Appendix B

NONTECHNICAL ABSTRACT

Acoustical waves at a frequency above 20kHz are called ultrasonic waves, which cannot to be heard by the human ear's. There are two different types of ultrasonic waves: bulk waves and guided waves. A bulk wave is the wave propagating in an infinite medium and is not affected by the boundaries of the medium. A bulk wave in air can be heard as a train whistle as reflected from a far away mountain. Guided waves include the ultrasonic waves in bounded waveguides, such as plates, pipes, and rods. Due to their excellent penetration possibility and great inspection sensitivity, ultrasonic waves are widely used in the non-destructive evaluations (NDE) of various structures.

Bulk waves in elastic isotropic materials involve longitudinal waves and transverse waves. The particle motion direction of a longitudinal wave is parallel to the wave propagation direction (a gas explosion underground); the particle motion direction of a transverse wave (also known as a shear wave) is perpendicular to the wave propagation direction (a shear force from an earthquake). The dominant particle motions of the so-called longitudinal guided waves in a hollow cylinder are either in the axial direction or in the radial direction; the torsional guided waves involve dominant circumferential-direction particle motions. Based on the particle behavior, the longitudinal or torsional guided waves can be separated into individual mode groups. Each group contains one axisymmetric wave mode with axisymmetric energy distribution and infinite flexural modes with non-axisymmetric energy distributions. All the wave modes in one mode group have pretty similar particle motions. By applying an axisymmetric excitation source, one can only generate axisymmetric guided waves in an elastic isotropic tubular structure.

Prior research shows that a group of guided waves in cylindrical structures can be focused at a predetermined spot by aligning the phases of all the major wave modes. There are usually two ways to focus at a particular circumferential position in a pipe: 1) using a partially loaded transducer to make the ultrasonic energy be naturally focused; 2) applying input time delays and amplitude controls of a multi-channel phased transducer array to focus at a preconcerted point.

However, the natural focusing and the phased array focusing are not always applicable. First, the transducers themselves have many limitations to achieve focusing. The excited wave types and groups are decided by the incident waves generated by the transmitters. In addition, appropriate excitation frequencies and reasonable transducer sizes are important for controlling energy distribution in pipes. Second, the properties of the hollow cylinder itself also strongly affect the focusing potential. The energy distributions in a pipe change with the pipe size and material. Some geometry and material inhomogeneities, such as elbows, branches, and anisotropic welds, may also influence the guided wave behavior in a tubular structure.

The purpose of this research work was to investigate the focusing possibility in hollow cylinders. The frequency and angle tuning (FAT) technique was presented to enhance the natural focusing inspection and to make sure that a pipe is thoroughly scanned for defects. Influence of the excitation source for natural focusing potential and phased array focusing potential was also studied. Contour charts of focusing potential at particular distances in a pipe were employed as a directory to find a right transducer size and frequency to carry out focusing. When guided waves are focused beyond small defects and transversely isotropic welds, the focal location is not affected by these geometry or material inhomogeneities. Nevertheless, a seam weld leads to anomalous variations of energy distributions and inaccuracy of phased array focusing. Also an elbow in a pipe extremely changes the guided wave behaviors. The so-called time reversal technique is used to achieve phased array focusing beyond an elbow. The time reversal technique utilizes a phased array as a time-reversal mirror (TRM), which records the signals from either a transmitter or a reflector at the preselected focal point and then re-emits the time-reversed signals. This time reversal technique can be implemented to focus beyond an inhomogeneous area in an isotropic hollow cylinder.