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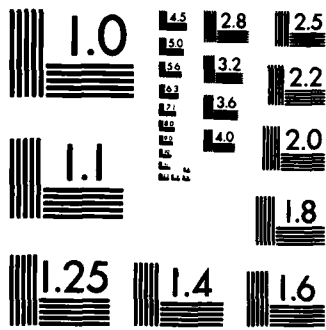
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ANALYSIS OF TRANSIENT STRAINS SURROUNDING RUNNING CRACKS
IN METAL AND PLASTIC PLATES

by

A. S. Kobayashi

August 1985

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1. Precis of Significant Accomplishments

The objective of this research program is to investigate experimentally the transient strain and stress distribution in the vicinity of a running crack in engineering materials.

Since the inception of this research project in February 1964, dynamic Moire fringe method and dynamic photoelasticity were used to determine transient strain and stress distributions in fracturing epoxy, magnesium and aluminum plates with central cracks and dynamic fracture toughness and crack arrest stress intensity factors in unstiffened and stiffened Homalite-100 plates. The Homalite-100 specimens consisted of single-edge notch (SEN) plates, with or without central holes subject to uniaxial tension, with or without impact loading, wedge-loaded (WL) rectangular double cantilver beam (DCB) specimens under static load, impact loaded Naval Research Laboratory (NRL) notch bend specimens and modified compact tension (M-CT) specimens. Wedge-loaded (WL) rectangular DCB specimens, NRL notch bend specimens, transverse WL M-CT specimens, and SEN plates, which were machined from thin annealed polycarbonate sheets, were also analyzed. An over-deterministic method has been used to re-evaluate the dynamic crack tip stress field, of the past and recent dynamic photoelastic tests. The results were used to verify a dynamic crack curving criterion, which is valid under combined modes I and II or mode I loading alone and which is based on either the maximum circumferencial stress or minimum strain energy density factor. A dynamic crack branching criterion, which requires a crack branching stress intensity factor as a necessary condition and the crack curving criterion as a sufficient condition, was also developed.

Research efforts for the last year involved the construction of a 2000-lb biaxial testing machine which was then used to conduct dynamic photoelastic analyses of dynamic crack curving and crack branching in Homalite-100 plates under biaxial tensile loading. Data generated was used to further verify or disprove the dynamic crack curving and branching criteria described above. Simultaneously a single-flash, white-light moire interferometric system, which utilizes a grating of 600 rulings mm, is being developed for studying dynamic crack propagation, arrest and curving in ductile aluminum.

2. All ONR Technical Reports and Other Related Publications

Forty-nine ONR technical reports and sixty-five papers were prepared from the results obtained in the twenty years of investigation. The latter includes:

A. S. Kobayashi, "Photoelastic Studies of Fracture," Treatise on Fracture, Volume 3, ed. by H. Liebowitz, Academic Press, pp. 311-369, 1971.

Experimental Techniques in Fracture Mechanics, SESA Monographs, I and II, Iowa State University Press, ed. by A. S. Kobayashi, 1973 and 1975.

A. S. Kobayashi, "Current and Future Experimental Methods," Fracture Mechanics, ed. by N. Perrone, H. Liebowitz, D. Mulville, and W. Pilkey, University Press of Virginia, pp. 481-496, 1978.

A. S. Kobayashi, "Computer Codes in Fracture Mechanics," Structural Mechanics Software Series, ed. by W. D. Pilkey and N. Perrone, University Press of Virginia, pp. 85-146, 1982.

A. S. Kobayashi, "Finite Element Method--A Companion in Experimental Mechanics," Computers & Structures, Vol. 19, Nos. 1/2, pp. 111-118, 1984.

A. S. Kobayashi, B. S.-J. Kang, and M. Ramulu, "Dynamic Crack Curving and Branching in Line-Pipe," ASME Journal of Pressure Vessel Technology, Vol. 104, No. 4, pp. 317-322, November 1982.

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M. Ramulu and A. S. Kobayashi, "Dynamic Crack Curving and Crack Branching," Material Behavior under High Stress and Ultra-high Loading Rates, Sagamore National Research Conference 29, pp. 241-250, 1983.

A. S. Kobayashi and M. Ramulu, "Recent Developments in Dynamic Crack Curving and Branching," Proc. of Int. Conf. on Dynamic and Mechanical Properties and Fracture Dynamics of Engineering Materials, Valtice, Czechoslovakia, pp. 64-77, June 16-18, 1983.

A. S. Kobayashi, "Crack Branching, Crack Arrest and Rapid Tearing," Workshop on Dynamic Fracture, ed. by W. G. Knaus, K. Ravi-Chandar and A. J. Rosakis, California Institute of Technology, pp. 169-177, 1983.

A. S. Kobayashi, "Dynamic Crack Propagation in Brittle and Ductile Materials," Structural Impact and Crash Worthiness, Vol. 1, ed. by G. A. O. Davis, Elsevier Science Applied Publishers, pp. 129-154, 1984.

A. S. Kobayashi, "Linear Elastic Fracture Mechanics," to be published in Computation Methods in the Mechanics of Failure, ed. by S. N. Atluri, Elsevier Applied Science Publishers.

S. N. Atluri and A. S. Kobayashi, "Elastic-Plastic and Inelastic Fracture," to be published in Computational Methods in the Mechanics of Failure, ed. by S. N. Atluri, Elsevier Applied Science Publishers.

M. Ramulu and A. S. Kobayashi, "Criteria for Dynamic Crack Curving and Branching," Advances in Fracture Research, Proc. of the Sixth International Conference on Fracture (ICF6), ed. by S.R. Valluri et al, Vol. 5, pp. 3099-3107, Pergamon Press, 1984.

S. N. Atluri and A. S. Kobayashi, "Mechanical Response of Materials," to be published in Handbook of Experimental Mechanics, ed. by A. S. Kobayashi, Prentice Hall, 1986.

A. S. Kobayashi, "Hybrid Experimental-Numerical Stress Analysis," to be published in Handbook of Experimental Mechanics, ed. by A. S. Kobayashi, Prentice Hall, 1986.

C. W. Smith and A. S. Kobayashi, "Experimental Fracture Mechanics," to be published in Handbook of Experimental Mechanics, ed. by A. S. Kobayashi, Prentice Hall, 1986.

A. S. Kobayashi and M. Ramulu, "Dynamic Fracture Mechanics," to be published in G. R. Irwin Commemorative Volume, The Journal of Aeronautical Society of India, 1984.

M. Ramulu and A. S. Kobayashi, "Mechanics of Crack Curving and Branching--A Dynamic Fracture Analysis," International Journal of Fracture, Vol. 27, pp. 187-201, 1985.

Technical Reports

A. S. Kobayashi, W. B. Bradley, and R. A. Selby, "Transient Analysis of a Fracturing Epoxy Plate," Technical Report No. 1, August 1964. Proc. of the 1st Int. Conf. on Fracture (Sendai), 1965.

- A. S. Kobayashi, D. O. Harris, and W. L. Engstrom, "Transient Analysis in a Fracturing Magnesium Plate," Technical Report No. 2, March 1966. Experimental Mechanics, Vol. 7, No. 10, pp. 434-440, October 1967,
- A. S. Kobayashi and W. L. Engstrom, "Transient Analysis in Fracturing Aluminum Plate," Technical Report No. 3, November 1966.
- A. S. Kobayashi and W. L. Engstrom, "Transient Analysis in Fracturing Aluminum Plate," Technical Report No. 3A, May 1976. Proc. of 1967 JSME Semi-International Conf., Tokyo, Japan, pp. 175-182, 1967,
- A. S. Kobayashi, W. L. Engstrom, and B. J. Simon, "Crack Opening Displacement and Normal Strains in Centrally Notched Cracks," Technical Report No. 4, January 1968, Experimental Mechanics, Vol. 9, No. 4, pp. 163-170, April 1969.
- A. S. Kobayashi, D. E. Maiden, B. J. Simon, and S. Iida, "Application of the Method of Finite Element Analysis to Two-Dimensional Problems in Fracture Mechanics," Technical Report No. 4, January 1968. Experimental Mechanics, Vol. 9, No. 4, pp. 163-170, April 1969.
- S. Iida and A. S. Kobayashi, "Crack Propagation Rate in 7075-T6 Plates Under Tensile and Transverse Shear Loadings," Technical Report No. 6, January 1969. J. of Basic Engineering, Trans. of ASME, Vol. 91, Series D, No. 4, pp. 764-769, December 1969.
- W. B. Bradley and A. S. Kobayashi, "An Investigation on Propagation Cracks by Dynamic Photoelasticity," Technical Report No. 7, February 1969, Experimental Mechanics, Vol. 10, No. 1, pp. 106-113, March 1970.
- W. B. Bradley and A. S. Kobayashi, "Fracture Dynamics--A Photoelastic Investigation," Technical Report No. 8, April 1969. Int. J. of Engineering Fracture Mechanics, Vol. 3, pp. 317-332, 1971.
- W. B. Bradley and A. S. Kobayashi, "A Dynamic Photoelasticity System," Technical Report No. 9, April 1969.
- A. S. Kobayashi and D. E. Maiden, "Stress Intensity Factors for a Straight Crack Approaching a Circular Hole," Technical Report No. 10, December 1969. Proc. of Air Force Conf. on Fatigue and Fracture of Aircraft Structure and Materials, AFFDL and AFML, pp. 217-224, September 1970.
- A. S. Kobayashi, B. G. Wade and D. E. Maiden, "An Investigation of Crack Arrest Capability of a Hole," Technical Report No. 11, 1970. Experimental Mechanics, Vol. 12, No. 1, pp. 32-37, January 1971.
- A. S. Kobayashi, S. T. Chiu, and R. Beeuwkes, "A Numerical and Experimental Investigation of the Use of J-Integral," Technical Report No. 12, May 1972. Engineering Fracture Mechanics, Vol. 5, No. 3, pp. 293-305, 1973.
- A. S. Kobayashi, B. G. Wade, W. B. Bradley, S. T. Chiu, "Crack Branching in Fracturing Homalite-100 Plates," Technical Report No. 13, June 1972. Engineering Fracture Mechanics, Vol. 5, pp. 81-82, 1974.

A. S. Kobayashi and B. G. Wade, "Crack Propagation and Arrest in Impacted Plates," Technical Report No. 14, July 1972. Proc. of the Conf. on Dynamic Crack Propagation, ed. by G. C. Sih, Noordhoff International, pp. 663-677, 1973.

A. S. Kobayashi, B. G. Wade, and W. B. Bradley, "Fracture Dynamics of Homalite-100 Sheets," Technical Report No. 15, September 1972. Deformation and Fracture of High Polymers, ed. by H. H. Kausch, J. A. Hassell and R. I. Jaffee, Plenum Press, pp. 457-505, 1973.

A. S. Kobayashi, B. N. Johnson, and B. G. Wade, "Crack Approaching a Hole," Technical Report No. 16, March 1973. Fracture Analysis, ASTM STP 560, pp. 53-68, 1974.

B. G. Wade and A. S. Kobayashi, "A Photoelastic Investigation on the Crack Arrest Capability of Pre-Tensioned Stiffened Panels," Technical Report No. 17, October 1973. Experimental Mechanics, Vol. No. 1, pp. 1-9, January 1975.

A. S. Kobayashi, "Some Two-Dimensional Problems in Fracture Mechanics," Technical Report No. 18, January 1974. Linear Fracture Mechanics ed. by G. C. Sih, R. R. Wei, and F. Erdogan, Enoo Publishing Company, Lehigh Valley, pp. 107-128, 1975.

A. S. Kobayashi, "Criteria for Crack Branching and Crack Arrest," Technical Report No. 19, December 1974. Progress in Experimental Mechanics, Durelli Anniversary Volume, ed. by V. J. Parks, pp. 83-97, May 1975.

A. S. Kobayashi and C. F. Chan, "A Dynamic Photoelastic Analysis of Dynamic Tear Test Specimens," Technical Report No. 20, October 1974. Experimental Mechanics, Vol. 16, No. 5, pp. 176-181, May 1976.

A. S. Kobayashi, S. Mall, and M. H. Lee, "Fracture Dynamics of Wedge-Loaded DCB," Technical No. 21, May 1975. Cracks and Fracture, ASTM STP 601, pp. 274-290, 1976.

A. S. Kobayashi, S. Mall, and W. B. Bradley, "A Dynamic Photoelastic Analysis of Crack Branching," Technical Report No. 22, July 1975. Proc. of the 12th Annual Meeting of the Society of Engineering Science, University of Texas at Austin, pp. 1005-1014, October 20-22, 1975.

A. S. Kobayashi, A. F. Emery, and S. Mall, "Dynamic Finite Element and Dynamic Photoelastic Analyses of Two Fracturing Homalite-100 Plates," Technical Report No. 23, December 1975. Experimental Mechanics, Vol. 16, No. 9, pp. 321-328, 1976.

A. S. Kobayashi and S. Mall, "Dynamic Photoelastic Analysis of Three Dynamic Fracture Specimens," Technical Report No. 24, January 1976. Dynamic Fracture Toughness, The Welding Institute, Cambridge, pp. 259-272, 1976.

- A. S. Kobayashi, A. F. Emery, and S. Mall, "Dynamic Finite Element and Dynamic Photoelastic Analysis of Crack Arrest in Homalite-100 Plates," Technical Report No. 25, May 1976. Fast Fracture and Crack Arrest, ASTM STP 627, pp. 95-108, July 1977.
- A. S. Kobayashi, S. Mall, and A. F. Emery, "Dynamic Finite Element and Dynamic Photoelastic Analyses of an Impacted Pre-Tensioned Plate," Technical Report No. 26, September 1976. Proc. of the 4th International Conference on Fracture, Vol. III, Waterloo, Canada, pp. 79-84, June 1977.
- A. S. Kobayashi and S. Mall, "Dynamic Fracture Toughness of Homalite-100," Technical Report No. 27, December 1976. Experimental Mechanics, Vol. 18, No. 1, pp. 11-18, January 1979.
- A. S. Kobayashi and S. Mall, "A Procedure for Evaluating Fracture Dynamic Parameters from Crack Velocities," Technical Report No. 28, May 1977. Recent Advances in Engineering Sciences, ed. by G. C. Sih, Lehigh University Publication, pp. 933-941, 1977.
- A. S. Kobayashi, S. Mall, Y. Urabe, and A. F. Emery, "A Numerical Dynamic Fracture Analysis of Wedge-Loaded DCB Specimens," Technical Report No. 29, October 1977. Numerical Methods in Fracture Mechanics, ed. by A. R. Luxmoore and D. R. Owen, University College of Swansea, pp. 209-270, 1978.
- A. S. Kobayashi and S. Mall, "Rapid Crack Propagation and Arrest in Polymers," Technical Report No. 30, October 1977. Journal of Polymer Science and Engineering, Vol. 19, No. 2, pp. 131-135, mid-February, 1979.
- S. Mall, A. S. Kobayashi and Y. Urabe, "Dynamic Photoelastic and Dynamic Finite Element Analyses of Dynamic Tear Test Specimens," Technical Report No. 31, January 1978. Experimental Mechanics, Vol. 18, pp. 449-456, December 1978.
- S. Mall, A. S. Kobayashi, and Y. Urabe, "Dynamic Photoelastic and Dynamic Finite Element Analyses of Polycarbonate Dynamic Tear Test Specimens," Technical Report No. 32, January 1978. Fracture Mechanics, ASTM STP 667, pp. 498-510, 1979.
- S. Mall, A. S. Kobayashi, and F. J. Loss, "Dynamic Fracture Analysis of Notched Bend Specimens," Technical Report No. 33, October 1979. Crack Arrest Methodology and Application, ASTM STP 771, pp. 70-89, 1980.
- L. Hodulak, A. S. Kobayashi, and A. F. Emery, "A Critical Examination of a Numerical Fracture Dynamic Code," Technical Report No. 34, February 1979. Fracture Mechanics ASTM STP 700, pp. 174-188, 1980.
- A. S. Kobayashi, K. Seo, J. Y. Jou, and Y. Urabe, "Dynamic Analyses of Homalite-100 and Polycarbonate Modified Compact-Tension Specimens," Technical Report No. 35, March 1979. Experimental Mechanics, Vol. 20, No. 3, pp. 73-79, March 1980.

L. Hodulak, A. S. Kobayashi, and A. F. Emery, "Influence of Dynamic Fracture Toughness on Dynamic Crack Propagation," Technical Report No. 36, March 1978. Engineering Fracture Mechanics, Vol. 13, No. 1, pp. 85-94, 1980.

A. S. Kobayashi and M. Ramulu, "Dynamic Stress Intensity Factors for Unsymmetric Dynamic Isochromatics," Technical Report No. 37, January 1980. Experimental Mechanics, Vol. 21, No. 1, pp. 41-48, January 1981.

A. S. Kobayashi, M. Ramulu, and B. S.-J. Kang, "Influence of Small-Scale Yielding on Dynamic Fracture," Technical Report No. 38, May 1980. Proc. of the 2nd International Conference on Numerical Methods in Fracture, University College, Swansea, pp. 535-538, July 1980.

A. S. Kobayashia and M. Ramulu, "Dynamic Mixed Mode Fracture." Technical Report No. 39, August 1980. Mixed Mode Fracture, ed. by G. C. Sih and P. Theocaris, Sitjhoff and Noordhoff, pp. 163-172, 1981.

A. S. Kobayashi, M. Ramulu, and S. Mall, "Impacted Notch Bend Specimen," Technical Report No. 40, March 1980, ASME Journal of Pressure Vessel Technology, Vol. 109, No. 1, pp. 25-30, February 1982.

M. Ramulu and A. S. Kobayashi, "Dynamic Crack Curving--A Photoelastic Evaluation," Technical Report No. 41, October 1981. Experimental Mechanics, Vol. 23, pp. 1-9, March 1983.

Y.-J. Sun, M. Ramulu, A. S. Kobayashi, and B. S.-J. Kang, "Further Studies on Dynamic Crack Curving," Technical Report No. 42, November 1981. Development in Theoretical and Applied Mechanics, Vol. XI, ed. by T. J. Chang and G. R. Karr, University of Alabama in Huntsville, pp. 203-218, 1982.

M. Ramulu, A. S. Kobayashi, and B. S.-J. Kang, "Dynamic Crack Branching--A Photoelastic Evaluation," Technical Report No. UWA/DME/TR-82/43, May 1982. Fracture Mechanics: Fifteen Symposium, ed. by R. J. Santud, ASTM STP 833, pp. 130-148, 1984.

M. Ramulu and A. S. Kobayashi, "Strain Energy Density Fracture Criterion in Elastodynamic Mixed Mode Crack Propagation," Technical Report No. UWA/DME/TR-82/44, September 1982. Engineering Fracture Mechanics, Vol. 18, pp. 1087-1098, 1983.

A. S. Kobayashi, "Numerical Analysis in Fracture Mechanics," Technical Report No. UWA/DME/TR-83/45, January 1983. Application of Fracture Mechanics to Materials and Structures, ed. by G. C. Sih, E. Sommer, and W. Dahl, Martinus Nijoff Publishers, pp. 27-56, 1984.

M. Ramulu, A. S. Kobayashi, B. S.-J. Kang and D. B. Barker, "Further Studies on Dynamic Crack Branching," Technical Report No. UWA/DME/TR-83/46, March 1983. Experimental Mechanics, Vol. 23, pp. 431-437, December 1983.

A. S. Kobayashi, "Hybrid Experimental-Numerical Stress Analysis," Technical Report No. UWA/DME/TR-83/47, April 1983. Experimental Mechanics, Vol. 23, pp. 338-347, September 1983.

A. S. Kobayashi, "Advanced Experimental Techniques in Crack Tip Mechanics," Technical Report No. UWA/DME/TR-83/48, June 1983. To be published in the Proceedings of the Tenth Canadian Fracture Conference CFC 10 Modeling Problems in Crack Tip Mechanics, August 1983.

M. Ramulu, D. B. Barker, and A. S. Kobayashi, "Analysis of Dynamic Mixed-Mode Crack Tip Stress Patterns," Technical Report No. UWA/DME/TR-84/49, May 1984. To be published in Experimental Mechanics.

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