Simulation on Far Field Eddy Current Detection on Condenser Tube Groups in Fossil Power Plants (I)

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Keywords: Far field eddy current, Computer simulation, Condenser tubes, Defects detection.

Abstract. Condenser tube tubes are widely applied in condenser in thermal power plants. Leakage often occurs in condenser tube groups due to the quality of condenser media or high serving stress. Condenser tube leakage not only brings economic losses to power stations, but even influences the safety operation of the power generation units. This paper simulates and experimentally studies the ferromagnetic heat exchanger tubes based on the detection mechanism of far field eddy current. The results show that the position of the far field is with the increase of the wall thickness and the inner diameter of the tubes, and the detection sensitivity of the far field is high for the same size defect, but the difference of the magnetic flux intensity varies equally when the defects with the same size are located at the inner and outer walls. This is consistent with the experimental results of real tube defect detection and meets the principle of far field eddy current detection. It is concluded that far field eddy current testing technology can better determine and identify ferromagnetic tube defects, and has a good application prospect for online nondestructive testing and safety performance evaluation of service tubes.

Introduction

Heating exchanging tubes are widely applied in thermal power plants [1,2]. Leakage often occurs in heat exchanging tubes due to the quality of exchanging media or high serving stress [3]. Exchange tube leakage not only brings economic losses to power stations, but even influences the safety operation of the power generation units.

It is important to detect the defects of the exchanging tubes before installation or during maintenance. The materials of the condenser tubes include ferromagnetic material and non ferromagnetic material. The defects type includes the following: corrosion, cracks, scratches etc. Figure 1 shows the condenser tube cracking.

To the Ferro-magnetic materials, the examination methods include the following: Magnetic particle examination, leaking magnetic examination and eddy current examination, ultrasonic examination etc. The efficiency of the magnetic particle examination is low and the examination results depend on the surface condition and artificial influences. Leaking magnetic examination is applied in ferromagnetic materials. Only surface and near surface defects can be detected. It is invalid to inner corrosion. Also the magnifying facilities must be adopted. Eddy current examination is faster with higher efficiency. Eddy current examination is based on electric-magnetic induction law. The defects are evaluated by the signals variations.
Traditional eddy current examination technique exams the surface and near surface defects of the sample tubes. The detecting accuracy depends on the lifting effect [4]. Far fields eddy current technique overcomes the above shortcoming [6]. It shows high examination efficiency and speed. It also covers 100% of the tube to be tested and is sensitive to the inner corrosion. It has been regarded as the most potential examination technique.

Basic Principles of Far Field Eddy Current

Inner through probe has been adopted in far field eddy current examination. It is composed of two spiral coils with the identical axle with the tube axle. One coil is for exciting with low frequency AC current and the other is examination coil, which is located in the position of 2-3 times of the inner diameter of the coil. Defects could be judged by measuring the different of the voltage of induction coil and the exciting current [6].

There 2 paths for the propagation of the eddy current in ferromagnetic tubes.

Path 1: Direct coupling in the inner side of the tube. Low frequency eddy current meets the equation of eddy current skin effect. The skin depth is shown in equation 1: When the propagation distance is greater than the skin depth.

\[
d = \frac{\sqrt{2/\mu\sigma \omega}}{\mu: \text{magnetoconductivity}}
\]
\[
\sigma: \text{conductivity}
\]
\[
\omega: \text{angle frequency}
\]

The energy attenuation is 36.8% of the original and the energy will decrease 36.8% when the eddy current propagates one skin effect depth.

Path 2: Indirect coupling from the outside of the tube. Low frequency eddy current penetrates near the exciting coil and propagate along the outside surface of the tube then re-enters the tube. Path 2 is called far field eddy current. Far field eddy current is sensitive to corrosion and cracks.
Numerical Simulation of Far Field Eddy Current

Figure 2. Model of far filed eddy current.

Table 1. Simulation parameters.

<table>
<thead>
<tr>
<th>Title</th>
<th>Outer Diameter (mm)</th>
<th>Inner Diameter (mm)</th>
<th>Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube</td>
<td>1611.4</td>
<td>12</td>
<td>400</td>
</tr>
<tr>
<td>Coil</td>
<td>5.4</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

Table 2. Grid types and size.

<table>
<thead>
<tr>
<th>Title</th>
<th>Grid type</th>
<th>Size(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube wall</td>
<td>mapping</td>
<td>0.1</td>
</tr>
<tr>
<td>Coil</td>
<td>mapping</td>
<td>5.40.1</td>
</tr>
<tr>
<td>Air area</td>
<td>Free triangle</td>
<td>regular</td>
</tr>
</tbody>
</table>

Simulation on the Relationship of Signal Amplitude Variation under Different Defect Position

Figure 2 shows the model of far field eddy current. Table 1 shows the simulation parameters and table 2 shows the grid types and size. The total numbers of the grid are 293815. According to the simulation, it can be concluded that at the point of 57.5mm to the exciting coil, the eddy current signal comes into far field area [7]. The simulation is to determine the optimized distance between the exciting coil and the examination coil. The simulation composes of tube with defects, coil. The artificial defect is a circle groove with 1 mm width and 1 mm depth. Figure 3 shows the simulation result. The magnetic induction intensity difference varies with the position of the exciting coil. When the distance between the exciting coil and the defect is larger than 60mm, the difference of magnetic induction intensity is larger than the difference when distance between the exciting coil and the defect is smaller than 60mm. This means that the detecting sensitivity increases. So it could be concluded that for the same size defect, the difference of magnetic induction intensity is larger when it is in far field compared with it in near field.

Also from the simulation, it could be obtained that the reasonable position for the in tube receiving coil is 5 times of the inner diameter, which is larger than the theoretical position, which is about 2-3 times of the inner diameter of the tube.
Simulation on the Influence on Sensitivity of the Defect Position

Figure 3 shows the model of far field eddy current for outer and inner defect. The artificial defect is a circle groove with 1 mm width and 1 mm depth on the outer side surface and in the inner surface. The simulation results show that the difference of magnetic flux intensity caused by inner defect is $2.927 \times 10^{-9} \text{T}$, the difference of magnetic flux intensity caused by outer defect is $4.043 \times 10^{-9} \text{T}$. This means it has the same sensitivity.

From the simulation, it could be obtained that the difference of magnetic induction intensity caused by the same size defects between the inner and outer of the tube is not apparent. The detection sensitivity of the far field eddy current probe is in the same level. The simulation shows that far field eddy current could quantify the defect at the inner wall and the outer wall of the tube. Normalization, usually adopted in traditional eddy current testing, is not necessary in far field current examination.
Conclusion

Two dimensional axial symmetry model has been established. The far field zone position has been determined according to amplitude and phase changing. It has been found that the examination sensitivity in the far field zone is higher than in the near field zone for the defect with the same size. The height of the defect is 1mm and the depth of the defect is 1mm. The distance between the defect and the exciting coil is 20-100mm (the step is 10mm). For the defects in the inner and outer wall, it has been confirmed that the same size defect in the inner and outer wall of the sample tube, the magnetic induction intensity difference is almost the same.

Acknowledgement

This research was financially supported by Jilin Electric Power Company Ltd., project numbered KY-GS-18-01-03

References


