구두발표 II-4

Thickness measurements of the L-shaped pipes using custom built EMAT sensors and special filters

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1. Abstract

The L-shaped pipes are widely used in the petro-chemical plants and vulnerable to the corrosion in the bending region because of the flow direction change and high temperature environment of over 600 ℃. Therefore, it is necessary that the corrosion status of the pipes should be monitored for safety purpose.

In this study we have tried to get the high resolution thickness information of the L-shaped pipes with EMAT(Electro-Magnetic Acoustic Transducer) sensors.

The thickness information can be obtained by getting delay time between two neighboring tone burst signals. The EMAT electronics is poor in the noise property, which gives low signal to noise ratio. So, we have applied the appropriate special filters to the raw signal to enhance the signal to noise ratio. We have improved the delay time resolution up to a few nano-seconds using digital signal processing techniques including cross-correlation, and compared the accuracy and processing time with the conventional methods such as the zero-crossing and the Fourier transform phase slope method. We have custom built the electronicsfor pulsing and receiving, the EMAT transducers for high temperature application, and the customized digital filters. Finally, we have performed thickness measurements of the L-shaped pipes used in the oil refinery plants, of which the results are to be compared with conventional caliper techniques.

2. Custom Built EMAT Sensor and Pulser/Receiver Electronics

The EMAT(Electro-Magnetic Acoustic Transducer) consists of two primary components, a magnet designed to induce a strong static magnetic flux within the test specimen directly below EMAT and a coil that is fed by a very large alternating current pulse. In this paper, the spiral geometry with 24.5mm diameter is used for the to generate the shear ultrasonic wave perpendicular to the contact plane with a specimen. The Cu Coil with 0.2mm diameter is used to make a coil. A neodyum magnet, 25mm in diameter and 40mm thick, is coupled through the gap of 2.0mm over the coil to prevent the signal disturbance that is electro-magnetically induced back from the magnets.Between the specimen and the coil, 0.2mm-thick stainless steel plate is placed.

All of the principal dimension such as the gap between the coil and the magnets was decided experimentally to get the best signal-tonoise ratio. The EMATs generate the ultrasonic wave indirectly by the Lorentz force of the eddy currents induced electromagn etically on the surface of the specimen by the strong static magnetic field. To get a good signal-to-noise ratio for the ultrasonic wave propagation through the thickness direction of a thick specimen, we need a high-powere lectronics to feed a high current pulsed signal in the an EMAT. And to receive the ultrasonic wave signal through the EMAT, the amplification circuit with the gain of 80 to 90 dB is generally necessary because the signal is very weak.. We have custom built a new electronics for the pulser circuit to drive the coil with a high power and a receiver circuit to amplify the multiply reflected ultrasonic wave signal within the specimen. Fig.3 presents the functional block diagram of the newly developed pulser/receiver electronics.

The developed electronics consists of three principal parts which are the pulsing circuit of the EMAT coil, the receiving circuit for amplification of the received ultrasonic wave signal through the EMAT coil and the diplexer circuit to isolate the transmitting and receiving signals through the same EMAT sensor.

The pulsing circuit is made of five part which are a crystal oscillator, a pulse counter, a signal multiplier, a gate driver and a power amplifier. The crystal oscillator provides the pulse counter and the signal multiplier with the carrier pulse clock to drive the EMAT coil and the base clock respectively. The pulse counter generates the controls signal and the firing period of the tone burst pulse to the coil is dependent on this signal. Then the signal multiplier generates the tone burst signals with the base clocks from the crystal oscillator and the control signals from the pulse counter and feeds these burst signals to the gate driver. The time between two successive the tone burst pulse is fixed at 10 msec and the driving clock frequency can be changed fro, 1MHz to 6MHz with a 1 MHz step. The generated signal goes thorough the gate driver circuit and is amplified in the power amplification circuit consists of the eight E class MOSFETs. Finally, the signal voltage is adjusted to the high voltage of 300Vp-p.

4. Experiments

We have performed a thickness measuring experiments using our EMAT sensor and pulser/receiver system. The specimens used for the experiment are the L-shaped steel pipe, which of diameter is 160mm and of thickness is 10mm. The received EMAT signal was sampled with the oscilloscope at the sampling rate of 50Ms/s and was transferred to PC via the USB GPIO device. The sampled data was processed and then the thickness was calculated by the developed dedicated signal processing software on PC. To decrease the noise, the moving average filter with the window size of 128 samples was used. The propagation speed of the ultrasonic shear wave is 3130 m/s. The zero crossing method and the cross correlation method were applied and the thickness data was obtained.

5. Conclusion

We have made the EMAT sensor and the pulser/receiver electronics and performed the thickness measurement experiment to the aluminum specimen using the custom built EMAT system. From the experimental results, we have concluded that the system has an accuracy of at least 0.05mm. But, the signal processing algorithm used needs significant enhancements to achieve the accuracy of 0.01mm.

In the succeeding research, a better method to measure the thickness need to be studied and we have a plan to build an advanced hardware system consists of the puser/receiver electronics and the digital signal processing electronics based on the high-performance DSP.