

Letters to the Editor.

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Two Kinds of Martensite.

MARTENSITE is a structure characteristic of quenched steels and consists of an aggregate of very minute needle-shaped crystals. It is a solid solution of carbon in α -iron and is very hard. During tempering at a gradually increasing temperature, the precipitation of the carbon from the solid solution in the form of cementite takes place in two steps at about 170° and 270°, as shown in Fig. 1 by the two stepped changes in the electric resistance-temperature curve, or by similar abnormality in the magnetisation-temperature curve, etc. Since the precipitation or the decomposition of martensite takes place in two steps, it is necessary to distinguish two kinds of martensite, α and β , the former being less stable, and hence more easily attacked by acid, than the latter. By X-ray analysis, Westgren and others have found that the martensite has a body-centred cubic lattice, carbon atoms being present within the interspace of the lattice.

Recently it has been found that beside the body-centred cubic martensite, a body-centred tetragonal martensite with an axial ratio $c/a = 1.03 \sim 1.06$ is contained in quenched steels. We have found by X-ray analysis that the former martensite, which is more stable than the latter and is to be identified with β martensite, is found in the inner portion of a quenched specimen; while the latter martensite, which is to be identified with α martensite, is always found in the surface layer of the specimen. The

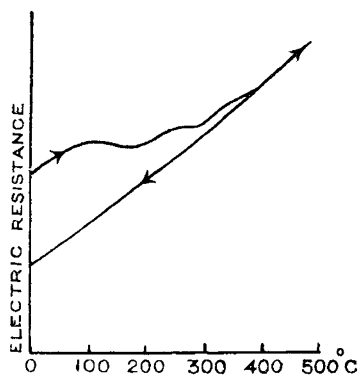


FIG. 1.—Resistance-temperature curve.

existence of the two kinds of martensite being thus far confirmed, the mechanism of their formation may be considered.

Since a face-centred cubic lattice may be considered a body-centred tetragonal one with an axial ratio $c/a = \sqrt{2}$ and also a body-centred cubic lattice as a body-centred tetragonal lattice with an axial ratio $c/a = 1$, the transformation from austenite to martensite takes place very probably in the order :

Tetragonal lattice ($c/a = \sqrt{2}$)
 → tetragonal lattice ($c/a = 1.06$)
 → tetragonal lattice ($c/a = 1$),
 or austenite → α martensite → β martensite.

Thus the mechanism of the formation of these

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martensites from austenite is very simple; the tetragonal lattice ($c/a = \sqrt{2}$) is first to be compressed uniformly in the direction of the c -axis and at the same time uniformly expanded in the perpendicular direction. α martensite is obtained when the axial ratio of the tetragonal changes from $\sqrt{2}$ to 1.06, and β martensite when the ratio changes farther to 1.

In the outer layer of a quenched steel, where the cooling is very rapid, the first change, austenite → α martensite, is partially arrested, and the second

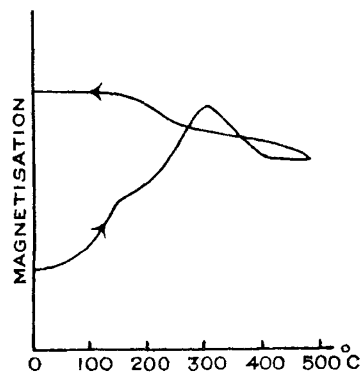


FIG. 2.—Magnetisation-temperature curve.

change, α martensite → β martensite, is completely hindered, so that the outer layer must contain α martensite mixed with a small quantity of retained austenite; while in the inner portion, where the cooling is less rapid, the first and the second change will take place almost completely, so that the inner portion must contain almost pure β martensite. These conclusions agree satisfactorily with the results of our experiments.¹

As regards the properties of α and β martensites, the following may be said with certainty :

Specific volume (V) :

$$V_{\text{au.}} < V_{\alpha \text{ mart.}} < V_{\beta \text{ mart.}}$$

Magnetisability (I) :

$$I_{\text{au.}} < I_{\alpha \text{ mart.}} < I_{\beta \text{ mart.}}$$

Specific electric resistance (R) :

$$R_{\alpha \text{ mart.}} < R_{\beta \text{ mart.}} < R_{\text{au.}}$$

Hardness (H) :

$$H_{\text{au.}} < H_{\alpha \text{ mart.}} < H_{\beta \text{ mart.}}$$

The following remark regarding the stepped change in Fig. 1 is very important. According to our view, the first step at about 170° is not due to the precipitation or the decomposition of the martensite, as it is usually believed to be, but to the transformation of α martensite to β martensite. Of course it is to be assumed that the decomposition of β martensite begins to take place far below 100°, its ratio being at first very small and rapidly increasing with the rise of temperature. In other words, the first step in Fig. 1 is not an abrupt change in the rate of decomposition of the martensite, but is due to the transformation of α martensite to β martensite, the rate of decomposition being assumed to increase steadily. The abrupt change in different physical properties in the vicinity of 170° agrees in its direction with what is to be expected from the inequality relationships given above.

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¹ See also the communication to *Werkstofftagung*, Nov. 31, 1927 (Berlin).