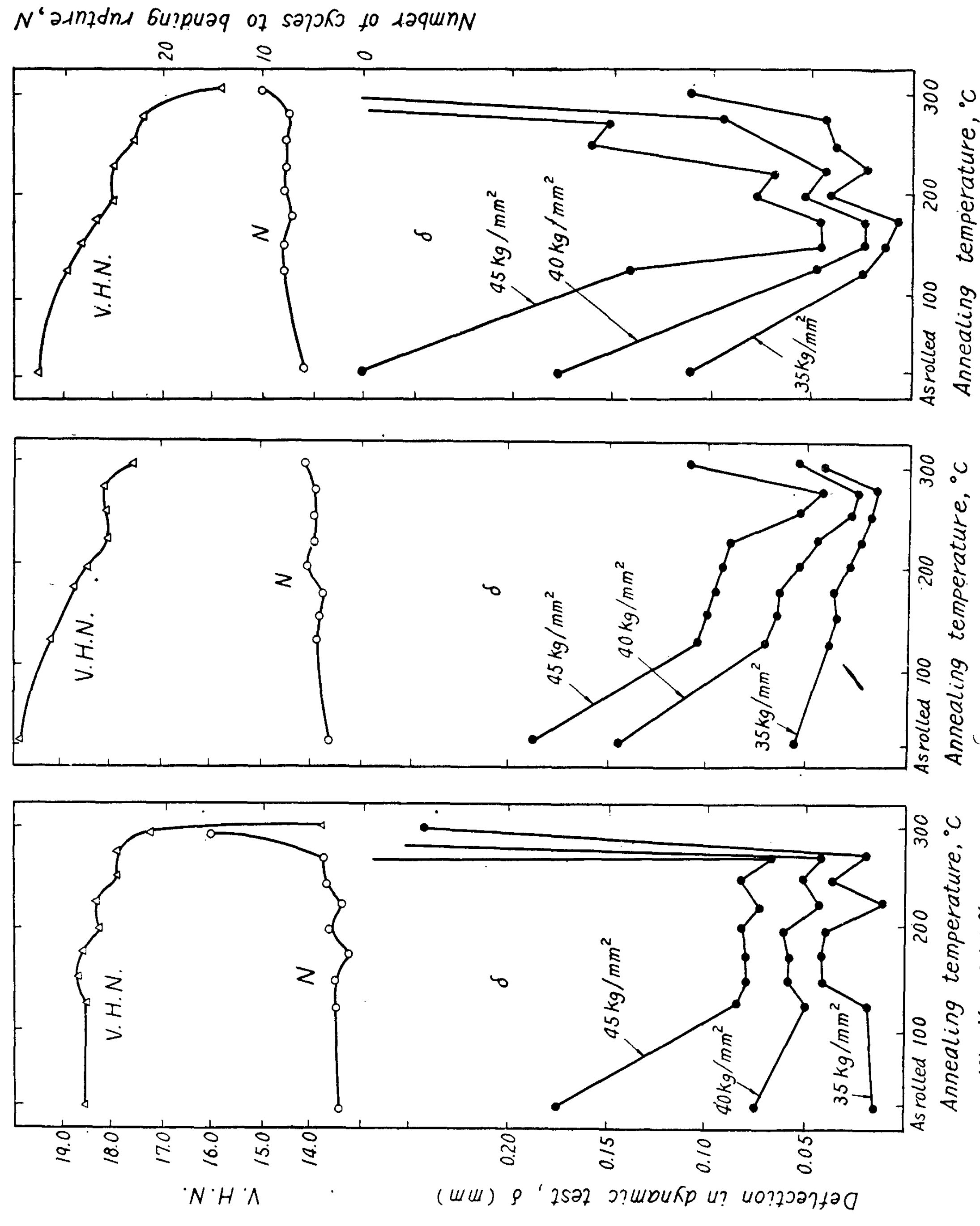

Fig. 4. Results of spring, hardness and bending test of 60/40 brass containing Mn (Reduction 50%).

deteriorate with increasing manganese content. After low-temperature annealing, however, the properties of the alloys were more improved than those of plain brass over a considerably wider range of annealing temperatures. The temperature, at which the deflection was minimum, was different with different contents of manganese, that is, in the alloys containing 0.55 and 0.84 per cent of manganese the minimum value of deflection was shown at a comparatively high temperature, whereas in the alloy containing 1.00 per cent of manganese it was observed at lower temperature than the above. Though abridged in the figure, the spring properties of the materials cold-rolled 70 per cent were superior to those cold-rolled 50 per cent, and the minimum deflection of them was sharper. The maximum value of spring limit of the alloy would be estimated to be about 70 kg/mm^2, which was better than that of the alloy containing iron, the maximum being 65 kg/mm^2.

On the other hand, the bending-rupture characteristics were comparatively stabilized through out the temperature range up to 275°C. However, the absolute values of bending cycles up to rupture were below 10 even at the rolling reduction of 50 per cent, which was not so good as expected. Those would become worse with higher reduction, and the reduction of 50 per cent might be the limit of cold-rolling for practical usage.

(ii) 60/40 brass containing tin

Fig. 5 shows the results on 60/40 brass cold-rolled 50 per cent and containing three different amounts of tin. The effect of the difference in tin content on spring properties was not so remarkable. As in the case of the alloy containing manganese, the spring properties of the alloy cold-rolled 70 per cent were superior to those cold-rolled 50 per cent, and the annealing temperature, at which the minimum deflection was sharply observed, was lower in the former than in the latter. The bending-rupture characteristics of the alloys, as expected, were comparatively inferior to those of the alloys containing manganese. However, the maximum spring limit of the sheets cold-rolled 70 per cent was estimated to be about 75 kg/mm^2, which would be higher than that in the case of manganese content.

(iii) 60/40 brass containing manganese and tin

Fig. 6 shows the results obtained from two kinds of 60/40 brass specimens, which were cold-rolled 50 per cent and contained manganese and tin together. The alloy was characterized by the good spring properties and its wide range of effective annealing temperature showing minimum deflection. Though the effect of tin was scarcely observable at the small content of manganese and tin, the combined effect of both elements could be observed at the higher content. Those tendencies could also be shown in the bending rupture test.

3. Comparison of spring and bending properties

The results obtained by spring and bending tests of several kinds of brass are summarized in Table 2. From the comparison of each property, the alloys containing manganese and tin, individually or together, might be considered as the most favorable materials among them. Furthermore, though it would be difficult

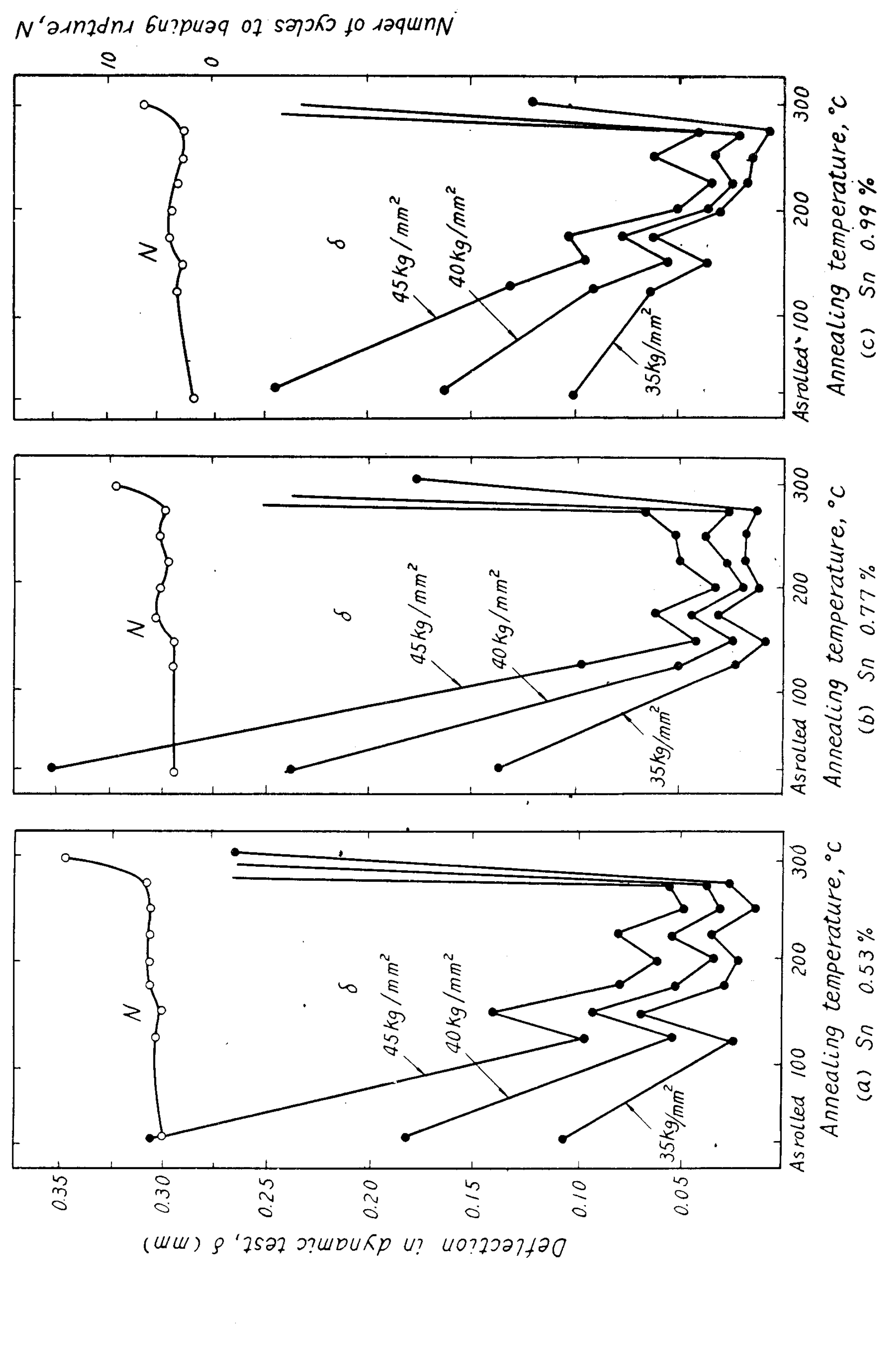

Fig. 5. Results of spring and bending test of 60/40 brass containing Sn (Reduction 50%).

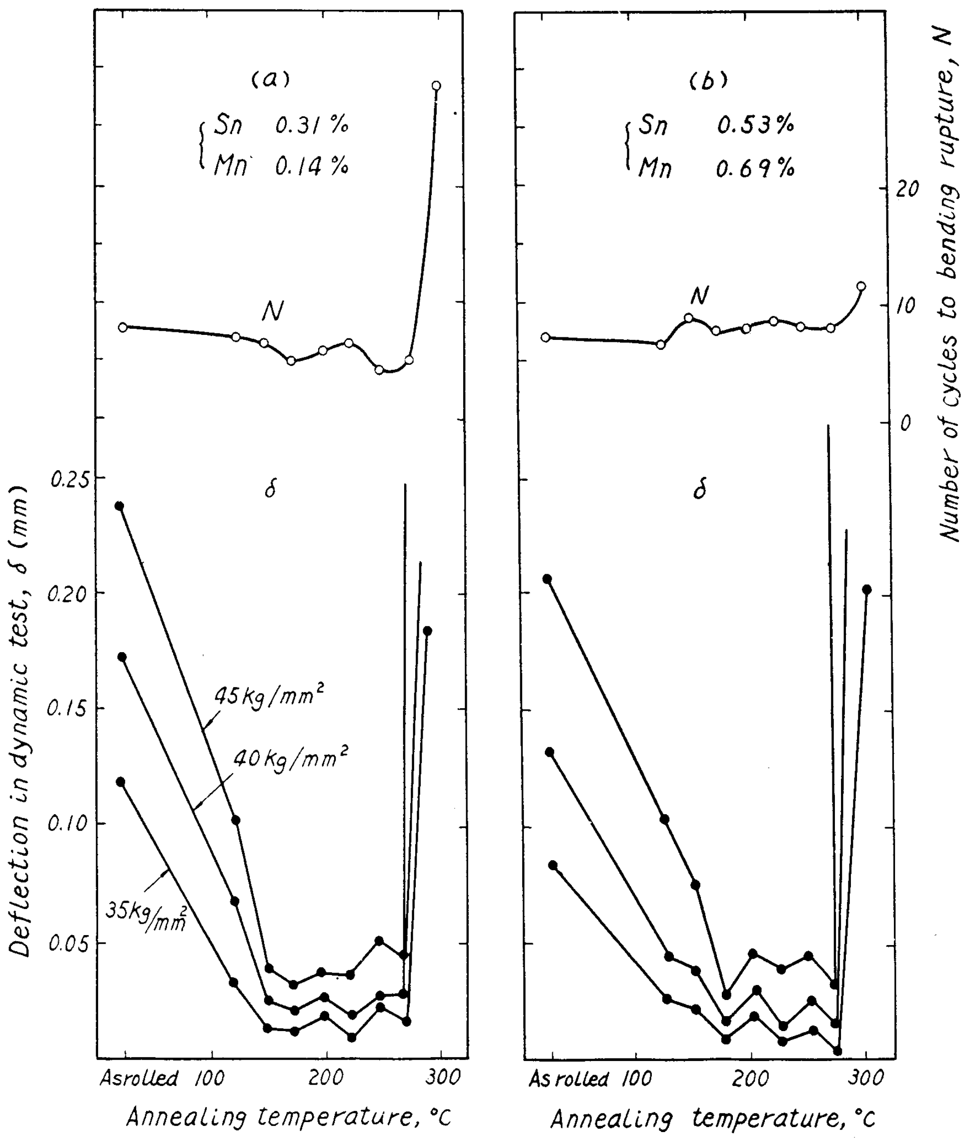

Fig. 6. Results of spring and bending test of 60/40 brass containing Sn and Mn (Reduction 50%).

to select the best one from those three alloys, the alloy containing manganese alone might be the most favorable one in practice, from the viewpoint of the good stability of bending characteristics for each annealing temperature.

It would be the most remarkable difference between the alloy containing manganese (or tin) and plain brass that the suitable annealing temperature range, at which the alloys showed the best spring properties, was 150~250°C (or 150~275°C) in the former, while it was only 225~250°C in the latter. In addition to this, the former had a good stability of bending rupture characteristics through out the temperature range. Though the increase in hardness by low-temperature annealing is usually observed in plain brass, it was not seen in the alloys containing manganese or tin. The phenomenon would be favorable to the forming operation.

Table 2. Spring and bending properties of various kinds of brass.

Chemical composition of brass				Spring limit (kg/mm^2)		Number of cycles* to bending rupture		Remarks	
Cu/Zn	Fe	Mn	Sn	As rolled	As annealed	As rolled	As annealed	Reduction by cold rolling (%)	Optimum annealing temp. (°C)
70/30	—	—	—	30	max 48	13	7~8	60	225~250
60/40	—	—	—	35	max 55	7	7	60	225~250
60/40	1.2 1.6 2.0	—	—	40	max 62~65	0~5	0~5	50, 70	150~250
60/40	—	0.56 0.84 1.00	—	42~45	max 70	5~8	5~8	50, 70	150~275
60/40	—	—	0.53 0.77 0.99	35~45	max 75	2~5	3~6	50, 70	150~275
60/40	—	0.14	0.31	33~47	60~70	2~8	2~8	50, 70	150~275
60/40	—	0.69	0.53	37~50	60~70	2~8	2~5	50, 70	150~275

* Thickness of test piece = 0.5 mm, Radius of bending = 5 mm.

The brass containing manganese or tin described above had no difficulty in the manufacturing procedures, including melting, casting and rolling. The ready-to-finish annealing of each material was carried out at 600°C as shown in Table 1. But it will be desirable to examine whether this temperature was most suitable for the purpose or not. Furthermore, it may be interesting to investigate whether the stress ageing treatment is favorable to the spring properties or not.

Summary

In the previos work, iron, manganese and tin were chosen as the third alloying elements in order to improve the spring properties of plain 60/40 brass. In the present case the effects of there respective elements on spring properties and bending characteristics (formability) of 60/40 brass sheet were compared. The results obtained may be summarized as follows:

(1) The addition of 1.2~2.0 per cent of iron to plain 60/40 brass improved the spring property considerably, but the bending characteristics were lowered. In practice, the reduction of final cold-rolling should be limited to about 40 per cent.

(2) The bending characteristics of 60/40 brass were improved by the addition of manganese, and the addition of tin was not so harmful to them.

(3) The spring properties of plain 60/40 brass were greatly improved by the addition of manganese or tin rather than by that of iron. Among them, the alloy containing manganese alone was superior to the others, from the viewpoint of stabilization of spring and bending properties through out wider annealing temperature range.

(4) It would be favorable to practical usage that those elements made the suitable range of low-temperature annealing wide. In addition to this, it would be useful for the forming operation that the hardening by low-temperature annealing was scarcely observable by the addition of those elements.