The following speakers took part in the discussion of the subject:—Professor Arnold; Messrs. J. P. Bedson, J. W. Chenhall, F. W. Harbord, and A. B. Chatwood; Captain Sankey; and Messrs. C. L. Bell and B. Talbot,

“The Dangerous Crystallization of Mild Steel and Wrought Iron.”¹

By Professor J. O. ARNOLD.

THE accuracy of the view enunciated by Sorby in 1864—that the irregular polygonal figures obtained on etching mild steel or wrought iron are allotrimorphic crystals, formed by the interference of cubes and octahedra—is now generally admitted. Andrews was the first to show that in wrought iron these large crystals often appear to be built up of a large number of smaller cubes or secondary crystals. Arnold and Jefferson showed that such is always the case with gold and copper; and that the varying orientation of the secondary crystals produces the curious optical effect which causes two adjacent crystals to appear, the one bright and the other dark, like the alternating bands produced by rolling glass in opposite directions. By general consent the term “secondary crystal” has fallen into disuse, and the term “etching figure” has been substituted, in accordance with the nomenclature of mineralogy. Stead made the interesting discovery that some mild-steel sheets, which were intensely brittle, presented huge crystals with varying orientations as marked as those in gold. He also proved that the fracture of this metal is analogous to mineral cleavage. Ewing, Rosenhain, and Humfrey have demonstrated that well-crystallized wrought-iron, after being stressed beyond its elastic limit, shows, in the interior of the crystals, planes which they have called “slip-bands.” There has been a tendency to generalize from the statements of Stead and Ewing, and to regard all fractures of metals as equivalent to mineral cleavage; in many cases this view is untenable. For instance, the Author has tested a bar of pure gold presenting the most intense crystallization, which bent backwards and forwards ten times through an angle of 180°, and then fractured as though broken in tension, with a reduction in area of about 90 per cent.; it had, in fact, drawn out to a point.

¹ *The Engineer*, vol. xcvi. p. 8. *Engineering*, vol. lxxvi. pp. 4 and 30.

Brittle Crystallization.—As pointed out by Heyn, the term “brittle crystallization” has led to some confusion. The Author suggests that it would be well to recognize specifically two kinds of brittleness. First, actual or mechanical brittleness, which causes the metal to snap on any attempt being made to bend it; second, potential or vibratory brittleness, which allows the metal to give excellent tensile tests, and readily to bend double without fracture, but nevertheless renders it liable to rupture suddenly under vibration or alternation of stress, at a stress far below its elastic limit.

Fig. 1.

Vibratory brittleness is of course much the more dangerous of the two kinds.

Determination of Vibratory Brittleness.—When examined under the microscope, steel liable to fracture under the influence of vibration usually presents a coarse structure, in which the junction-lines of the ferrite and pearlite crystals are sharply defined, whilst in form the constituents are sharply angular. Usually however, the indications of the microscope possess only the melancholy interest of a post-mortem examination. To detect vibratory brittleness the Author has devised a modification of the alternating stress or

fatigue test, which can be rapidly carried out. The method is illustrated in *Fig. 1*. A horizontal slide S, making about 100 double strokes per minute, has a slotted angle-bar attached to it. The test-piece is $\frac{3}{8}$ inch square, $5\frac{1}{2}$ inches in length over all, with 4 inches projecting above the die in which it is gripped. The top of the test-piece is deflected $\frac{1}{2}$ inch each way from the centre, receiving about 200 blows per minute from the slotted angle-bar. Fracture of course always takes place along the top of the die. At this point the steel is but slightly deflected at the rate of 200 alternations per minute. Here the metal becomes hot, reaching probably the temperature of minimum ductility, which has been observed by André Le Chatelier to be in the vicinity of 100° C. or 200° F. Under this test a steel known to possess vibratory brittleness, but which nevertheless bends double while cold and elongates 30 per cent. in a length of 2 inches under a maximum stress of 30 tons per square inch, will be found to snap after receiving about 200 blows, equivalent to a time endurance of about 1 minute. On the other hand, steel little liable to fracture under vibration has a time endurance of about 2 minutes, equivalent to 400 blows. It is evident that a large number of such tests can be carried out in a day. It is absolutely necessary that the test-bars should be exact to size; and they must be polished with fine emery-cloth till quite free from tool-marks.

Heat Treatment of Mechanically Brittle Steel.—Stead has shown that the coarse structure of mechanically brittle steel is made much finer by heating it to slightly over 900° C. or 1,650° F.; that is to say, above Osmond's point Ar 3. This fact is strikingly exemplified by the specimens exhibited; but although the structure is fined down by such treatment, the operation does not produce a satisfactory normal crystallization; and experience has shown that crystallization so coarse as to produce mechanical brittleness can be thoroughly removed only by hot working, or, better still, by consignment to the scrap-heap for re-melting.

The following speakers took part in the discussion of the subject:—Mr. F. W. Harbord, Captain Sankey, and Messrs. M. Longridge, J. P. Bedson, E. G. Constantine, C. E. Phipps, J. Barker, B. Talbot, S. H. Farrar, and J. W. Chenhall; and Mr. E. Heyn, who was unable to be present, communicated his views in writing.