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REPORT NO. 660/4

Discussion Of Paper Entitled

"COLD-WORKING OF HOLLOW CYLINDERS
BY AUTO-FRETTAGE"

By

H. O. Mann

October 1936

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Discussion of Norman E. Woldman's Paper

"COLD-WORKING OF HOLLOW CYLINDERS
by Auto-Fretting"

In view of recent advances in ideas concerning the true phenomena of plasticity of metals the theories advanced in the first part of the paper are considered superceded by the newer and better established ones. An excellent survey of the entire field is found in the work of Prof. P. W. Bridgeman, "The Physics of High Pressure", and in the book "Distortion of Metal Crystals" by C. E. Elam, Oxford 1935, with the best theory and one which has the support of several leading authorities, presented in "The Mechanism of Plastic Deformation of Crystals" by G. I. Taylor, Proc. Royal Society, Vol. 145 No. A855, 1934.

The author's diagram (Fig. 7) and accompanying discussion on Page 21, intended to depict the characteristic behavior of material before cold-work, after cold-work, and after stabilizing, are misleading. In the diagram the "After Cold-Working" curve should extend upward almost to the yield position of the "After Low Temperature" curve. This latter curve should be on the same modulus line as the "As Received" curve since there is no change in the modulus of elasticity produced by cold-working. In his discussion of the return of elastic strength by low temp. heat treatment the author appears to consider the terms

"proportional" and "elastic" strength as applying to the same condition, where as a matter of fact there is a definite difference between the two. The fact that a material exhibits considerable hysteresis with no evidence of proportionality of stress to strain is no indication that ^{it} is not still perfectly elastic in the sense that upon release of pressure applications very close to the final cold-working pressure, the material will still return to its original after cold-work dimensions. The real effect of the low temp. or stabilizing treatment is to bring about a return of proportionality of stress to strain. This is well illustrated in Figures A and B. Figure A shows typical stress-strain curves obtained from test specimens from a forged cold-worked cylinder in the cold-worked condition and after stabilizing for 5 and 8 hours. The curve noted as unstabilized shows the characteristic hysteresis looping with a very low proportional limit. Stabilizing for 5 hours at 300°C has released a part of the hysteresis with a resultant increase in proportional limit. The additional three hours or total of eight hours soaking has completely stabilized the material and produced a clearly defined proportional limit which is practically equal to the elastic strength of the material. Further and more comprehensive evidence of the results of stabilization is indicated from the curves shown in Figure B. These curves are plotted stress vs residual strain from

readings obtained by the use of extremely sensitive instruments and show quite clearly that stabilization after cold-working merely relieves hysteresis and brings out a clearly defined proportional limit point. In this connection it may be well to note that the time and temperature required for complete stabilization will be found dependent to a large degree on the material composition.

Regarding the remarks in the first paragraph, page 12, contrary to the author's statement, we have found that so long as the temperature used is just sufficient for stabilization and not high enough to produce a change in material microstructure, the only change in physical properties produced is the elimination of hysteresis looping with the accompanying development of a clearly defined proportional limit, no other property being affected.

In connection with the general subject of cold-working it may be of interest to note that the increased elastic strength produced by cold-working either a hollow cylinder by radial expansion, or a rod or bar by longitudinal stretching, can be readily predetermined from the true-stress curve obtained from the tension test of a single specimen of the material, as shown in Figure C. These were obtained from a cylinder before cold-work and after

cold-work and stabilization. It will be noted that the curve of the after cold-work and soak condition superimposes on the before cold-work curve, at a distance to the right equivalent to an amount of stretching or cold-working of the before cold-work specimen equal to that given the cylinder at the position from which the specimen was taken. The new proportional limit point indicating the increased elastic strength produced. From such an initial curve it is possible to determine the elastic strength at any part of a cylinder wall provided the percentage permanent enlargement at that particular point is known.

The curves noted in Figure C were obtained from centrifugally cast material which accounts for the large drop at the yield point. It has been our experience that this drop is definitely associated with the hot worked condition of the material, that is, the presence of porosity, voids, etc. The condition when present is greatly reduced in magnitude and many times completely eliminated by slight cold-working.

In conclusion it is desired to point to the fact that for all the large amount of investigative work which has been done on the subject of cold-working hollow cylinders, the true reason for the increased elastic strength produced has not as yet been conclusively established. Further re-

search into the new theories regarding the plastic deformation of crystals and the phenomena of stabilization by low temperature heat treatment, will undoubtedly lead to a clarification of the entire subject. The paper as presented, while it represents a review or survey of available literature, can only therefore be considered as a summation of ideas which may be subject to change at a later date.

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