ACOUSTIC EMISSION AND THE PORTEVIN-LE CHATELIER EFFECT

Progress Report

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Abstract

The Portevin-Le Chatelier effect is the phenomenon of discontinuous yielding that occurs during the tensile loading of many crystalline metals and alloys. It produces a step-like or serrated stress-strain curve. The acoustic emission from the solids during the strain increments are being monitored and correlated with strain-hardening behavior as a function of composition, grain size and temperature. It has been found that transitions in parabolic strain-hardening are accompanied by increases in acoustic emission. This suggests that microstructural changes do occur during such transitions. At elevated temperatures, the Portevin-Le Chatelier effect, in brass, coexists with a steady uniform creep deformation. The energy released as acoustic emission differs from that released at room-temperature tests. This is being studied as it relates to creep mechanisms and grain size.

Other developments related to the main research program include the implementation of a spark-discharge technique for simulating acoustic emission in a tensile specimen, so that calibrations can be performed. Also, a technique has been designed for analyzing the frequency content of the transient acoustic-emission signal.

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Summary

During this period, work has been performed in the following areas: AE during strain-hardening transitions, AE and the Portevin-LeChatelier Effect at elevated temperatures, calibration techniques, and, AE from weld defects.

I. AE during strain-hardening transitions - Distinct changes in AE have been observed at or very near parabolic-hardening transitions for aluminum, brass and copper. (Documents 5 and 7) These solids represent various purities, large differences in stacking-fault energies, grain size, annealing procedures and yield strengths. Yet all strain-harden according to the generalized parabolic hardening law and all exhibited similar variations in AE. The PLC effect, even when absent, such as for OFHC copper, often appears at the transitions in hardening and so does additional AE. Because of the AE at the transitions, underlying microstructural changes are now being hypothesized. Studies of the frequency spectrum of the AE are planned.

II. Elevated temperatures - At elevated temperatures, $1/2 - 2/3$ solidus temperature, the AE is unlike that occurring in the same material at room temperature.

At high temperatures, the stored energy, rather than being released all at once and in a uniform way, as it is at room temperature during the regular PLC strain increments, is released in small amounts continuously and in larger amounts irregularly. (Document No. 6) The AE occurring during the PLC yield increments at high temperature is being further studied, especially as it relates to creep mechanisms and grain size.

III. Calibration techniques - In order to pursue studies of the influence of grain size on AE, it became clear that an AE simulation and calibration procedure was necessary. Whenever a specimen with different grain size is to be tested, the monitoring system should be adjusted, so that the same sensitivity to a given simulated AE is achieved. Also during long testing periods, it is necessary to check the response of the system.

Commercially-available AE simulators were experimentally studied. One developmental model was found to be acceptable for plate-like structures. [That study was performed with the cooperation of the vendor and the results are to be presented, at the vendor's expense, at the Fall meeting of the Acoustic Emission Working Group; see document 9.] A considerable amount of time was then devoted to developing a similar spark discharge AE simulator for tensile tests. This resulted in a means of applying to the tensile specimen an acoustic signal having low amplitude, high frequencies, and fairly short duration. This signal is reproducible within 5%. This technique is now regularly used in all tensile tests.

IV. Acoustic-Emission Detection of Weld Defects - Under the direction of W. F. Hartman, a student project on "NDT using AE" was conducted with the facilities associated with this contract. The results were presented at the Fall meeting of ASNT (Document 8).

Compliance with Contract Requirements

(i) Research

The experiments on the PLC effect at elevated temperatures and the studies of AE during strain-hardening transitions have been in compliance with the proposed program of research. Other research has included an effort towards developing a reliable calibration procedure. This was not originally planned;

but it was determined to be a necessary preparation for the proposed grain-size studies, which have now commenced.

Several items of proposed investigation have been delayed. The measurement of Luder's-band speeds had been postponed until the late (November) delivery of special equipment. Material problems have delayed the single crystal studies. Proper quantitative studies of the spectral characteristics of the AE during PLC strain increments will require additional equipment.

(ii) Personnel

The principal investigator and Project Director, William F. Hartman, has devoted approximately 35% effort to the contract work. He will continue this amount of participation for the remainder of the current term.

Bibliographic Material - List of presentations and documents prepared under this contract are attached.

Lectures and Presentations by William F. Hartman
Acknowledging AEC Support under Contract AT(11-1) 2204
During the Period November 1, 1972 - November 1, 1973

- November 22, 1972, "Acoustic Emission As An Aid In Studying Strain Hardening," Materials Science Seminar, The Johns Hopkins University, Baltimore, Maryland.
- December 8, 1972, "Acoustic Emission During Discontinuous Yielding," 10th Meeting of the U.S. Acoustic Emission Working Group, Pasadena, California.
- March 14, 1973, "Acoustic Emission As An Aid In Studying Strain Hardening Phenomena," National Spring Conference of the American Society for Nondestructive Testing, Los Angeles, California.
- May 15, 1973, "Acoustic Emission and the Portevin-Le Chaterlier Effect," Third International Congress on Experimental Mechanics, Los Angeles, California.
- July 19, 1973, "Detecting Flaws in Welds by the Use of Acoustic Emission Techniques," 11th Meeting of the U.S. Acoustic Emission Working Group, Richland, Washington.
- August 15, 1973, "Acoustic Emission and Discontinuous Yielding," 13th Mid-western Mechanics Conference, University of Pittsburgh, Pennsylvania.
- September 19, 1973, "Acoustic Emission Research and Technology - An Overview," Chesapeake Bay Section of the American Society for Nondestructive Testing, Howard County, Maryland.
- October 18, 1973, "Acoustic-Emission Detection of Flaws in Butt-Welded Plates," National Fall Conference of the American Society for Nondestructive Testing, Chicago, Illinois.
- October 30, 1973, "An Overview of Acoustic Emission Research and Technology in the U.S.," Detroit Chapter of the Society for Experimental Stress Analysis, Lawrence Institute of Technology, Detroit, Michigan.

DOCUMENTS PREPARED UNDER CONTRACT AT(11-1)-2204

- C00-2204 - 1 Hartman, William F., "Acoustic Emission and the Portevin-Le Chatelier Effect," Progress Report, March 1 - November 1, 1972.
- C00-2204 - 2 Hartman, William F., "Acoustic Emission and Discontinuous Yielding," Developments in Mechanics, Vol. 7, Proceedings of 13th Midwestern Mechanics Conference, pp. 875-885, Pittsburgh, 1973.
- C00-2204 - 3 Hartman, William F., "Towards Correlating Acoustic Emission with Strain-Hardening Transitions," submitted for publication.
- C00-2204 - 4 Hartman, William F., "Acoustic Emission and the Portevin-Le Chatelier Effect," to appear in the Proceedings of Third International Congress on Experimental Mechanics, Los Angeles, May 1973.
- C00-2204 - 5 Hartman, William F., "Acoustic Emission as an Aid in Studying Strain-Hardening Phenomena," Materials Evaluation, Vol.31, No.11, 1973, pp. 237-240.
- C00-2204 - 6 Hartman, William F., "Acoustic Emission and the Portevin-Le Chatelier Effect," to appear in Experimental Mechanics.
- C00-2204 - 7 Hartman, William F., "Acoustic Emission During Strain-Hardening Transitions in Copper," submitted for publication.
- C00-2204 - 8 Hartman, William F., "Acoustic Emission Detection of Flaws in Butt-Welded Plates," Abstract of presentation at the National Fall Conference of the American Society for Nondestructive Testing, Chicago, 1973. (Manuscript in preparation)
- C00-2204 - 9 Hartman, William F., "Experiments with a Portable Acoustic-Emission Simulator and Calibration Device," Abstract of presentation at the 12th Meeting of the U.S. Acoustic Emission Working Group, New York, 1973. (Report in preparation)