LETTERS TO THE EDITORS

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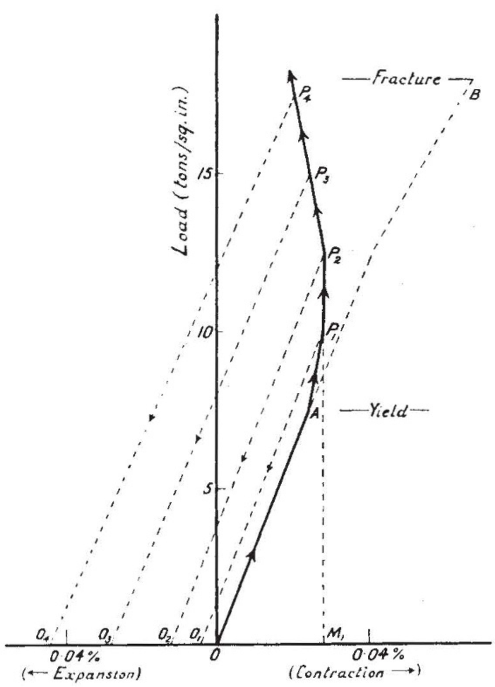
IN THE PRESENT CIRCUMSTANCES, PROOFS OF "LETTERS" WILL NOT BE SUBMITTED TO CORRESPONDENTS OUTSIDE GREAT BRITAIN.

A Lattice Stress-Strain Diagram

THE technical application of metals involves a detailed knowledge of their behaviour under external stresses. In the usual method of testing, measurements are made of the changes in external dimensions of a test piece when stresses of known magnitude are applied, as in the determination of the elementary load extension diagram. It is nowadays practicable, however, by use of modern X-ray diffraction technique, to obtain simultaneously with the external load-extension diagram the analogous diagram for the atomic lattice itself, in which direct measurements are made of the displacements of the atoms from their normal positions under stress and of their recovery when the applied stress is removed.



Percentage change in (310) spacing

The 'lattice stress-strain diagram', as it may be termed, presents novel features of theoretical and practical interest. The main characteristics may be illustrated by the accompanying figure, which records measurements made on pure iron in the following way. When a metal is stretched in one direction, it contracts by a related amount in the perpendicular direction, and the measurements refer to the contraction in this latter direction of selected atomic planes, here the (310). The contraction in the spacing of these planes has been plotted against the applied tensile stress.

The load-contraction curve then obtained is given by $0AP_4$. Up to the external yield point, which corresponds to the point A, the contraction in atomic spacing is proportional within limits of measurement to the applied stress. Beyond the yield point, however, the contraction proceeds at a slower rate and reaches a limiting value indicated at P_1P_2. With still further increase in stress the atomic spacing actually tends to expand.

If the stress applied is less than the yield value, the atomic spacing returns to its original value upon removal of the load. In the range $0A$, therefore, the atomic displacements are reversible and in accordance with Hooke's law. If, however, the applied stress is greater than the yield value then, when the stress is removed, the contracted spacing does not merely return to its normal value during recovery, but passes beyond that value and ends up with an expanded value, which persists indefinitely at room temperature. Thus, on unloading from the point P_1, the curve follows the line P_10_1 and the atomic spacing exhibits the permanent expansion 00_1 over the normal value at 0. The greater the load involved, the greater is the final permanent set imposed on the atomic spacing, an effect illustrated by the further lines P_20_2, P_30_3 . . .

If after being unloaded from P_1 the specimen is reloaded to the same stress, then the curve, commencing at 0_1, follows the line 0_1P_1, the total range of contraction being then 0_1M_1. This total range increases with the value of the applied stress up to the fracture stage as shown by the additional curve $0B$.

The lattice load-contraction diagram thus reveals information on the properties of the metallic state which could not have been deduced from consideration of the corresponding external load-contraction diagram. We may conclude that two processes occur upon loading a specimen: first, a contraction of the atomic spacing which, since the external dimensions also contract, is to be expected, and, second, as the yield point is exceeded, some form of distortion which results in a permanent expansion of the lattice. It is as if the metal, though actually at room temperature throughout, were undergoing a rise in temperature and that the expansion thus resulting was imposed on the contraction due to the simultaneous external elastic deformation. This expansion is retained by the lattice spacing after removal of the load and represents an absorption of energy or 'latent energy' due to cold work. Its observation is of particular interest since it provides a systematic approach to the study of the phenomena, often exhibited by metals, which have been vaguely classified under the heading of 'internal strains'.

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