of work hardening than either of the specimens deformed at a rate 20 times slower or 10 times faster. This illustration suggests that, at the temperature in question, there is a maximum work hardening rate corresponding to a specific strain rate. A similar maximum work hardening rate will be observed if the temperature is raised or lowered, provided that the strain rate is adjusted accordingly. Thus, if the temperature is raised, the strain rate at which maximum work hardening is observed also rises.

Finally, one of the other well-known manifestations of dynamic strain aging is the phenomenon called *blue brittleness* when it occurs in steel. In approximately the center of the temperature range where the other phenomena of dynamic strain aging are observed, it has been found that the elongation, as measured in a tensile test, becomes very small or passes through a minimum on a curve of elongation plotted against the temperature. This subject is considered in Section 23.13 with regard to how it differs from the intermediate temperature creep embrittlement phenomenon.

The various dynamic strain aging phenomena do not appear to the same degree in all metals. However, they are commonly observed and it is probably safe to state that, in general, dynamic strain aging is the rule rather than the exception in metals.

PROBLEMS

9.1 At room temperature the stable crystal structure of iron is bcc. However, above 1183 K it becomes fcc. The iron fcc crystal structure is able to dissolve a much larger concentration of carbon than is the bcc structure. A primary reason for this is believed to be that while the fcc structure is more close packed, the octahedral interstitial sites in this lattice are much larger than the sites occupied by the carbon atoms in the bcc structure. The hole at the center of the fcc unit cell is such a site. See Fig. 1.6A. The minimum opening in one of these sites corresponds to the distance between atoms along a ⟨100⟩ direction. Note that this is the same as in the bcc case. Compare the fcc opening with that of the bcc lattice. For the sake of convenience assume the fcc iron atom diameter is the same as that of the bcc atom at room temperature.

9.2 The data reported by Chipman also give a solubility equation for carbon in alpha iron (bcc iron) when the carbon is supplied by graphite particles in the iron. This equation is

$$C_{cg} = 27.4 \exp\{-106300/RT\}$$

where C_{cg} is the carbon concentration in weight per percent in equilibrium with the graphite, R is the gas constant in J/mol-K, and T is the absolute temperature. Write a computer program for this equation and use it to obtain the weight percent of the carbon as a function of the temperature between 300 and 1000 K at 50°. Plot the data to obtain a curve and compare the curve with that in Fig. 9.3.

9.3 An approximate equation giving the atom fraction of carbon soluble in Austenite, or the fcc cubic form of iron, when the carbon comes from Fe_3C, is

$$C_\gamma = 1.165 \exp\{-28960/RT\}$$

where Q is in J/mol, R in J/mol-K, and T in degrees K. Write a program that first gives the atom fraction of carbon at a given temperature and then converts the answer to weight percent carbon. With the aid of this program determine the atom fraction and weight percent carbon in Austenite at 1000, 1100, 1200, 1300, 1400, and 1421 K, respectively.

9.4 In polar coordinates the hydrostatic pressure (see Eqs. 4.10 and 9.17) may be written in the form

$$-\tfrac{1}{3}(\sigma_{rr} + \sigma_{\theta\theta} + \sigma_{zz})$$

where, due to the two-dimensional nature of the stress field of a dislocation, $\sigma_{zz} = \nu(\sigma_{rr} + \sigma_{\theta\theta})$. Using the expressions for the stress components of an edge dislocation, given earlier, derive Eq. 9.19.

9.5 Szkopiak and Miodownik, *J. Nucl. Mat.*, **17** 20 (1965), computed the interaction constant, A, for niobium containing oxygen. They took the shear modulus, μ, to be 3.7×10^{10} Pa, the Burgers vector or atom diameter as 0.285 nm, and ν Poisson's ratio as 0.35. Their equivalent for ε equaled 0.0806. Demonstrate that these values make $A = 6.81 \times 10^{-30}$.