Application of the Kernel Change Detection in Eddy Current Testing

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Summary

The Kernel Change Detection (KCD) algorithm is adapted to detect damaged zones in an electric conductive tube using probe impedance signal. The purpose is to reduce the number of measurement data, that will be processed for estimating flaw characteristics using Particle Swarm Optimization (PSO) algorithm.

INTRODUCTION

Two main problems should be treated, for defect localization and characterization in ECT: the Forward problem and the Inverse problem.

- Inputs: Electromagnetic proprieties (conductivity \(\sigma\), permeability \(\mu\)) of the materials and geometrical parameters (Position \(P\), Depth \(D\), Length \(L\)) of the defect.
- Output: the computed probe impedance \(Z\) (FEM Simulation).
- Properties: well-posed, unique solution and computationally heavy.

<table>
<thead>
<tr>
<th>Defect</th>
<th>Parameters</th>
<th>Depth (mm)</th>
<th>Estimated Depth (mm)</th>
<th>Length (mm)</th>
<th>Estimated Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defect (1)</td>
<td>10 x 10</td>
<td>0.58</td>
<td>0.84</td>
<td>5</td>
<td>7.08</td>
</tr>
<tr>
<td>Defect (2)</td>
<td>25 x 25</td>
<td>0.84</td>
<td>0.846</td>
<td>3</td>
<td>2.99</td>
</tr>
</tbody>
</table>

ECT INVERSION METHODOLOGY

- Data
- Localization (KCD)
- Modeling (FEM)
- Update parameters (PSO)
- Characterization

**THE KCD ALGORITHM**

- Use the classification to compute a detection index \(I(t)\).
- \( \begin{cases} 0 < I(t) ≤ \eta & \text{no change is detected at } t \text{ (Fig.3)} \\ I(t) > \eta & \text{a change is detected at } t \text{ (Fig.3)} \end{cases} \)

**THE INVERSE PROBLEM**

- Inputs: the measured probe impedance \(Z_i\) \((i = 1, ..., n)\).
- Outputs: the estimated electromagnetic properties \((\sigma, \mu)\) of the material and/or the geometrical parameters of the defect \((P, D, L)\).

METHATHMATICAL FORMULATION

- The cost function \(F(\theta)\) is described as the mean square error:

\[
F(\theta) = \frac{1}{2} \sum_{i=1}^{n} (Z_i - Z(\theta))^2
\]

with \(Z(\theta) = \sum_{k=1}^{m} a_k \theta_k\).

- Evaluate \(F_k(\theta)\) according to a detection criterion computed by using KCD

\[
F_k(\theta) = \sum_{i=1}^{n} \left( \frac{1}{2} |Z_i - Z(\theta_k)| \right)^2
\]

- \(I_k\): detection indexes related to the beginnings and the ends of defects.

\[
\bar{\theta}_k = \arg\min_k F_k(\theta_k)
\]

INVERSE PROBLEM SOLUTION

1. Choose the horizon \(h\) by maximizing the sparsity

\[
S(h) = \arg\min_h \left( \frac{\sum_{i=1}^{n} |a_i(h)|}{\sum_{i=1}^{n} |a_i(h)|} \right)
\]

2. Use the PSO algorithm to minimize iteratively the objective function (Eq.5)

CONCLUSIONS

- An adaptation of the KCD algorithm, for defect localization has been proposed.
- The use of KCD and PSO for defect detection and characterization is eddy current non destructive testing (EC-NDT) shows a very good performances in terms of computational cost and estimation accuracy.