PAPER 4 - A CORRELATION BETWEEN THE MEAN FREE PATH OF DISLOCATION MOTION AND THE "GROWN-IN" DISLOCATION DENSITY

Background and results

Reid et al (1) have drawn the attention to a rather striking and general correlation between the dislocation multiplication factor U for a material and the corresponding density, ρ_0, of "grown-in" dislocations. Their findings indicate that

$$U = K \cdot \rho_0^{-\frac{1}{2}} \tag{1}$$

where K is apparently a universal constant. Now, since U is related to the mean free path, s_0, as (see PAPER 1-this homepage)

$$U = \frac{m}{b \cdot s_0} \tag{2}$$

where b is the nominal value of the Burgers vector and m is the Taylor factor, the following relationship between s_0 and ρ_0 can be derived

$$s_0 = \frac{m}{b \cdot K} \cdot \rho_0^{-\frac{1}{2}} \tag{3}$$

We have reinvestigated the Reid et al (1) hypothesis and applied it to various types of steel and obtained the result presented in Figure 1.

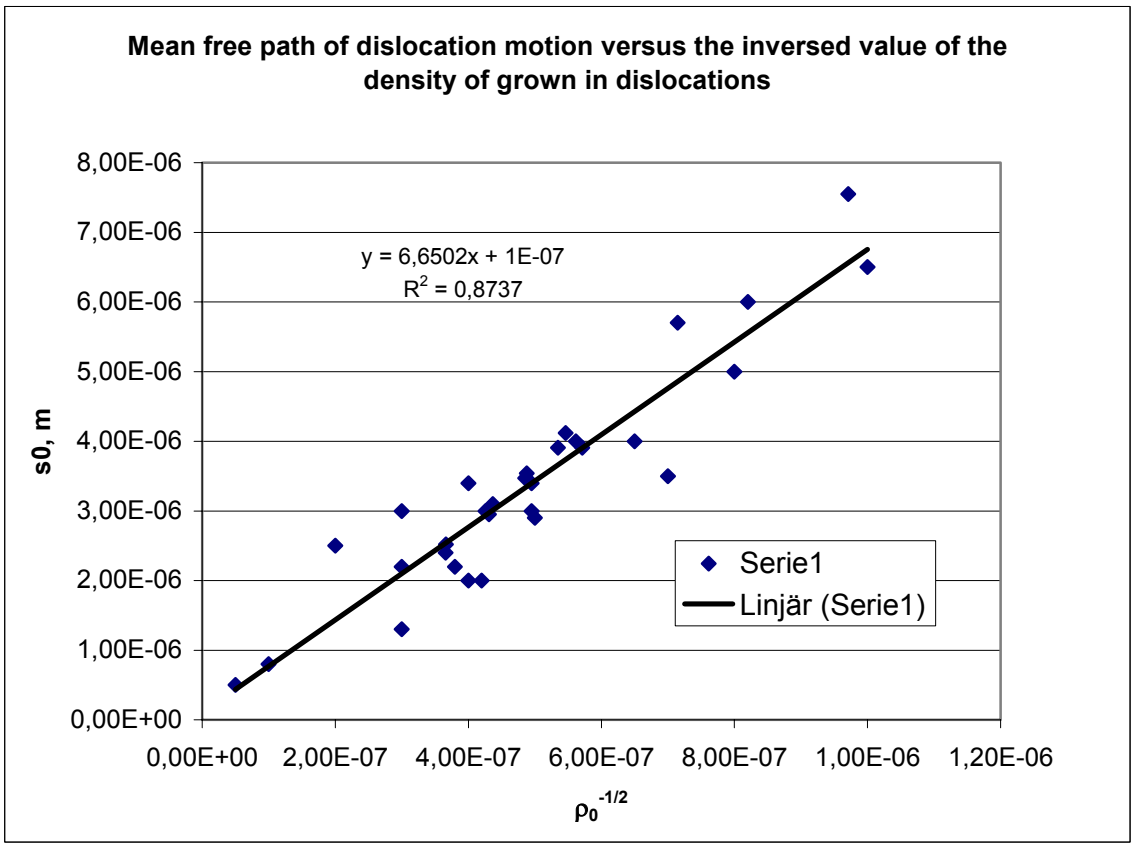

Fig 1 Mean free path, s, as a function of $\rho_0^{-1/2}$ *for various types of steel*

This result indicated that the relationship between s_0 and ρ_0 may be written

$$s_0 = 6.65 \cdot \rho_0^{-1/2} + 1 \cdot 10^{-7} \quad (4)$$

Discussion

This relationship indicates that there is a strong connection between the mean distance, s_0, travelled by mobile dislocations and the average distance between the "grown-in" dislocations. The slope of the plot indicates that s_0 is approximately 6 to 7 times larger than the mean distance between the "grown-in" dislocations and thus that it presumably is the initial tangled structure of dislocations that defines the value of s_0 and the dislocation cell diameter.

To explain the latter conclusion we may recall firstly that the "grown-in" dislocations are not homogeneously distributed in the material but heaped up in tangles of varying density and secondly that mobile dislocations may bypass grown-in dislocations by cross slip and at higher temperatures by climb as well. Of course, it is more difficult to for the mobile dislocations to bypass a group of tangled dislocations than a single dislocation and it is hence reasonable to believe that s_0 is related to the average distance between grown-in dislocation tangles which in turn are correlated to ρ_0. As the amount of straining increases the mobile dislocations will immobilise at the tangles which rather rapidly transform to cells, i.e. s_0 will be approximately equal to the average cell diameter , d. Since ρ_0 is strain independent and since cross slip is an easy event in iron because of the high stacking fault energy and the large number of slip systems in the bcc structure – i.e. the mobile dislocations may easily bypass all obstacles but the grown-in tangles – it is not surprising that s_0 is strain independent and approximately equal to the cell diameter, d.

This observation by Reed et al is most interesting and certainly worth more studies.

References

1. C.N. Reid, A. Gilbert and A:R: Rosenfield, Phil.Mag.12(1965)409
2. Y. Bergström, Reviews on powder metallurgy and physical ceramics 2(1983)79-265