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ACOUSTIC EMISSION AND THE PORTEVIN-LE CHATELIER EFFECT

Progress Report

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ABSTRACT

The discontinuous yielding during tensile loading of many crystalline solids results in a serrated or steplike stress-strain curve and is known as the Portevin-Le Chatelier effect. Replicable features of the discontinuous yielding of dead-weight loaded annealed specimens of several FCC materials have been documented and compared with the acoustic emission accompanying such deformations. It has been found that the energy of the acoustic emission during a yield increment correlates with the elastic energy stored since the last yield increment.

The materials tested represent different purities, grain sizes, stacking fault energies, annealing procedures and yield strengths. Yet, all exhibit several regions of parabolic strain-hardening. The probable coefficients for each of these regions are discretely related and when a hardening transition occurs it is usually accompanied by a distinct change in the acoustic emission. The research is continuing with the realization that acoustic-emission monitoring can become a unique aid in studying metallurgical phenomena of strain-hardening.

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Summary

The research summarized in this report was motivated by the observation that several features of the acoustic emission from deforming metals and alloys were very similar to features of the Portevin-Le Chatelier Effect in the same metals and alloys. It was thought that a basic investigation into the possible correlations of these two phenomena would provide both new information on the genesis of acoustic emission and a unique perspective for studying plastic deformation of structural materials. To this end, significant progress has been made.

Equipment which has been designed and constructed during this period includes a dead-weight tensile testing machine, special gripping devices which also serve as quiet enclosures for wide-band, heavily-damped, piezoelectric transducers, various optical and mechanical strain measuring devices, specially constructed furnace, and an acoustic-emission monitoring system, consisting of wide-band, high-gain, preamplifiers, electronic filters, event counters and a dual beam oscilloscope. Experiments have been conducted at both room temperature and elevated temperatures. The materials which have been tested are 100 aluminum, α -brass, yellow brass, commercial copper and OFHC copper, all highly annealed.

A strong correlation between acoustic emission and discontinuous yielding has been found. Our research indicates that certain features of the acoustic emission are closely related to the basic physics of

strain-hardening of crystalline solids. Major results thus far may be summarized by the following:

I. At room temperature, the acoustic emission appreciably diminishes when the Portevin-Le Chatelier effect ceases, i.e. when the stress-strain curve becomes smooth. This is true for aluminum and copper. Evidence of this is contained in (1), appended.

II. A major portion of the acoustic emission during a yield increment correlates with the elastic energy stored since the last strain increment. This will have important implications in identifying the principal strain-hardening mechanisms during discontinuous yielding (1).

III. All of the materials tested exhibit strain-hardening which can be described by a quantized set of parabolic deformation modes. As the deformation proceeds through a transition, strain, changes in the acoustic emission have been observed. In fact, the acoustic emission in the vicinity of a transition strain is often very dramatic and this fact is a significant illustration of the basic importance of the parabolic transition phenomenon. This observation is reported in (2), appended.

IV. We have observed the PL effect in brass at temperatures as high as two-thirds of the melting temperature in $^{\circ}\text{K}$. Since the piezoelectric effect vanishes at high temperature, these tests require the use of a wave guide allowing the transducer to monitor the emissions at a temperature which is lower than the specimen. At elevated temperatures steady creep usually occurs and it is necessary to separate this mode of deformation from the discontinuous yielding. The acoustic emission is unlike that which occurs in the same material at room temperature. At high

temperatures, many acoustic events occur between the major yield increments. Although an explanation for this behavior is not yet available, nevertheless it suggests that the thermal dependence of strain-hardening phenomenon can be viewed anew with the aid of acoustic-emission data from high-temperature deformations. Experimental investigations of this behavior are continuing.

V. Estimates of the speed of the slowly propagating discontinuous yielding have been obtained from photographed oscillographic displays of acoustic-emission signals. This technique is very tedious and inefficient and the data is rather sparse. An improved method has been planned. This will permit continuous location of the source(s) of the acoustic emission within the specimen and therefore, during a yield increment, the average propagation speed of the moving deformation band can be obtained with confidence.

Compliance with Contract Requirements

(i) Research Performed

Basically, the work undertaken thus far is in agreement with the original proposal. Several anticipated areas or methods of investigation have not yet materialized or have just recently begun. These include testing under conditions of continuously increasing dead-weight loads. Thus far, only incremental dead-weight loading has been used. Only preliminary results have been obtained from elevated temperature tests, and those tests are continuing. The method of measuring the speed of the propagating Lüder's band is also being modified.

(ii) Personnel Effort

The principal investigator and Project Director, Professor William F. Hartman, has devoted 25% of his time to the contract work since March 1, 1972. He will continue this amount of participation for the remainder of the current term.

The participation of Professor James F. Bell has been 6% of his time since April 1, 1972. He will continue this limited participation only until the current agreement terminates.

Bibliography

The following have been written on the work performed to date.

1. Hartman, William F., "Acoustic Emission and Discontinuous Yielding," submitted for presentation at the Thirteenth Midwestern Mechanics Conference and publication in the Proceedings, University of Pittsburgh, August, 1973, C00-2204-2.
2. Hartman, William F., "Towards Correlating Acoustic Emission with Strain-Hardening Transitions," submitted for publication in Scripta Metallurgica, C00-2204-3.
3. Hartman, William F., "Acoustic Emission and Portevin-Le-Chatelier Effect," Abstract of paper accepted for presentation at the Third International Congress on Experimental Mechanics, Los Angeles, May, 1973. (Manuscript in preparation). C00-2204-4.