Technical Note: Application of SWAT to the Nondestructive Inspection of Welds

BY C. E. HARTBOWER

SWAT is an acronym for Stress Wave Analysis Technique. Stress waves are produced by the release of elastic energy resulting from the growth of a crack in a stress field. Thus, SWAT constitutes a unique nondestructive inspection method in that the material defect, when propagating, transmits its own signal, with the sensor acting as the receiver. In other words, the material undergoing crack growth both generates and transmits the signal. The SWAT system, consisting of sensors, amplifiers and filters (to eliminate extraneous low-frequency noise) serves as the receiver; system sensitivity can be preset to trigger on a selected signal amplitude, and the operational and reliability status of the system can be checked by periodically inserting a calibration signal. The utility of SWAT as a new, highly sensitive method for monitoring crack growth has been demonstrated in several researches. 1-7

The objective of the experiment described here was to demonstrate the feasibility of SWAT as a method for obtaining data on delayed weld cracking. In the fabrication of HY-80 submarine hulls, a minimum period of seven days is allowed before nondestructive inspection to be certain that any delayed cracking that might occur will have been completed. Obviously, if a quantitative measurement can be made of the time involved in the delayed cracking process, it may be possible to shorten the minimum time between completing a weld and nondestructive inspection and, thereby, save submarine production time.

The Test Weldment

HY-80 steel (MIL-S-16216-G) in the form of 2-in.-wide by 10 in. long by 0.70 in. thick bars were welded to form a test plate 8 in. wide by 10 in. long. Thus, there were three longitudinal welds 10 in. long joining four 2 in. wide bars. The joint design was simply a square butt; incomplete penetration was deliberate to assure cracking. The welding was done by the tungsten-arc process using a 600 amp, automatic welding unit and Linde-83, 1/16 in. diameter filler metal conforming to AWS-ASTM classification E-708-G.

The welding sequence is shown in Fig. 1; note that two weldments 4 in. wide by 10 in. long were prepared first and then joined to make the 8 in. wide x 10 in. long test weldment. Passes 1-4 and 9-10 were fusion passes (without filler metal); passes 5-13 involved filler metal automatically fed into the arc at 20 kw. The arc travel speed was 6 ipm at 350 amp and 10 v. The interpass temperature was not controlled; however, the time between passes was recorded, indicating the interpass temperature to be between 300 and 500° F. Contact-pyrometer readings taken after the final pass showed the weldment to be about 225° F at the time the SWAT system was activated.

The SWAT System

The weldment was placed in a sound-insulated chamber at 4:30

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P.M.; the SWAT system was activated at 4:41 P.M. Figure 2 is a schematic of the system. With 100X amplification followed by a 30 kc high-pass filter and then 1000X amplification, a 38 kc input signal (approximately resonance frequency of mounted accelerometer) is amplified 5000X.

In the counter system, two levels of stress-wave amplitude were recorded. The counter stripchart printout recorded cumulative count and count rate (number/minute). By a voltage setting, the count-rate printout was adjusted to read signals just above the background noise level. The cumulative count was set to record the larger stress waves, approximately 5X those of the count-rate printout.

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Table 1—Delayed Cracking in Welded HY-80 Steel

<table>
<thead>
<tr>
<th>Date</th>
<th>Time of Signal</th>
<th>Clock time</th>
<th>Stress-wave emission</th>
<th>Count per minute</th>
<th>Cumulative count per minute</th>
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<tbody>
<tr>
<td>3 Apr '69</td>
<td>02:25 PM</td>
<td>03:40</td>
<td>(Started welding)</td>
<td>04:40</td>
<td>(Welding completed)</td>
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<tr>
<td>49</td>
<td>0</td>
<td>50</td>
<td></td>
<td>5</td>
<td></td>
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<td>51</td>
<td>2</td>
<td>53</td>
<td>437</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>6</td>
<td>54</td>
<td>1</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>05/04</td>
<td>16</td>
<td>05/06</td>
<td>925</td>
<td>52</td>
<td></td>
</tr>
<tr>
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<td>07:19</td>
<td>7082</td>
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</table>

* Counter triggered at 1.0 volt.
* Triggered at 0.25 volt.

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The influence of electrode shape on the cathode emission surface, the arc and the anode surface is so significant that those experiments which have failed to specify electrode shape, the length to holder, the cold and hot resistance, or the time of data taking, can only report varieties of trends. In some experiments the failure to recognize resistive heating of the cathode has confounded conclusions. Yet it may be of advantage to the serious scientist to exploit the difference in electrode shapes to isolate the behavior of those sub-systems that ate of so much interest to physicists and welding researchers, or to exploit the difference in results given from a cold electrode or a hot electrode, or the resistance rise-rate of various electrode systems.

The resistive components which react negatively to current increase, give a function which drops to a level at 200 amp and is nearly constant through higher currents. The difference in levels for different electrodes and the subtle tendencies with increasing current may contain clues that expose more laws governing cathode emission or the arc.

The resistive components which rise with current give a function $r$, which rises at a constant rate with current. The finer electrodes start and remain higher than the blunter. Each of these functions may be further analyzed and tested for their representation of real sites of physical events and for their own several components that tell separate stories.

References


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Test Results

Table 1 lists the stress waves that were recorded over a period of approximately 87 hr of continuous monitoring. Note that count rate (highest sensitivity setting) recorded the first burst of stress waves 9 minutes after activating the counter system. Note also that the greatest stress-wave activity occurred in the first seven hours (cumulative count of 70778). In the next 24-hour period, the cumulative count increased by only 29, and in the following 24-hour period, the cumulative count increased by only 1. There were no stress waves recorded in the 3rd 24-hr period. Thus, for all practical purposes, the cracking occurred in the first 24 hr after welding was completed.

Discussion of Results

The weldment for this test was designed to crack. The square but joint involved incomplete penetration, and the initial fusion passes were small and cracked before the filler passes were deposited. Thus, the cracking that occurred during welding may have resulted in some degree of stress relief and thereby shortened the period of delayed cracking. Therefore, a quantitative measurement of the duration of delayed cracking will require monitoring restrained joints that are representative of shipyard practice and free of hot cracking.

References


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