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R. W. Derby, K. K. Klindt,
A. A. Abbatiello and J. G. Merkle
Oak Ridge National Laboratory
Oak Ridge, Tennessee

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HEAVY SECTION STEEL TECHNOLOGY PROGRAM

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CRACK SHARPENING BY LOCAL FATIGUE

R. W. Derby
Oak Ridge National Laboratory

Introduction

Where it is desirable to put a sharp crack into a body which is too big to put into an electron beam welding device or to subject to cyclic loading the method of local fatigue is highly suitable. The technique, first described by Clark and Ceschini (Experimental Mechanics, March 1969), depends on the cyclic application of high pressure to a sealed notch. L. F. Kooistra originally suggested that we look into this method as a means for sharpening the flaws in the 6-in. wall thickness vessels which are to be tested during FY 72. It soon became obvious that one of the best ways to check out both the concept and our ability to apply it was by actually sharpening the flaws in the 6-in.-thick tensile specimens being tested at Southwest Research Institute. The balance of this report describes some of the equipment we used and the troubles we ran into.

Clamping and Sealing

The basic set up is shown in Fig. 1. In order to hold the seal plate over the notch required a large clamping force. This problem was overcome by using six 1-1/2-in.-diam studs which were torqued up with an impact wrench.

An elastomer O-ring was used as a seal. Several difficulties worth mentioning were alignment and fretting. During assembly it was difficult to keep the O-ring from sliding around while the impact wrench was being operated. Fortunately it was possible to design several guide plates which would hold the O-ring and seal plate centered at all times.

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It proved impossible to take any short cuts on surface finish. Any gap at the interface of the plate and the specimen or any excessive roughness would cause a rapid fretting away of the O-ring such that one seal might only last several hundred cycles instead of the desired 25,000. Once everything had been polished and carefully assembled one O-ring would easily last through one complete sharpening operation.

Pumping and Controls

In Fig. 2 one sees the first and simplest arrangement for providing the cyclic pressure. A high pressure pump is shown with check valves removed. When the piston goes up the pressure goes up and when the piston goes down the pressure goes down again. The amount that the pressure goes up is determined by the volume of the system. By picking a volume to match the compressibility of the fluid and the stroke of the pump it was possible to get from 0 to 17,000 psi on a single stroke. Unfortunately, with our small pump it was impossible to meet this ideal condition except with a test block in which the volume of the flow was very small. Hence the arrangement shown in Fig. 3. Here the pump is used in a normal manner. After a few strokes the pressure reaches the desired value. An air operated valve is then activated by a solenoid and the pressure is dumped. One minor point worth mentioning is that the relief valve must be held open long enough for the pressure to drop. To do this a time delay relay was put in the system.

Using the pump-and-dump method we were able to put about 500 cycles per hour from 0 to 18,000 psi on two large tensile specimens simultaneously. Since only 25,000 cycles were more than enough we were able to sharpen two specimens in less than 48 hours.

Monitoring Crack Growth

Two methods of monitoring crack growth were used. At first, we depended exclusively on ultrasonics where both the through transmission and reflection techniques were employed. See Fig. 4 for a schematic. The tightness of the fatigue crack made it difficult to tell exactly how much extension had occurred, particularly in the early tests. In

fact, the most reliable and convenient signal came when the notch was under full pressure and the crack open to its fullest. Although good agreement was obtained between predicted and measured extension for the last few specimens, we believe that there is a real need for research on the detection of tight flaws.

Another difficulty was keeping good contact between the probe and the specimen. See Fig. 5 for one version of probe holder. In the end a bottle of oil was mounted so that it supplied a slow, but steady drip to the face of the specimen.

An alternative to ultrasonics we tried to correlate the change in compliance of the specimen with crack growth. See Fig. 6. The method depended on measuring the cyclic movement of the ends of the specimen with a dial gage. As the crack grew there would be more motion. The success of this procedure is shown in Fig. 7 which is a summary of the predictions and post-test measurements for all six big specimens and a test block.

Summary

A reliable and convenient method for sharpening flaws in large specimens has been described. Some of the problems involved with sealing, pumping, and monitoring have been described in the hope that others who travel the same route will be spared the expense and annoyance of learning everything the hard way.

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Fig. 1. Schematic of Clamping and Sealing System.

FIGURE 2 Crack Starting Using Variable Volume for Pressure Control.

FIGURE 3 Crack Sharpening Using Controlled Pressure.

CRACK GROWTH CHANGES SIGNAL VALUE

A SIMILAR NET EFFECT ON THE SIGNAL CAN BE
PRODUCED BY MOVING THE PROBES UP OR DOWN
IN UNISON FOR

(a) INITIAL CALIBRATION

(b) TO FOLLOW CRACK GROWTH PROGRESS

Ultrasonic Signal Transmission Through HSST Tensile Specimen.

FIGURE 4

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FIGURE 5 Ultrasonic Probe Mount.

TYPICAL EXAMPLE

A DEFLECTION OF 0.0025 in. AT START OF CYCLING
WHICH GROWS TO 0.0035 in. INDICATES $\frac{3}{8}$ in. OF
CRACK GROWTH

Crack Growth vs Number of Cycles for Large HSST Tensile Specimen.

FIGURE 6

ITEM	PREDICTED DEPTH		ACTUAL DEPTH AFTER FRACTURE
	USING ULTRASONIC	USING DIAL INDICATOR	
	inches	inches	inches
TEST BLOCK	$\frac{3}{8}$	NOT USED	0.2
DB-5	$\frac{3}{16} \pm \frac{1}{16}$	TEST RUN	$\frac{1}{2}$
DB-6	$0.2 \pm \frac{1}{16}$	TEST RUN	$\frac{3}{8}$
DB-7	NOT AVAILABLE	$\frac{3}{8}$ (ON TARGET)	0.4
DB-8	$\frac{3}{8} \pm \frac{1}{16}$	$\frac{3}{8}$ (ON TARGET)	$\frac{3}{8}$
DB-9	$\frac{7}{16} \pm \frac{1}{16}$	10% OVER TARGET	$\frac{1}{2}$
DB-10	NOT AVAILABLE	5% UNDER TARGET	0.4

LARGE HSST SPECIMEN CRACK DEPTH
(TRYING FOR $\frac{3}{8}$ CRACK GROWTH)

FIGURE 7