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DESIGN OF STRESS CORROSION SPECIMEN FOR DETERMINATION OF
 K_{Isc} IN PRESSURIZED GASEOUS HYDROGEN EXPOSED TO IRRADIATION

MASTER

I. INTRODUCTION

Department 4830 has been requested to determine the feasibility of obtaining the threshold stress intensity factor (K_{Isc}) for Inconel 718, A-286 and SAE 9310 when subjected to the combined effects of 1500 psi gaseous hydrogen and nuclear environment. The reactor environment will include a fast neutron fluence of about 10^{20} and a specimen temperature in the range between 155 and 200°F.

The specimen development and calibration will be conducted in three phases where phase 1 will be to design and evaluate a test specimen for phases 2 and 3, phase 2 will be the initial specimen testing in the General Dynamic Reactor without gaseous hydrogen (GH_2) and will be performed to verify instrumentation concepts and confirm the specimen design through testing in the reactor environment, and phase 3 will be in reactor testing to determine the combined effects of 1500 psi GH_2 and the nuclear environment.

II. CURRENT STATUS SUMMARY

The preliminary program plan outlining objectives and procedures has been submitted. A time schedule showing important milestones and delivery dates is shown in Table 1. Presently the time period between Milestones 5 and 6 is unrealistic in that time should be allowed to analyze the data from the reactor

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tests before ordering instrumentation for the encapsulated specimens. Alternatively the present plan should be changed to reschedule the reactor tests from January 15, 1972 to December 1971 and order the long lead time instrumentation in December 1971.

A. SPECIMEN CONFIGURATION

1. Stress Corrosion Specimen

Sketches for modified WOL specimen, 1-1/2 and 2.0-in.-thick compact tension (CT) specimen, and encapsulated specimen design have been submitted. Minor dimensional changes to existing 1.0-in.-thick CT specimen were also made.

2. Encapsulated Specimen

Sketches for the encapsulated specimen design have been submitted to a possible vendor to determine their ability and tentative cost for providing the encapsulation device. Received one design for the encapsulation device; the tentative cost is \$200 per specimen. This encapsulation device requires specimen design modifications which have to be further evaluated with regard to heat transfer and compliance with fracture testing criteria.

B. INSTRUMENTATION

Fabrication of COD gages to be used for gaseous hydrogen tests has been initiated.

1. Stress Wave Analysis Technique (SWAT)

a. Sensors

Preliminary information concerning stress wave emission sensors that could be used in the reactor has been obtained. Comparison test data between a possible sensor (Endevco P15) for use in the reactor tests and the sensor (Endevco 2213E) presently being used for data collection by ASPC

has been obtained. Both sensors (P15 and 2213E) were connected to voltage amplifiers and the P15 results compared very favorably to the results obtained using the 2213E sensor. The major problem associated with the P15 type sensors is the low capacitance (on the order of 50 pf). However, one of the presently available P15 sensors (Model 6237 M-9) is 2-1/2 times as sensitive as the 2213E (Endevco measurements) sensor and would require only slight modification to increase the capacitance to 100 pf. The Endevco Model 6237 M-9 sensor at 100 pf with 15 feet of 20 pf/ft of cable is comparable in sensitivity to the system presently used by ASPC.

b. Cables

It has been decided that the triaxial cable will be a better choice than the biaxial cable due to less noise generated by the reactor environment. Endevco has a source for a triaxial cable with a capacitance of 20 pf per foot which would be acceptable. However, the delivery time is 6-8 weeks after receipt of order which may be a problem if not ordered by December 1, 1971.

2. Alternate Approaches to Detect Slow Crack Growth

a. Strain Gages

Strain gages can be placed in a position so as to monitor the occurrence of slow crack growth. However, under normal conditions the strain gage technique would be much less sensitive than acoustic emission.

b. Time

For the development studies, an applied stress intensity (K_{I1}) will be established for which the crack arrest time is a maximum of three or four days. For the reactor test, a portion of the specimens will be loaded to a higher K_{I1} value to insure crack arrest within the scheduled test period.

III. ACTIVITIES DURING THE REPORTING PERIOD

The schedules shown in Table 1 indicate the important program milestones and delivery dates. As can be seen in Table 1, the time between Milestones 5 and 6 is unrealistic since the decisions regarding instrumentation should not be made until after the reactor test. There are two alternatives; (1) reschedule the January 1972 test to December 1971, or (2) order all electrical components with deliveries scheduled for January 15, 1972. In order to provide for all contingencies, the latter alternative would require purchasing some components that may not be required for the March 1972 reactor test.

Phase I - Design and Evaluation of Test Specimen

The machine shop has initiated fabrication of two compact tension specimens and two modified WOL specimens for each material.

Sketches of the anticipated design for the encapsulated specimen have been submitted to a vendor to determine his capabilities and tentative cost for providing the encapsulation device. A design for a circular encapsulating device was received from Solar Division of International Harvester Co. and the tentative cost is \$200 per specimen. However, the circular encapsulation device will require specimen design changes. Depending on the manufacturing method employed, these changes will require an additional machining time of 1/2 to 2 hours per specimen. Solar was asked about building a flexible encapsulation device in a rectangular configuration and their reply was they could not, regardless of material thickness.

The following methods are being considered to bond the encapsulation device to the specimen:

- (1) Welding - electron beam welding appears to be the best approach because of the size of the weld and heat affected zone. The major drawback to welding will be the cost.
- (2) Brazing - this approach may cause problems in that heat treatment may be required after brazing. This is particularly true with the 9310 alloy where it is necessary to get adequate quench in the region of the notch which will be covered by the bellows at the time of heat treatment. Also, the effect of heat treatment on the plastic zone/precrack region (pre-cracking should be performed prior to bellows attachment) is not known.
- (3) Bonding Agent - Epoxy 6203 has been used in a radiation environment, but it is no good at fluence values exceeding 5×10^{17} .

Phase II - Initial Specimen Testing in General Dynamics,
Fort Worth, January 1972

This test series has been rescheduled for General Dynamics, Fort Worth, and will be conducted without gaseous hydrogen to verify instrumentation concepts and the specimen design through testing in a reactor environment.

Two tentative SWAT system designs (Figure 1), one incorporating voltage amplification and the other charge amplification, are being considered for testing in the reactor. The major disadvantages of the charge amplifier system is the high noise level which results in a low signal to noise ratio

and signal amplification (about 500X). The advantage of the charge system is that the initial cable length is unlimited.

The voltage amplifier system has the advantage of low noise which gives a high signal to noise ratio coupled with high amplification ($\sim 5000X$). The disadvantage to the voltage system is that the initial cable length is limited by the capacitance of the cable and transducer and the effect of radiation on capacitance of the cable. The cable limitation can be offset somewhat by using a preamplifier which, however, may require lead shielding.

Current tests being conducted at ASPC under an ARPA contract have shown that the rating of sensor sensitivity by pC/g or other "normal" methods used by instrumentation suppliers have no valid basis for acoustic emission. The ARPA program will be completed by the end of July and a better prerequisite for determination of sensor sensitivity for acoustic emission will be known by that time. In the meantime the sensors proposed for the reactor test are being compared with those used for the ARPA data collection.

As pointed out in the last monthly, the P-15 crystal compared very favorably with the 2213 sensors normally used by ASPC. However, the Model 2285E (P-15) sensor used in the reactor test had a capacitance of 50 pf/ft which meant the cable, which usually run 20-40 pf/ft would have a large effect on the system sensitivity, i.e., it would appreciably reduce the system sensitivity. Alternatively, Endevco, has a transducer, Model 6237M-9 (P-15) which, with slight modifications, would have a capacitance of 100 pf. With these modifications, it would be possible to use an existing sensor thereby considerably reducing the purchase price and delivery time and at the same time permit the use of longer cables.

Endevco also has a triaxial cable which has a capacitance of 20 pf/ft. If we would use a cable length of 15 feet to the first preamp., it would essentially produce a system sensitivity comparable to current ASPC system (2213 sensor). With 15 feet of cable between the sensor and preamp, the fluence at the preamp would be in the range of 10^6 to 10^7 R and by using 5 to 6 in. of lead shielding the fluence would be reduced to the range of 10^4 to 10^5 R. This fluence level will not affect hardened electronics but its effect on the existing preamplifier is not known. The balance of the system components (exception the sensors and preamplifiers) shown in Figure 1 will require only slight modification as they will see no adverse environment.

Alternate methods of detecting crack growth are as follows:

1. Mount strain gages in front of crack tip as shown in Figure 2. Strain gages were suggested as an alternative to accelerometers and are available for comparative tests to determine the ability of each technique to detect crack growth. Strain gages offer an advantage in that radiation has a negligible effect on the gages and subsequent electronics. However, two problems are anticipated in that the gage leads must come out of the encapsulation device, and the method used to bond gages to the test piece will be troublesome.
2. During the preliminary tests, an attempt will be made to find the applied stress intensity (K_{Ii}) for obtaining K_{Isc} in pressurized gaseous hydrogen in a maximum of three or four days. It would then be anticipated that for the reactor

test consisting of fourteen days slow crack growth would have terminated for the same K_{Ii} value. This is the least attractive method as in the absence of some crack growth monitoring device it would be impossible to prove that slow crack growth has actually terminated within the test period employed.

It is more likely that the same technique will be used in conjunction with acoustic emission or strain gages.

Phase III - Testing the Combined Effect of 1500 psi GH_2
and the Nuclear Environment

Progress in establishing an encapsulative device is discussed in Phase II.

IV. ANTICIPATED ACTIVITIES DURING THE NEXT REPORTING PERIOD

Test compact tension specimens and initiate testing of modified WOL specimens in accordance with the program plan previously submitted. Both acoustic emission and COD gage will be employed to determine the SWAT system sensitivity necessary to detect crack growth.

Because of the problems associated with a collapsable encapsulative device, a study will be initiated to determine the following for a more rigid encapsulation device.

- (1) how much load would be taken up by this device?
- (2) how the increased crack length would be affected by the device.
- (3) how much gas pressure would drop off with crack growth.

Gulton Industries has been contacted and requested to supply a sensor for comparison tests with the Endevco P-15 sensors. Answers regarding this request are expected the week of 12 July 1971.

Attempt to obtain irradiated sensors for comparison with the Gulton and Endevco sensors before and after irradiation. John Stadig has been requested to assist in obtaining the irradiated sensors.

Determine the preamplifier to be used in the reactor assuming a fluence of 10^4 to 10^7 .

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Milestones for K_{Isc} Determination of Encapsulated Specimens.

△ - Milestones

1. Decide on materials and amount of each to be purchased.
2. Based on tests conducted with acoustic emission, strain gages, and test time, preliminary crack detection instrumentation will be decided on for the January test.
3. As this also encompasses the specimen design, it will terminate Phase II.
4. Delivery requirement for January test.
5. Completion of Phase II.
6. Delivery requirement for March test.
7. Completion of program, final report due.

Figure 1. Anticipated Acoustic Emission System for Detection of Slow Crack Growth

1. Voltage Amplifier

2. Charge Amplifier

Figure 2. Schematic of Possible Strain Gage Location to be Used for Crack Growth Detection.

Crack has grown beyond strain gage A and gage B would be used to monitor crack growth.