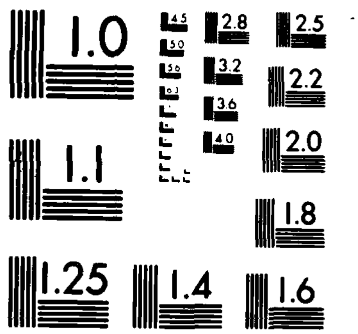
AD-A150 091 FRACTURE ANALYSIS OF CRACKS IN COMPLETE CYLINDRICAL SHELLS(U) HARVARD UNIV CAMBRIDGE MA DIV OF APPLIED SCIENCES J L SANDERS 03 DEC 84 N00014-81-K-0668 1/1

UNCLASSIFIED F/G 20/11 NL

END
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

AD-A150 091

December 3, 1984

Final Technical Report

OFFICE OF NAVAL RESEARCH Contract N00014-81-K-0668

"Fracture Analysis of Cracks in Complete Cylindrical Shells"

Principal Investigator: J. Lyell Sanders, Jr.
Division of Applied Sciences
Harvard University

Scientific Officer: Yapa Rajapakse

During the course of this investigation several significant contributions to the state of the art in fracture analysis have been made. It makes sense to discuss these contributions in the context of other activity on the problem of circumferential cracks in pipes or cylindrical shells. The circumferential through-crack problem in shallow cylindrical shells had been investigated by a succession of authors (Folias, Erdogan and Delale, Duncan and Sanders, and Simmonds). The solution, i.e. the determination of the stress intensity factors and/or the energy release rate had been established for the complete range of the parameters involved according to linear elastic fracture mechanics. However, it was not known how long the crack might be in relation to the circumference for the results to be valid, since the analyses were all based on shallow shell theory. In 1979 Barsoum et al. obtained results for long circumferential cracks in the complete cylinder by finite element methods. The calculations were necessarily for pipes of finite length and some unknown end effects were present. The present investigator published results (1982) obtained by a new analytical method for long circumferential through cracks in a pipe under axial tension. These results were in closed form and applied to pipes of infinite length. Research under the present contract began with similar calculations made for the pipe under combined bending and tension. Results obtained by this means agree quite well (in an overlap range) with previous results from shallow shell theory, and since the results were in closed form no "parameter studies" were necessary.

Since a circumferential crack in an actual installation may well occur close to some joint or similar attachment our attention turned to investigating what the end effects might be. The problem of choice was a semi-infinite pipe with one end rigidly fixed and with a circumferential crack at the fixed end. This problem also yielded to the analytical method and results for combined bending and tension were obtained in closed form. The results show that the stress intensity at the crack tip is alleviated by the proximity of the rigid boundary by about thirty percent. Of course, for a more flexibly held end the relief would be somewhat less. A similar problem in which the crack is located close to, but not at, the rigidly fixed boundary was attempted but proved not to be tractable by the same methods. However, some research done at NASA Houston by Forman et al. came to our attention, and together with our results answers the question in a satisfactory engineering sense. The work was done by finite element methods, and did not cover the full range of parameters. However, their results are about the same as ours when the crack lies about a radius away from a rather stiff end. When the crack lies a diameter or more away from a stiff end there is practically no alleviating effect.

Interest in analytical solutions to part-through crack problems was revived when confidence in the Rice-Levy line-spring model was established after some years of doubt. Several investigators have used it for problems of short cracks in cylindrical shells by means of shallow shell theory and integral equations. We looked at the problem for longer cracks. Our research has established theoretically that the most critical stress intensity factor is that corresponding to the point of deepest penetration of the crack (in the tension case) and is independent of the crack length or variation of crack depth provided the crack is sufficiently "long" and provided the depth variation is sufficiently "smooth", i.e. does not vary much over a distance equal to the edge effect length. Our results (again in closed form) simplify the problem; there is no need for example, to investigate the effects of various crack depth profiles for long cracks.

A complete account of the present investigator's cylindrical shell equations in complex form, upon which our work has been based, was previously available only in Russian (Novozhilov Anniv. Vol.). A "neatened up" version together with further developments of the sort necessary for the kind of analyses under discussion here was written and published during the period of this contract.

OFFICE OF NAVAL RESEARCH Contract N00014-81-K-0668

The methods of solution developed during the course of our research appear to have uses beyond linear elastic fracture analysis of circumferential cracks. Cracks in reasonably thin pipes are like cracks in thin plates. In plane stress the Dugdale model is available for treating the case of large scale yielding. The important point is that the elastic field equations remain applicable. At present it seems likely, or at least hopeful, that some form of "crack opening angle" criterion for crack extension is valid. If fracture toughness curves for flat plates can be obtained theoretically then it seems to me that toughness curves for "long" circumferential cracks in pipes can be gotten perhaps even more easily than for flat plates.

The following papers have been written during the period of the contract:

1. "Circumferential Through-Crack in a Cylindrical Shell Under Combined Bending and Tension", by J. Lyell Sanders, Jr., Journal of Applied Mechanics, Vol. 50, pp 221, March 1983.

2. "Analysis of Circular Cylindrical Shells", by J. Lyell Sanders, Jr., Journal of Applied Mechanics, Vol. 50, pp 1165-1170, December 1983.

3. "Circumferential Part-Through Cracks in Cylindrical Shells Under Tension", by J. A. Alabi and J. L. Sanders, Jr., Journal of Applied Mechanics (to appear).

4. "Circumferential Crack at the Fixed End of a Pipe", by J. A. Alabi and J. L. Sanders, Jr., Engineering Fracture Mechanics (to appear).

END

FILMED

3-85

DTIC