1

To provide some perspective on the dimensions of atomic defects, consider a metal specimen that has a dislocation density of $10^4\ mm^{-2}$. Suppose that all the dislocations in $1000\ mm^3$ were somehow removed and linked end to end. How far (in miles) would this chain extend? Now suppose that the density is increased to $10^{10}\ mm^{-2}$ by cold working. What would be the chain length of dislocations in $1000\ mm^3$ of material?

Answer

$$\begin{aligned}
&10^4\ mm^{-2} \cdot 1000\ mm^3 \\
&= 10^7\ mm \\
&= 10^4\ m \\
&= 6.213712\ mi
\end{aligned}$$

$$\begin{aligned}
&10^{10}\ mm^{-2} \cdot 1000\ mm^3 \\
&= 10^{13}\ mm \\
&= 10^{10}\ m \\
&= 6.213712 \times 10^6\ mi
\end{aligned}$$

2

Consider two edge dislocations of opposite sign and having slip planes that are separated by several atomic distances as indicated in the following diagram. Briefly describe the defect that results when these two dislocations become aligned with each other.

Answer

Since they are opposite, they will annihilate each other, leaving no defect if they are close to each other, or else they will just do nothing.

22

a

Describe in your own words the three strengthening mechanisms discussed in this chapter (i.e., grain size reduction, solid-solution strengthening, and strain hardening). Be sure to explain how dislocations are involved in each of the strengthening techniques.

Answer

Grain size reduction:

- The more disorderly the structure, the stronger it is, so by decreasing the grain size, there is more disorder

Solid-solution strengthening:

- Mixing metals is stronger than single metal metals.
- Slip reduction is higher as there are different sized atoms

Strain hardening

- Plastic deformation strengthens the metal
- This moves the atoms from its original lattice, which makes higher slip reduction

b

Use the internet to find metal that for sale that is advertised as strengthened as each of the methods listed in Part a. (Jargon: Metal that has been processed to have a small grain size is commonly called “fine grained.” “Cold working” is a term commonly used to described processing that strain hardens a metal.)

✓ **Answer**

Fine grained: https://www.alro.com/divsteel/metals_gridpt.aspx?gp=0095
Solid solution: https://automotive.arcelormittal.com/products/flat/HYTSS/solid-solutions
Strain hardened: https://www.mcmaster.com/products/hardened-shafts/?s=hardened-shafts

29

Two previously undeformed specimens of the same metal are to be plastically deformed by reducing their cross-sectional areas. One has a circular cross section, and the other is rectangular; during deformation, the circular cross section is to remain circular, and the rectangular is to remain rectangular. Their original and deformed dimensions are as follows:

	Circular (diameter, mm)	Rectangular (mm)
Original dimensions	15.2	125 x 175
Deformed dimensions	11.4	75 x 200

Which of these specimens will be the hardest after plastic deformation, and why?

✓ **Answer**

Which ever has done the most cold work processing:

$$\frac{\pi\left(\frac{15.2}{2}\right)^2-\pi\left(\frac{11.4}{2}\right)^2}{\pi\left(\frac{15.2}{2}\right)^2} = 43.8\%$$

$$\frac{125(175)-75(200)}{125(175)} = 31.4\%$$

The circular sample will be harder as it has more code work processing done.

5

In section 8.13 Callister and Rethwisch the statement is made that “increasing the percent of cold work enhances the rate of recrystallization, with the result that the recrystallization temperature is lowered...” This is illustrated Fig 8.23 for steel. The idea is further developed in an article by Burgel, Portella, and Preuhs which discusses nickel base superalloys used in the aerospace industry entitled "Recrystallization in single crystals of nickel base superalloys." pubished the journal Superalloys in 2000. In their introduction, they state “Recrystallization poses one of the major difficulties in post-casting processing of directionally solidified, especially single crystal blades of nickel-base superalloys. There are several possible sources for the necessary plastic deformation during manufacturing and processing of the new parts as well as during service and reconditioning: contraction stresses during cooling of the solid in the shell mold, removing the ceramic mold and core material mechanically, stamping identification marks, grinding the airfoil and the fir tree root to net shape, impact damage, removing of coating residues mechanically, etc. The deformation is either concentrated at the component surface or can extend into the bulk material. Figure 1 shows an example of unacceptable recrystallization in the root-airfoil transition area after solution heat treatment of a new part. The formation of new grains can take place during solutioning heat treatment even after relatively small degrees of work. Higher amounts of plastic deformation are needed to initiate recrystallization at lower temperatures, e.g. during age hardening or service exposure.”

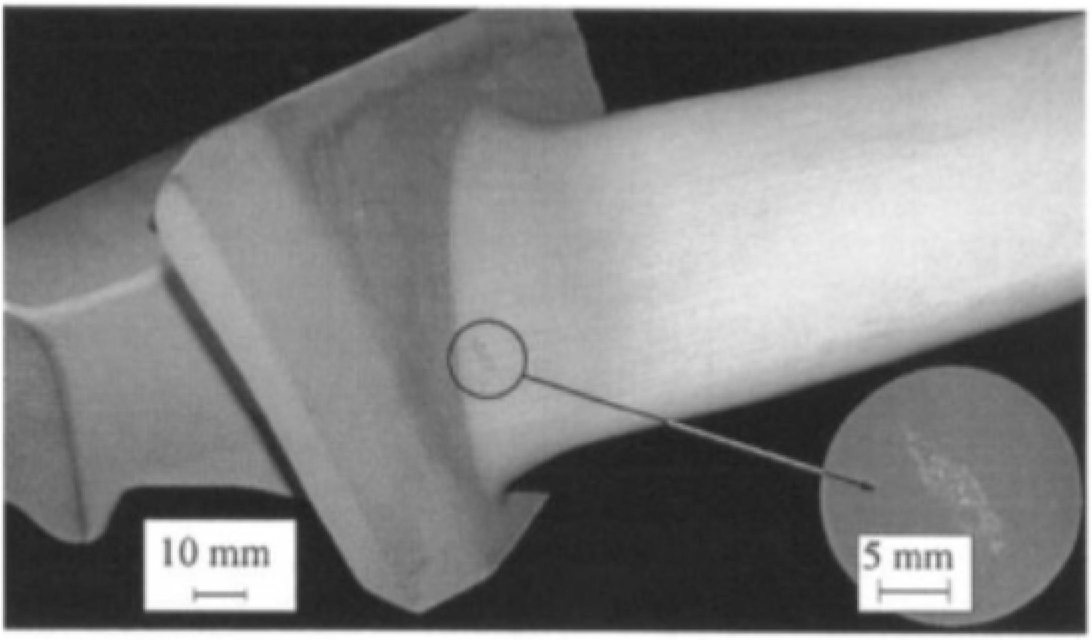

Figure 1: Recrystallization phenomena on a turbine airfoil after solution heat treatment.

Explain in simple everyday language what the quote from the paper is saying.

✓ **Answer**

Processing must be finely controlled in order to prevent unnecessary additional plastic deformation in the metal.