Comments on "Impurities and the Thermal Components of Flow Stress in BCC Metals" by E. Pink (J. Materials Sci. **3** *(1968) 450)*

In the preceding paper [1] Pink has pointed out that anomalously low values of the thermal component of flow stress τ^* would result if the athermal component of flow stress τ_μ, were determined at temperatures where strain-ageing is prevalent. Under such conditions, determination of τ^* from stress-relaxation experiments comes into prominence. This method has been suggested earlier by the present author [2].

Pink has attributed the increase in flow stress that occurs when strain-ageing is operative, to a contribution τ_j^* due to the interaction of impurities with dislocations. In as much as the magnitude of this contribution is dependent on temperature and strain rate, Pink believes this to be an additional thermal component to the flow stress. This possibility as suggested by Pink needs careful consideration.

If the same rate-controlling mechanism is operating under strain-ageing conditions also, then the total flow stress can be written as

$$\tau = \frac{1}{V^*}\,[H^0 + KT\ln(\dot{\gamma}/bL\nu_0)] + \tau_\mu$$

where V^* is the activation volume, H^0 is the activation energy at zero effective stress and L is the total length of mobile dislocation line per unit volume; b, ν_0, $\dot{\gamma}$, K and T have their usual significance. The first term on the right-hand side of the equation represents the thermal component of flow stress τ^*. From this equation it is obvious that an increase in τ^* due to strain-ageing can come only from a reduction in the mobile dislocation density, L. Such a possibility has been suggested by Conrad [3] and experimental evidence supporting this is available [4-6].

However, there have also been instances when strain-ageing leads to an increase in the long range or athermal stress τ_μ. For instance, there have been reports that the increase in dislocation density per unit strain is greater when dynamic strain-ageing occurs [7-9]. This would naturally lead to an increase in τ_μ. Any precipitation [10] during strain-ageing can also be expected to make a contribution to τ_μ. Hartley [5] has pointed out that in specimens prestrained at a lower temperature, then strain-aged at the appropriate temperature and retested at the prestraining temperature, if the level of stress/strain curve is raised so that the extrapolation of the uniform strain hardening portion of the stress/strain curve with the elastic portion does not coincide with the stress at which pre-strain was terminated, the difference in the two stresses can be equated to an increase in τ_μ due to strain-ageing. Such an increase in τ_μ has in fact been observed in the Ta/O system by Rosenfield and Owen [11].

It is of interest to consider how these two different situations would influence stress-relaxation curves, since strain-ageing would continue during the period of relaxation also. In the first situation, (i.e. when τ_j^* is a contribution to the thermal component τ^*) the mobile dislocation density will continuously decrease and the relaxation rate will be decreasing at a faster rate, than if no strain-ageing were to occur. But as τ_μ does not change significantly during this period, the total stress relaxed would be the τ^* at the time the test was interrupted.

In the second situation also, i.e. when $\tau\mu$ increases due to strain-ageing, the relaxation rate would be decreased compared to no strain-ageing conditions. But in this case, as $\tau\mu$ increases with time, the stress relaxed would be lower than the actual τ^*. It should also be pointed out that when strain-ageing occurs, calculation of activation volume from stress-relaxation data would lead to larger values compared with the values obtained from the strain-rate change method. This has been observed in zirconium/oxygen alloys by Dasgupta and Arunachalam [12].

If dynamic recovery, instead of strain-ageing were to occur, similar anomalous behaviour in stress-relaxation would again be observed, but the change in this case would be in the opposite direction to that observed during strain-ageing.

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Book Reviews

Composite Materials

A. Kelly, G. C. Smith, P. J. E. Forsyth, A. J. Kennedy

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At this stage in the development of materials science, new books on broad aspects of the subject are to be welcomed. The science and technology of materials are passing through a formative stage, which is largely concerned with bringing together hitherto isolated topics in a consolidated whole. The subject of composite materials is typical of this development. The expression "composite materials" is itself relatively new, and there are few books on the subject available for the student or the research worker, although there is no shortage of books on individual composite materials like concrete or glass-fibre resin systems.

To some extent, the title of the latest book by Kelly, Smith, Forsyth, and Kennedy is misleading. It is almost solely concerned with metal systems, and only makes passing reference to other composites. Subject to this limitation, it represents a valuable contribution to the subject, as would be expected from four authors of such standing.

The book is based on a series of lectures delivered at the Institution of Metallurgists Refresher Course held in November 1965. Dr Kelly introduces the subject with a chapter on the theory of strengthening of metals. This is a broad review of the subject, beginning with the theoretical strength of metals and then dealing with the major variables such as the effect of grain size, solution and precipitation strengthening, the effect of elevated temperatures, work hardening of metals containing disperse phases, and fibre reinforcement. It constitutes a masterly summary of the state of knowledge today, although the arguments are put forward at a very brisk rate, presumably owing to limitations of space. Readers without a specialised metallurgical background, like the reviewer, would have benefited from a more leisurely treatment. Furthermore, a small section devoted to possible geometrical arrangements, and the problem of packing disperse phases of different geometries, would have been useful.

The following chapter on dispersion strengthened materials by Mr G. C. Smith is a very well-rounded review of this important subject, supplemented by a long list of references to recent work. The section on techniques for producing dispersed phase alloys is admirable, and will enable the general reader to compare techniques used in the metals field with those used with other materials. It is followed by sections on the dispersed phase, deformation and fracture behaviour, low-temperature properties, high-temperature properties, and the joining and uses of these materials.

Mr P. J. E. Forsyth of the RAE Farnborough contributes the next chapter on fibre-strengthened materials. This is a subject which has generated a great deal of enthusiasm in recent years, although there are now signs that a more sober reappraisal is taking place. We still see the possibilities, but the difficulties in the way of commercial development are not overlooked. The author has adopted a balanced approach and has tempered enthusiasm with realism. The section deals mainly with the theory of reinforcement (this is a very clear treatment), discontinuous fibres, orientation effects, methods of producing fibre-composite materials, the production and availability of fibres, and the properties of some experimental composites. It represents an excellent summary of an important and growing field. We are reminded on page 100 *et seq* that the significance of the bond between the whisker and the matrix is not fully understood. It appears that more work on this