48. *The Effect of Transformation Stress on Specific Volume of Iron at A_3 Point.*

By Mizuho SATÔ.

(Comm. by K. HONDA, M.J.A., Oct. 12, 1950.)

The effect of transformation pressure on the difference of specific volumes in liquid and solid states of metals at melting points has previously been treated by Dr. Honda and the present author⁽¹⁾, showing that the theory agrees satisfactorily with the experiment made by Prof. Bridgman. It is evident, however, that in solid phase transformation the difference of specific volumes in the first and the second states is very small, so that the effect of transformation stress on this quantity will scarcely be observed. In the present case, the effect of the transformation stress on specific volume of each phase during A_3 transformation will be considered.

If the case of the transformation $\alpha \rightarrow \gamma$ during heating from its centre in the spherical transformation system by Dr. Honda is taken, there exists a tension between α - and γ -iron layers, as volume contraction is caused by this transformation, then the volume change at constant temperature, $(\delta v/v)_T$, can be given by

$$\left(\frac{\delta v}{v}\right)_T = -\kappa \delta p, \quad (1)$$

where κ is the isothermal compressibility.

According to Dr. Honda⁽²⁾, the value of κ for iron at A_3 point is taken to be 1.5×10^{-6} cm²/kg, and so the volume expansion due to the tension $\delta p = -2000$ atmos accompanying the transformation $\alpha \rightarrow \gamma$ becomes

$$\left(\frac{\delta v_\alpha}{v_\alpha}\right)_{A_{c3}} = 0.30 \% ;$$

the γ -iron in equilibrium with α -iron expands its volume nearly equal to this calculated value during heating.

In the case of cooling, a pressure is produced accompanying the transformation $\gamma \rightarrow \alpha$, whose magnitude is equal to that of tension. This causes the volume contraction in the same degree as in the case of volume expansion, that is,

$$\left(\frac{\delta v_\gamma}{v_\gamma}\right)_{A_{c3}} = -0.30 \% ;$$

(1) K. Honda and M. Satô: Proc. Jap. Acad., **26** (1950), No. 1, 32.

(2) K. Honda: Proc. Jap. Acad., **25** (1949), No. 1, 11.

the α -iron in equilibrium with γ -iron contracts its volume nearly equal to this calculated value during cooling.

The volume change due to the transformation of iron at A_3 point has already been observed by Prof. S. Satô⁽³⁾ accurately, by making use of his own devised apparatus, a differential dilatometer. In the annexed figure, the lines bd and ae are two isothermals at A_{c3} and A_{r3} points respectively; mn is the bisector of the loop, so that it follows:

$$am = mb, \quad dn = ne, \quad mb \doteq ne.$$

Along the line mn , there is no stress, while tension and pressure act on the ranges of mb and ne respectively. Let k be the point of intersection of the line mk parallel to the abscissa and the vertical bd , then the vertical distance kb corresponds to the increase of length of α -iron due to tension accompanying the transformation $\alpha \rightarrow \gamma$.

According to Prof. S. Satô's experiment, the lengths corresponding to the points m and b are measured to be

$$l_a = 70.908 \text{ mm and } l'_a = 70.975 \text{ mm}$$

respectively. Thus the relative change of length becomes

$$\frac{l'_a - l_a}{l_a} = \frac{\delta l_a}{l_a} = 0.095 \%,$$

from which it follows:

$$\left| \frac{\delta v_a}{v_a} \right|_{Ac3} \doteq \left| \frac{\delta v_r}{v_r} \right|_{Ar3} \doteq 3 \frac{\delta l_a}{l_a} = 0.29 \%,$$

which agrees fairly well with the above calculated value 0.30 %.

In the above calculation, the temperature-correction in volume change has not been taken into consideration, but if this correction term be taken into account, (1) will be written in the form of

$$\frac{\delta v}{v} = -\kappa \delta p + \beta \delta T, \quad (2)$$

where β is the thermal cubic expansion coefficient, which may be taken to be $4.665 \times 10^{-5} \text{ deg}^{-1}$ for iron at A_3 point. Taking $\delta T = 10^\circ$,

(3) S. Satô: Sci. Rep., **14** (1925), 513; Kinzoku no Kenkyû, **2** (1925), 477.

we get for $(\delta v/v)_{Ac3}$ the value 0.35 %, which is larger than the value 0.29 % observed by Prof. S. Satô, but the agreement may be seen to be satisfactory. This agreement means that the tension accompanying the transformation $\alpha \rightarrow \gamma$ causes the volume expansion, while the pressure accompanying the transformation $\gamma \rightarrow \alpha$ produces the volume contraction, as is to be expected.

Conclusion.

1. The relative changes of volume of iron at A_{c3} or A_{r3} point are calculated to be about 0.3 %, which agrees satisfactorily with the value 0.29 % observed by Prof. S. Satô.

2. The loop of the elongation-temperature-diagram is described by the volume changes due to tension and pressure accompanying the transformations $\alpha \rightarrow \gamma$ and $\gamma \rightarrow \alpha$.

3. The transformation stress of 2000 atmos for iron, which has been calculated by Dr. Honda as the mean value of pressures during A_s transformation, hits on quite satisfactorily to the stress theory.

In conclusion, the author wishes to express his hearty thanks to Dr. Kôtarô Honda, under whose valuable advices the present investigation has been carried out.