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Original Paper

Effect of Heat Treating Conditions on Mechanical Properties of Needle for Spinning Machine

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The heat treating conditions were discussed in this investigation as concerned to the hardening the small mass of 0.6%C steel, such as needle-block of a carding machine (a sort of spinning machine). The three points bending test were carried out to examine the toughness of heat treated specimen. Results are summarized as; 1)The hardness of above 800 VHN is obtained by quenching from just above A_3 transforming temperature, when the holding time is 60 sec. The higher temperature is required as the holding time is reduced. 2) The toughness is decreased with raising the quenching temperature and prolonging the holding time due to the growth of austenite grain.

1. Introduction

As the raw fibers for yarns are supplied in an entangled fashion, they must be straightened and smoothened in a parallel fashion before they are spun into yarns. This process is called the carding. Fig.1 shows the outline of the carding machine. The fibers are caught on the needles arranged around the rotating cylinder, and disentangled and straightened. In the conventional machines, a flexible band with needles called "metallic wire" is wound spirally around the cylinder (Fig.2(a)). The metallic wire is about 5 km in length, and therfore, it is generally difficult to wind it. Recently, a new type of metallic wire, which has ten row of needles is developped as shown in Fig.2(b). In this investigation, the heat treating conditions on a small mass specimen of 0.6%C steel were discussed in order to obtain some fundamental data to heat treating the new metallic wire.

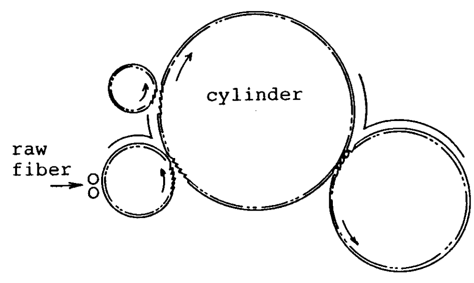
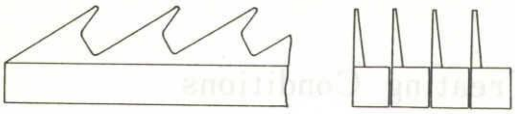
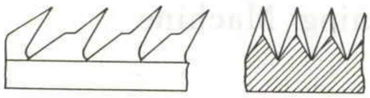


Fig.1 Outline of the carding machine



(a)conventional type of metallic wire



(b)new type of metallic wire

Fig.2 Illustrations of two types of needle-blocks (metallic wire)

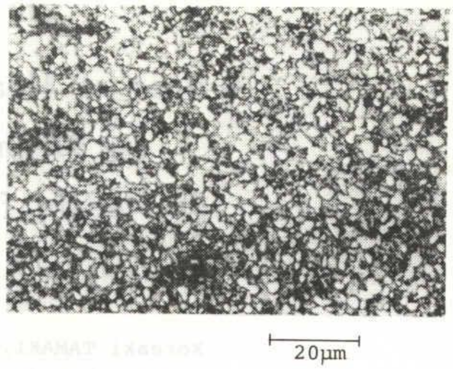


Photo.1 Microstructure of the material in as-received condition

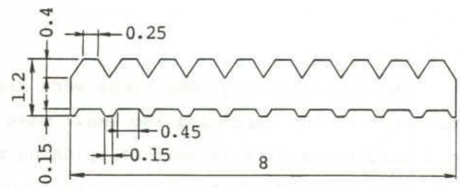
2. Experimental procedures

2.1 Material and heat treating conditions

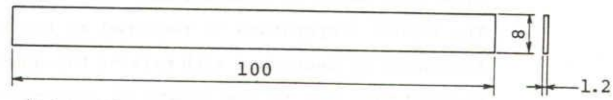
0.6% carbon steel wire rod corresponding to JIS SWRH 62A was used as a material for the metallic wire of carding machine. The material was rolled into the strip of wavelike cross section as shown in Fig.3(a). The bending test specimen of 100 mm in length was taken from the steel strip. After the bending test, the specimen was used for measuring the hardness and examining the microstructure.

This material has the microstructure of ferrite with grobular cementites in as-received condition as shown in Photo.1, and the hardness is 230 Vickers hardness number (VHN).

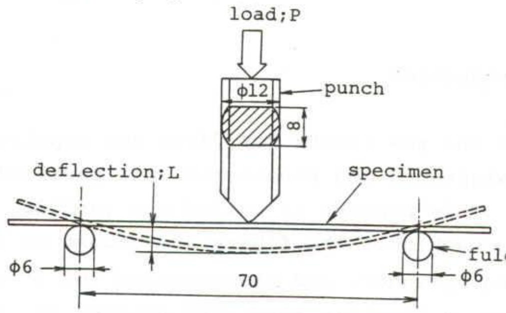
The specimen was heat treated to achive the enough hardness for applying it as a metallic wire.



(a)Cross section of the material



(b)Bending specimen



(c)Outline of the three points bending test

Fig.3 Dimension of the specimen and the outline of the three points bending test

Heat treatments were carried out according to the following procedures. The thermocouple was welded at the center of the specimen and the specimen was inserted to an electric furnace; its temperature were varied between 750 to 1400 °C.

i) Heat treatment I;The specimen was heated rapidly to a given temperature in about 10 seconds, and held at this temperature for 60 or 100 seconds, and then quenched in water, as shown in Fig.4(line (a)).

ii) Heat treatment II; The specimen was heated rapidly to a given temperature in about 10 seconds, and immediately quenched in water, as shown in Fig.4(line (b)).

iii) Heat treatment III; The specimen was heated slowly to a given temperature in about 50 seconds, and immediately quenched in water, as shown in Fig.4(line (c)).

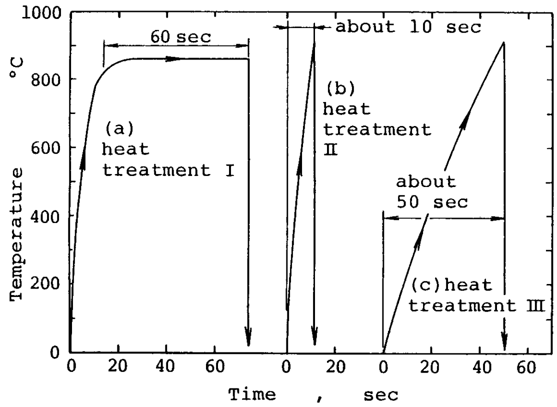


Fig.4 Heating method of the specimens

2.2 Three points bending test

It is required that the metallic wire is not only hard but also tough. Three points bending test was carried out to evaluate the toughness of heat treated specimens. The outline of bending test is shown in Fig.3(c). The distance between two fulcrums was 70 mm. The specimen was bent by a punch, which had as edge of 90 degree with the nose circle of 0.5 mm radius. The punch was located in the center of two fulcrums. The load, P and corresponding deflection at the center of the specimen, L were measured till the specimen was fractured.

3. Experimental results

3.1 Results of hardness test

Results of hardness test are shown in Fig.5. Hardness measurements were carried out in five times to each specimen, and the average value was plotted in

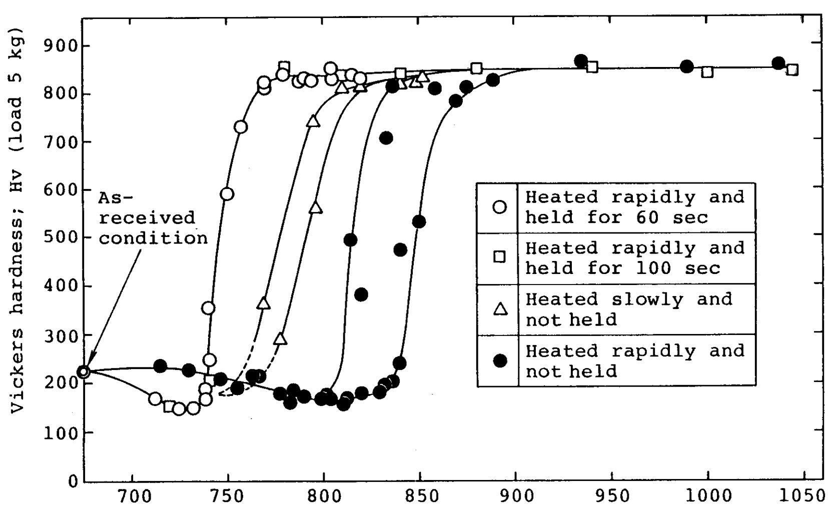


Fig.5 Influences of the quenching temperature and the heating method on the hardness of as-quenched specimens

the figure.

In the case of heat treatment I (○ mark), the hardness is increased steeply with increasing the quenching temperature between 740 to 770°C, and it reached to about 840 VHN at 770°C. The hardness is not varied at higher quenching temperatures. Influence of holding time on the hardness is not remarkable in the range of 60 to 100 seconds (□ mark).

In the case of heat treatment II (● mark), the hardness was increased steeply with increasing the quenching temperature between 800 to 900°C. In this region, the hardness values were scattered. The hardness remains in a constant value when the quenching temperature was higher than 900°C, and this maximum hardness is same as that in the case of heat treatment I. In the case of heat treatment III (△ mark), the hardness curve locates in the middle between two cases of heat treatments mentioned above.

3.2 Results of three points bending test

As the result of bending test, the fracture load, which is the final load when the specimen is fractured is shown in Fig.6. The bending tests were carried out for the specimens, of which the hardness were above 800 VHN.

The fracture load of the specimen of heat treatment I is smaller than

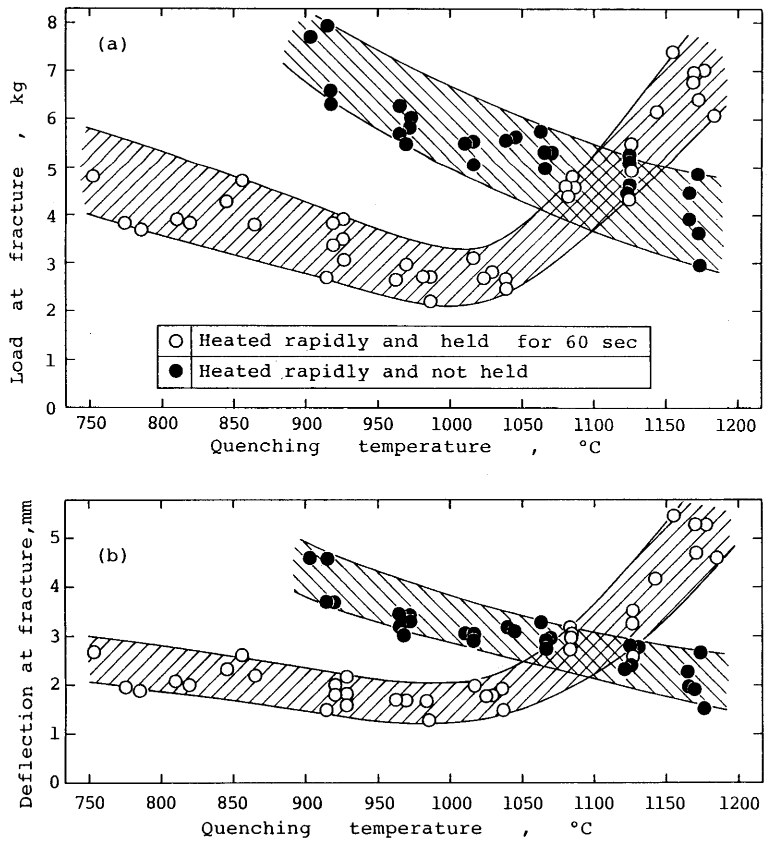


Fig.6 Results of the three points bending test
(a)Load at fracture (b)Deflection at fracture

that of heat treatment II when the quenching temperature is lower than 1050°C, but its fracture load is increased when the quenching temperature exceeds 1050°C.

The same tendency is recognized in the deflection at fracture as shown in Fig.6(b), because the fracture occurs within elastic region for most of bending tests.

4. Discussions

According to $Fe-Fe_3C$ equilibrium diagram, the A_1 and A_3 temperatures of 0.6% carbon steel are 727 and 760°C, respectively. In the case of heat treatment I, the hardening begins to occur by quenching from 740°C and the maximum hardness is achived by quenching from 770°C. Therefore, the reaction of $\alpha+Fe_3C \rightarrow \gamma$ is almost finished within the holding of 60 seconds at the quenching temperature. In the case of heat treatment II, the reaction begins and finishes at a higher temperature range, because the diffusion of carbon is the rate-determining step in the reaction. Therefore, higher quenching temperature is required for the heat treatment II. Photo. 2 shows the microstructure of the specimen heated to 890°C by heat treatment II. Although its hardness is as high as 810 VHN, the grobular cementite still remains in martensite matrix. The temperature of 950°C is required to dissolve fully the grobular cementites.

Photo.3(a) and (b) show the fracture surfaces of the specimens of heat treatment I and II, respectively, both of which were quenched from 950°C. The fractures occurred along the prior-austenite grain boundaries. It is clear that the facet size of heat treatment I is larger than that of heat treatment II.

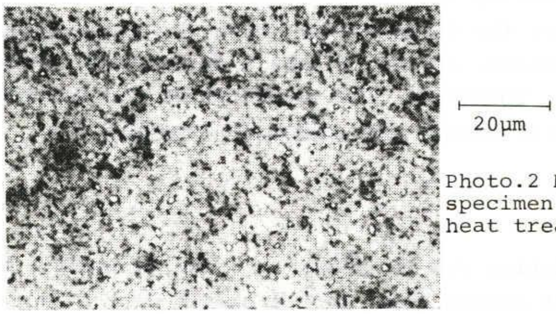
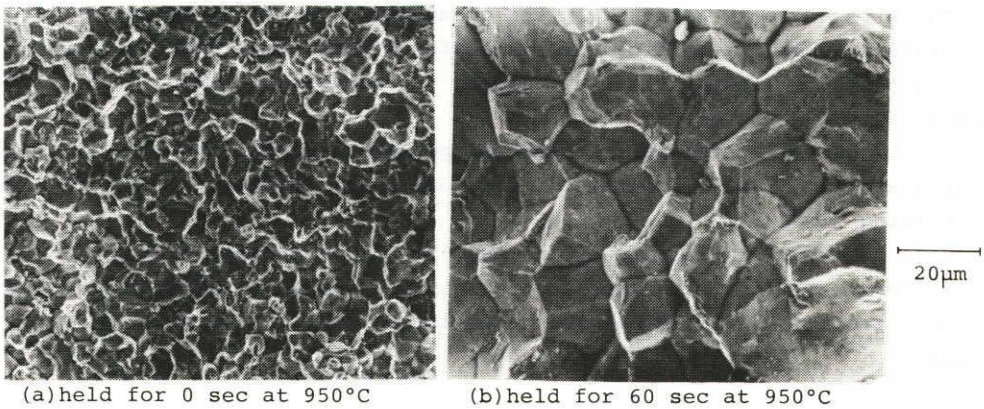


Photo.2 Microstructure of the specimen heated to 890°C by heat treatment II



(a) held for 0 sec at 950°C (b) held for 60 sec at 950°C

Photo.3 Fracture surfaces of the specimens quenched from 950°C

This is due to that the prolonged holding time at elevated temperature promotes the growth of austenite grain. The half of the cross product of fracture load and deflection becomes the total strain energy absorbed in the specimen untill being fractured. This total strain energy is generally decreased with raising the quenching temperature, and is larger for the specimens of heat treatment II than for that of heat treatment I. It is thought that this tendency is caused by the growth of austenite grain. In the case of heat treatment I, the total strain energy is increased steeply when the quenching temperature exceeds 1100°C, nevertheless the austenite grain is very coarsened.

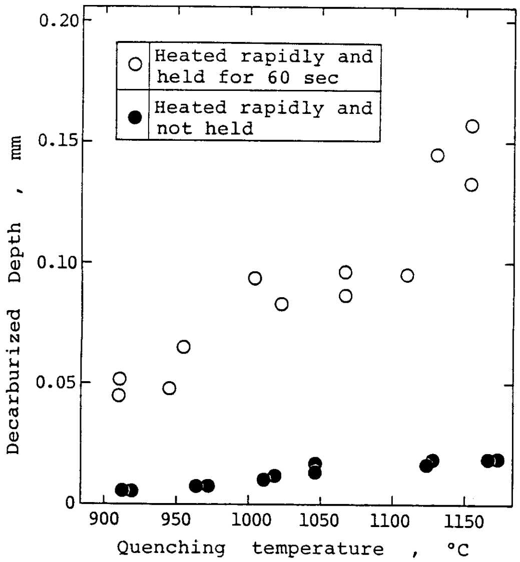


Fig.7 The influence of quenching conditions on the depth of decarburized rayer

Fig.7 shows the depth of decarburized zone, which were evaluated by using a microscope. In the case of heat treatment I, the decarburized depth is increased steeply with raising the quenching temperature. The microstructure of decarburized layer is ferrite and, therefore it deforms plastically without cracking. On the bending test, the initiation of crack will be prevented by the tough decarburized layer covering the brittle area of the specimen. In the case of heat treatment II ,however, the decarburized depth is scarcely increased with raising the quenching temperature, and it is only 0.02 mm even if the quenching temperature exceeds 1050°C. Therefore, the toughness of the specimen of heat treatment II is decreased with raising the quenching temperature.

5. Conclusions

The heat treating condition was discussed in order to apply a new type of metallic wire made from 0.6% carbon steel to the needle part of a carding machine. Following results were obtained.

(1) The wire is fully hardened by the quenching from the A_3 transformation temperature, when the holding time at austenitizing temperature exceeds 60 seconds. As the holding time is reduced, the temperature required for hardening should be raised (Fig.5).

(2) The toughness of the fully hardened specimen is small, because the size of prior-austenite grain is coarsened with raising the temperature and prolonging the holding time.

(3) Some decarburizing occurs during holding for 60 seconds at elevated temperature. The heat treatment II will be recommended for preventing it, if such decarburized layer will not be tolerated in the service condition of a carding machine.