STEAM GENERATOR TUBE INSPECTION WITH EMAT'S

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ABSTRACT

A brief summary of newly developed techniques for ultrasonic inspection of small diameter tubes using EMAT's is given. The technique employs a periodic-permanent magnetic torsion wave transducer which fits inside and can be quickly translated through the tube. Both dominant and higher order ultrasonic modes traveling longitudinally along the tube can be individually excited by varying the transducer design parameters. Experimental results are presented which define transduction efficiencies in aluminum, Inconel, and steel and the sensitivities of the various wave types to different defects. The ability of these techniques to detect flaws in difficult regions such as U-bends and dents is reported.

This poster presents the results of a recently completed study that demonstrated the feasibility of inspecting steam generator tubes in a pressurized water reactor for commercial electrical power generation. The purpose was to show that compact EMAT's can be constructed which operate efficiently from within the 7/8 in. OD, 0.050 in. wall Inconel tubes and hence make possible ultrasonic inspection at comparable rates to those exhibited by the presently used eddy current systems.

Figure 1 presents a more detailed statement of the objective, problem, and proposed solution.

Figure 2 contains a schematic sketch of the periodic permanent magnet EMAT developed to generate torsional modes of the tube. Also shown is a photograph of some of the probes and a schematic of a pitch-catch configuration used in the study.

Figure 3 presents the elastic wave dispersion curves for a flat plate of the same thickness as the tube wall and indicates the operating points of the transducers.

Figure 4 shows the ultrasonic signals from a variety of machined defects in aluminum tubes as pictured. Note that the end reflections which clutter the A-scans would be absent in the 70 meter long steam generator tubes.

Figure 5 shows that defects can be detected in regions where the tubes have been dented, a problem that occurs in steam generators as a result of corrosion products building up where tubes pass through support plates.

Figure 6 is a tabulation of the measured reflection coefficients for a wide variety of defects for both the \( n = 0 \) and \( n = 1 \) tube modes.

Figure 7 presents the conclusions of this work.

Acknowledgement

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OBJECTIVE:
ACCURATE DEFECT CHARACTERIZATION IN INCONEL OR FERRITIC STEAM GENERATOR TUBING IN ORDER TO PROVIDE A BASIS FOR PLUGGING UNSERVICEABLE TUBES.

PROBLEMS:
1. LARGE NUMBER OF TUBES
2. RADIATION CONTAMINATION
3. LIMITED ACCESS
4. FAST PULLING RATES REQUIRE LOW-DRAG-NON-CONTACT PROBES
5. REGIONS WHERE ESTABLISHED EDDY CURRENT INSPECTION TECHNIQUES ARE NOT RELIABLE.

SOLUTION:
NEW NON-CONTACT ULTRASONIC TORSION WAVE TRANSUCER TO COMPLEMENT ESTABLISHED EDDY CURRENT INSPECTION TECHNIQUES.

Figure 1. Statement of objective, problems, and solution.

Figure 2. Torsional wave.
Figure 3. Dispersion curves for a 0.05 in. (0.127 cm) thick inconel plate.

Figure 4. Defect detection in aluminum tubing.
Figure 5. Detection of defects in dented tubes.

**Reflection Coefficients for Machined Defects**

<table>
<thead>
<tr>
<th>Defect Description</th>
<th>n=0</th>
<th>n=1</th>
<th>dB n=0</th>
<th>dB n=1</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Aluminum Tubes 7/8&quot; O.D. .049&quot; Wall</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) .188&quot; Diam .010&quot; Deep Flat Bottom Hole</td>
<td>.02</td>
<td>.107</td>
<td>-34</td>
<td>-19</td>
</tr>
<tr>
<td>2) .109&quot; Diam .03&quot; Deep Flat Bottom Hole</td>
<td>.016</td>
<td>.093</td>
<td>-36</td>
<td>-21</td>
</tr>
<tr>
<td>3) .067&quot; Diam Through Hole</td>
<td>.15</td>
<td>.087</td>
<td>-17</td>
<td>-21</td>
</tr>
<tr>
<td>4) .25&quot; Wide .005&quot; Deep Circumferential Slot</td>
<td>.05</td>
<td>.62</td>
<td>-26</td>
<td>-4</td>
</tr>
<tr>
<td>5) .005&quot; Wide .005&quot; Deep Circumferential Slot</td>
<td>.019</td>
<td>.017</td>
<td>-35</td>
<td>-23</td>
</tr>
<tr>
<td>6) .25&quot; Wide .005&quot; Deep 2&quot; Long Axial Slot</td>
<td>.008</td>
<td>.1</td>
<td>-42</td>
<td>-20</td>
</tr>
<tr>
<td>7) .011&quot; Wide .005&quot; Deep 2&quot; Long Axial Slot</td>
<td>.01</td>
<td>.03</td>
<td>-40</td>
<td>-30.5</td>
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<tr>
<td>B. Steel (4130) Tubes 7/8&quot; O.D. .049&quot; Wall</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>8) .067&quot; Diam Through Hole</td>
<td>.24</td>
<td>.138</td>
<td>-12.4</td>
<td>-17</td>
</tr>
<tr>
<td>C. Inconel Tubes 7/8&quot; O.D. .049&quot; Wall</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>9) .067&quot; Diam Through Hole</td>
<td>.35</td>
<td>.073</td>
<td>-9</td>
<td>-23</td>
</tr>
<tr>
<td>10) .3&quot; Long .03&quot; Wide .02&quot; Deep Transverse V-Groove</td>
<td></td>
<td></td>
<td>-</td>
<td>-21</td>
</tr>
</tbody>
</table>

Figure 6. Summary of measured defect signals.
1. NEW TYPE OF NON-CONTACT ELECTROMAGNETIC TRANSUDER HAS BEEN DEVELOPED FOR INSPECTION OF TUBES FROM INTERIOR OR EXTERIOR.

2. TRANSDUCERS MAKE TUBE INSPECTION FEASIBLE IN GEOMETRICALY DIFFICULT REGIONS,
   a. DENTS AT TUBE SUPPORTS
   b. U-BENDS

3. TRANSDUCERS ALLOW NEW INFORMATION TO BE OBTAINED THAT IS COMPLEMENTARY TO EDDY CURRENT DATA.
   a. CIRCUMFERENTIAL DEFECTS
   b. THINNING AND WALL THICKNESS MEASUREMENT POSSIBLE WITH HIGHER ORDER MODE

4. PROBES WORK WELL IN FERRITIC TUBES.

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Figure 7. Conclusions.