The Application of PEC Thermography to Multiple Surface Defects Detection of Metal Material

Jing Xie
Tel: +86 532 86983071; e-mail: xiejing@upc.edu.cn

Changhang Xu, Naiwang Zhou, Weiping Huang, Guoming Chen

China University of Petroleum (East China)
Qingdao, China
I. Introduction

*Pulsed eddy current (PEC) thermography* uses *induced eddy current* to heat the object being detected.

Defect area has *abnormal temperature* which results from:
- *heating period*: cause uneven distribution of eddy current
- *cooling period*: obstruct heat diffusion

be captured by an infrared thermal camera
Nowadays, research focuses on the detection of defects with **single type** on metal. (crack detection mainly)

We investigated the detection of various defects (through-hole, blind hole, cracks, groove).

**Two specimens:**
- different materials (ferromagnetic and non-ferromagnetic)
- various defects

To investigate the influence of:
- excitation time
- coil location

on the detection results
II. Experimental Set-up

Controlled by induction unit, Generate eddy current on specimen

Get infrared thermal video which records the surface temperature of the specimen
The Application of PEC Thermography

- Cooling unit
- Wires & Pipes
- Specimen and coil
- Infrared camera
- Induction unit
- PC
<table>
<thead>
<tr>
<th>Specimen</th>
<th>Material</th>
<th>Shape</th>
<th>Size (mm)</th>
<th>Defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td><strong>C45E4 Steel</strong> (ferromagnetic)</td>
<td>Plate</td>
<td>$111 \times 40 \times 8$</td>
<td>A1: crack&lt;br&gt;A2, A3: groove</td>
</tr>
<tr>
<td>B</td>
<td><strong>Brass</strong> (non-ferromagnetic)</td>
<td>Thin walled pipe</td>
<td>$550 \times 25 \times 23_1$ (thickness)</td>
<td>B1: circular groove&lt;br&gt;B2, B3, B4, B5: blind holes&lt;br&gt;B6: through-hole</td>
</tr>
</tbody>
</table>
III. Results and discussion

Excitation time
Coil Location

A. Excitation time
Experiments were conducted by fixing all other detection parameters (excitation frequency, coil location, current strength...)

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Excitation time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.1, 0.2, 0.3, 0.5, 1, 3</td>
</tr>
<tr>
<td>B</td>
<td>0.3, 0.7, 1, 3, 7, 10, 12, 15, 20</td>
</tr>
</tbody>
</table>
We obtained fifteen thermal videos of these two specimens. To evaluate excitation time settings, a measure is needed.

**Steps:**

a. To find the optimum frame for video corresponding to each excitation time

b. To evaluate the quality of the selected frame using a quantitative measure
a. Find the optimum frame for video

A high quality frame should have high contrast between defects and sound areas usually occurs at the end of the temperature-rising period.

The frame with highest average temperature of defects
The temperature variation of defects on specimen A with excitation time of 0.3 s.

The frame captured at 0.16s is selected as the optimum one for A when excitation time is 0.3s.

We got fifteen frames corresponding to excitation time settings.
The optimum frames of thermal video for specimen A
The optimum frames of thermal video for specimen B
b. To evaluate the quality of the chosen frame using a quantitative measure

A frame with higher contrast between defect and sound area → easy to recognize defect → brings more effective detection result

The quantitative measure: Mean contrast between defects and sound area averaging over all defects in the chosen frame (marked as $C_{BF}$)
The optimum frame

Gray-level image

Compute the difference of gray value between each defect and sound area

Average over all defects

Quantitative measure
$C_{BF}$ for each excitation time setting
B. Location of the inducting coil

Coil location was investigated for two types of defects: directional defects and non-directional ones.

Directional defect: A1; B1
Non-directional defects: A2, A3; B2~B6
For the ferromagnetic specimen, when the central axis of coils is **perpendicular** to the directional defect:

- **directional one:** \( \times \)
- **non-directional one:** \( \checkmark \)

**parallel** to the directional defect:

- **directional one:** \( \checkmark \)
- **non-directional one:** \( \checkmark \)

For ferromagnetic metal, the location of coils has **a great influence** on the detection result.
For the non-ferromagnetic metal, the central axis of coils is \textit{perpendicular} to the directional defect.

- directional one: $\sqrt{}$
- non-directional one: $\sqrt{}$

For the non-ferromagnetic metal, the location of coils has \textit{no apparent influence} on the detection result.
IV. Conclusion

A series of experiments were conducted on a ferromagnetic specimen and a non-ferromagnetic one with various defects.

- A quantitative measure to evaluate the exciting time setting is proposed. Other than excitation time, this measure can be used to evaluate other detection parameter setting.

- Considering directional defects and non-directional ones, we analyzed the influence of coil location on the detection results.

These will be valuable to widen and normalize the pulse eddy thermography detection for metal part with multiple defects.
Thank you for your attention!