

SUMMARY

The application of the autofrettage principle to materials of 165,000 psi yield strength has been experimentally investigated. Resulting from this investigation are a series of relationships for the stresses and displacements in overstrained thick-wall cylinders in the open-end condition. These relationships, which can be used for pressure vessel design purposes, are based on the von Mises yield criterion but incorporating empirical constants for simplicity. The agreement between these relationships and the experimental data is good.

REFERENCES

1. WRIGHT, R. E. "Elastic-Plastic Analysis of a Cylindrical Tube" Western Regional Technical Report WVTRR-6907, March 1969.
2. FAUBI, J. H. "Residual Stresses in Heavy Wall Cylinders", *J. Franklin Inst.*, pp. 409-419, May 1955.
3. FAUBI, J. H. and FURBER, A. R. "Influence of Residual Stress on Behavior of Wall Closed-End Cylinders" *Trans. A.S.M.E.*, 75, No. 3, April 1953.
4. KOEHLER, W. T. "On Partially Plastic Thick-Walled Tubes" C. B. Blezner Ann. Volume on Applied Mechanics, N. V. de Technische Litgeverij, H., Stam, B., 1953.
5. LANGENBERG, F. C. "Effect of Cold Working on the Strength of Hollow Cylinders" *Trans. Amer. Soc. Steel Treating*, 8, No. 10, October 1925.
6. MAC GREGOR, C. W., COFFIN, L. F., and FISHER, J. C. "Partially Plastic Walled Tube" *J. Franklin Inst.*, pp. 47-50, February, 1948.
7. NEWHALL, D. H. "Selected Design Data Pertaining to Gun Tubes and High Pressure Vessels" Watertown Arsenal Report No. WGD-4, December 1943.
8. NEWHALL, D. H. "Plastic Strains in Thick Hollow Cylinders Overstrained by Pressure" Watertown Arsenal Report No. WGD-7, January 1944.
9. PRAGER, W. "Stress-Strain Laws of the Mathematical Theory of Plasticity" *J. of Appl. Mech.*, 70, pp. 226-235, September 1948.
10. SOPWITH, D. G. and DE G. ALLEN, D. N. "The Stresses and Strains in a Partially Plastic Thick Tube under Internal Pressure and End Load", *Proc. Roy. Soc., London*, Ser. A, 205, pp. 69-83, 1951.
11. SHILL, M. C. and YOUNG, JOHN "An Experimental Investigation of Over-Straining in Mild-Steel Thick-Walled Cylinders by Internal Fluid Pressure" *Trans. A.S.M.E.*, pp. 355-363, April 1952.
12. TIMOSHENKO, S. *Strength of Materials, Part II*, Van Nostrand, 1942.
13. TURNER, L. B. "The Stresses in a Thick Hollow-Cylinder Subjected to Internal Pressure" *Trans. Camb. Phil. Soc.*, XXI, No. XIV, pp. 377-396.
14. WARREN, A. G. "Autofrettage", *Symposium on Internal Stresses in Metals and Alloys*, pp. 209-218, Institute of Metals, 1947.

BRITTLE FRACTURE IN LOW CARBON STEEL UNDER TENSILE AND TORSION TEST

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Abstract—To elucidate the mechanism of brittle fracture in mild steel, the stress condition and the related phenomena in brittle fracture were studied. The experiments were conducted at liquid nitrogen temperature on surface cracked thick-walled hollow cylindrical specimens with test portions of the same shape. From the tensile and torsion tests, of an identical low-carbon steel having a considerable range of grain size, that is, ranging from ASTMGS No. 1.4 to ASTMGS No. 5.5

The following characteristics and conclusions were obtained:

- (1) In the tensile test, microscopic fracture produced both spiral and axial fracture surfaces. The propagation direction of the spiral fracture surface makes about 45° with the specimen axis.
- (2) The spiral part of the fracture surface appears to occur earlier than the axial part of the fracture surface in torsion fracture.
- (3) Under the same plastic strain, the fracture surfaces of both spiral part and axial part in torsion fracture were found to be of the cleavage type.
- (4) The plastic deformation prior to cleavage fracture is greater in the torsion test than in the tension test.
- (5) In the torsion fracture test, very little dependence is found of fracture stress on ferrite grain size.
- (6) The ratio τ_{11}/σ_{11} of torsional fracture stress τ_{11} to tensile fracture stress σ_{11} increases considerably with increase of ferrite grain size, for example, varying from 0.55 to 0.82 corresponding to the variation of the grain size from ASTMGS No. 5.5 to ASTMGS No. 1.4.
- (7) At liquid nitrogen temperature, the ratio τ_{11}/σ_{11} of torsional yield stress τ_{11} to tensile yield stress σ_{11} increases considerably with the increase of ferrite grain size, for example, varying from 0.50 to 0.63 corresponding to the variation of the grain size from ASTMGS No. 5.5 to ASTMGS No. 1.4.
- (8) The stress criterion for brittle cleavage fracture in low carbon steel does not obey the maximum tensile stress law, nor the maximum shear stress law, nor the von Mises criterion nor the modified von Mises criterion by Peterson. The tensile stress component and the shear stress component of applied stress should be involved at the same time in brittle fracture. In this respect, the Cottrell theory of brittle fracture is most favorable.

The possibilities of the interpretation of the results mentioned from (1) to (8) in terms of the Cottrell's theory of brittle fracture in mild steel or in terms of another mechanism suggested are discussed.