Signal Characteristics of Guided Wave for Condenser Tube of NPP

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1. Introduction

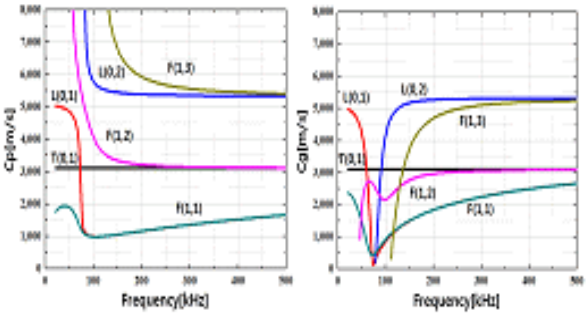
A Condenser is a large heat exchanger of the shell and tube type. Cooling water enters through the waterbox, through the tubesheet and into the tubes(about 80,000tubes/unit). The shell side of the condenser receives steam from the low pressure turbines exhaust. The steam is cooled to a liquid by passing over the tubes where the cooling water is circulated. Because seawater is used as a coolant, condenser tubes are easily damaged. For such a reason, nondestructive testing conducted periodically. But nondestructive testing takes a lot of manpower and time. Guided wave technique can overcome these shortcomings.

In this study, we made an effort evaluating a guided wave defect signal.

2. Methods and Results

2.1 Dispersion curves for condenser tube

Generating a torsional guided wave, we use the MsS sensor (magnetostrictive sensor). The T-wave mode is like a shear wave in a material and has one displacement component along the circumferential direction of the tube. Fig.1 shows the theoretical dispersion curve of guided wave in a condenser tube.



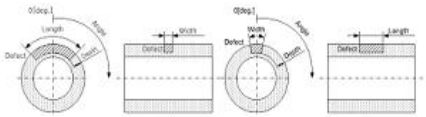
(a) Phase velocity (b) Group velocity

Fig. 1. Dispersion curve of guided wave

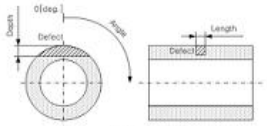
2.2 Specimens

Fig.2 and Table.1 shows the test shape of specimens and specification.

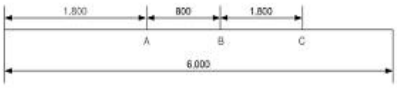
-Material : titanium
-OD : 22.225mm
-Thickness : 0.71mm
-Length : 6m
-Defect section area : 3%, 5%, 7%, 10%
-Wear depth : 10%, 30%, 50%



(a) circumferential notch (b) axial notch



(c) wear



(d) position of defects

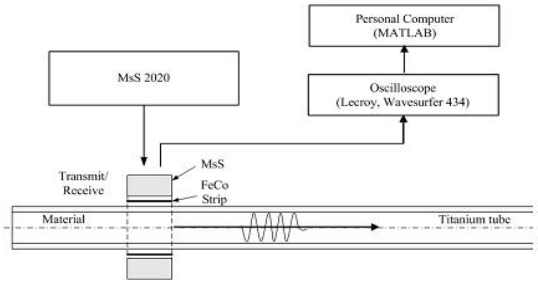
Fig. 2. The shape of various defects and specimens

Table.1. Defect-size specification

Circumferential notch				
Type	Angle[°]	Depth[m]	Length[mm]	Defect area[%]
A	70.8	0.350	0.33	
B	170.3	0.210	0.33	10
C	349.6	0.070	0.32	
Axial notch				
Type	Width[mm]	Depth[m]	Length[mm]	Defect area[%]
A	0.34	0.350	13.60	
B	0.33	0.210	22.60	10
C	0.32	0.070	67.68	
Wear				
Type	Depth[%]	Length[mm]	angle[°]	
A	50	10	0	
B	30	10	0	
C	10	10	0	

2.3 Test equipment

The MsS instrument system(model MsS2020) was used in order to generate and receive the guided wave signal. Fig.3 shows a schematic diagram and detail of this system. The Optimized MsS probe was excited with tone-burst of a given frequency and digital oscilloscope was used in collecting data.



(a) Schematic diagram

(b) Experimental details and MsS

(c)

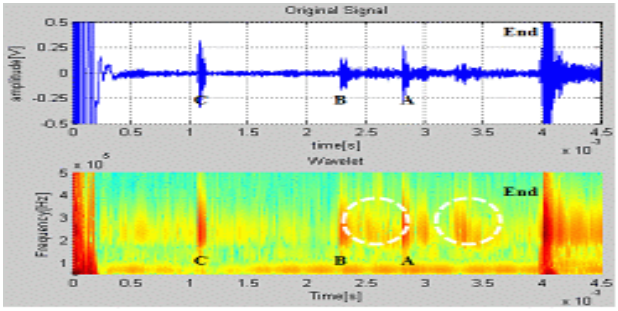
Fig. 3. Experimental setup of heat exchanger tube inspection system with MsS guided waves

2.4 Experimental methods

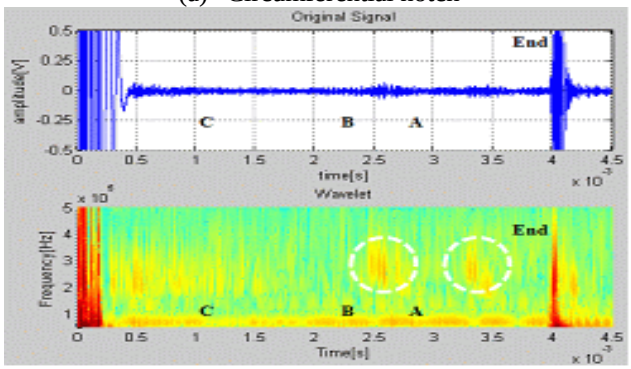
MsS probe that has 250kHz center frequency was installed in the end of the tube specimens. Guided wave signal was collected by using the pulse-echo method. Then, data was compared for analysis.

2.5 Signal characteristics by the type of defects

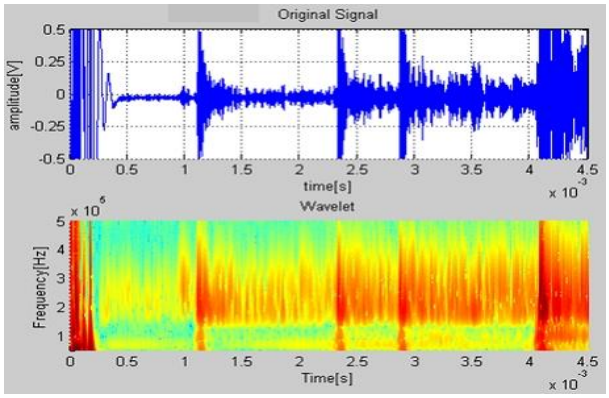
The responded signals from the defects show a non-dispersive characteristic of the torsional wave mode (T(0,1)). Fig.4(a) shows a 10% depth of a notch defect signals in the circumferential direction. It is evident that a responded signal linearly increase as the defect area grows. Fig.4(b) shows the axial notch signal. But we cannot find a torsional responded signal. The reason for this is to be closely related to the axial cross-section area of the defect. From the above results, we learned, it is difficult to finding an axial notch defects. But we can determine the location of the defect through a time-frequency analysis. In case of a circumferential notch, we can see a location of the defect. Fig.4(c) shows the wear defect signal, from where we can distinguish defect signal.



(a) Circumferential notch



(b)Axial notch



(b) wear

Fig. 4. Experimental result of detectability for various defects

3. Conclusions

The defect signal of a condenser tube has been evaluated by using the torsional guided wave.
The results of this study showed that:

1) Circumferential notch defect signal increases proportionally along with the growing defect area. But we cannot find a axial notch signal.
2) Though we cannot distinguish the axial notch by the torsional wave, we can determine the location of the defect through the mode conversion signal.

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