The Detection of Oblique Defects in Tubes Using Rotary Ultrasound Testers

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Abstract

Rotary ultrasonic testers are widely used in the industry to inspect tubes for both surface and internal defects. Typically occurring natural defects are modeled by surface notches and flat bottomed holes. The most frequently used artificial defects are longitudinal notches. These are notches having a depth of 5% or 10% of wall thickness, typically 10 to 25 mm long oriented parallel to the center line of the tube. More stringent requirement is to find transverse notches which are oriented 90 degrees to the center line. Lately, more companies require finding oblique defects which are oriented at some angle between the longitudinal and transverse directions. The paper examines the applicability of rotary testers to find obliquely oriented defects.

Keywords: oblique, transverse, ultrasound, rotary, tube, defect, flaw, notch, transducer, API, ASTM

Introduction

The purpose of nondestructive testing is to find every kind of defects in the material which may be present. In case of tubes these defects may be on the surface, inside or outside or within the wall of the tube without breaking the surface. To verify the proper operation of a nondestructive testing system and the ability to find small defects we use calibration standards. These are short lengths of tubes with artificial defects such as flat bottom holes and notches of specified depth and length on both inside and outside surfaces. It would be ideal to find every kind of defects using a single transducer and a single testing channel, unfortunately it is not possible. Surface defects are tested by shear waves in clockwise and counter clockwise directions for longitudinal defects and forward and reverse directions for transverse defects. Each of these directions needs a dedicated transducer and testing channel. Shear wave generation requires that the incident angle of the ultrasonic beam is a specific value. To assure a uniform sensitivity of detection every part of the ultrasonic beam has to arrive at the surface of the tube at this angle. Cylindrically focused transducers allow the best uniformity for both longitudinal wave and shear wave testing. When testing for longitudinal defects the required angle of incidence is established by offsetting the transducer left or right. The magnitude of offset is proportional to the diameter of the tube and has to be reset for every diameter. In case of transverse defects offset is not applicable and special transducers are required where the incident angle is built into the transducer housing. The orientation of longitudinal and transverse defects may vary perhaps +/- 5 degrees and still remain detectable but in the remaining directions the flaws are undetectable using the above described method.

Discussion

Until recently finding notches in the two main orientations, longitudinal and transverse, were considered to be sufficient for verification of test equipment with the assumption that some part of natural defects will have components coincident with these two directions. Presently there is more and more interest for finding defects what are called oblique and are modeled with notches oriented at 25-to-45 degrees to either main direction. Before advancing to oblique defect detection let us review the methods generally used for longitudinal and transverse crack detection. Figure 1 shows the detection of longitudinal cracks by offsetting the transducers in the horizontal direction. Surface defects are tested by ultrasonic waves propagating in shear wave mode. In immersion testing shear waves are generated from longitudinal waves by setting the angle of incidence to specific value as defined by Snell's law. Snell's law states that the ratio of the sine of incident angle to the sine of the refracted angle equals the ratio of the sound velocity in one medium to the sound velocity in the other medium. The required incident angle for water and steel is about 19 degrees for a 45 degree shear wave generation. In case of tube testing the ultrasonic beam is cylindrically focused. For best results the focal line should be located in the center of the tube. See Reference 1.

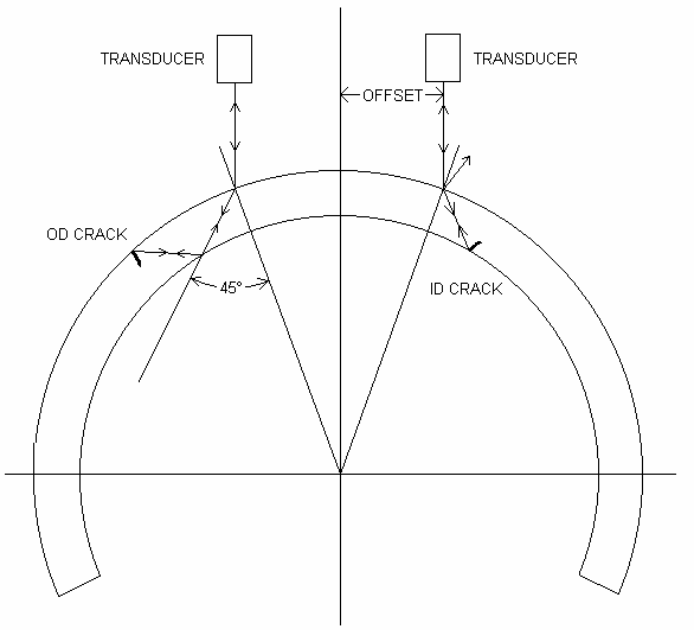

Figure 1.

Transducer offset for longitudinal defect detection.

The required offset is the function of the diameter of the tube and there are tables by which it is set in the rotary tester.

When testing for transverse defects the angle of incidence has to be set in a plane containing the center line of the tube. See Figure 2.

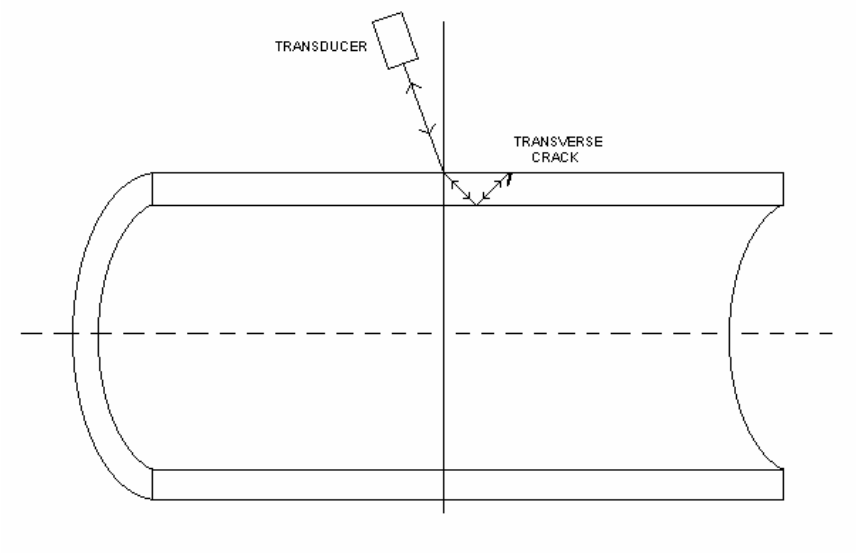

Figure 2.

Detection of transverse cracks.

Changing the angle of transducer is not practical, so in rotary testers we use special transducers where the transducer element and the focusing lens are mounted in the transducer housing at the required angle of incidence. This way the transducer can be mounted in fixed vertical position, independent of tube diameter since it is located above the center of the tube. The photograph of Figure 3 shows the two kinds of transducers. On the left is the transducer with cylindrical focus in the center line of the transducer housing. This transducer is used for longitudinal defect detection by offset. The transducer on the right is also cylindrically focused but the center line of the beam is at 19 degrees to the center line of the transducer housing. It is possible to generate a shear wave which is oriented at 45 degrees or any other angle to the cross section of the tube by combining the above described two methods. More specifically, use a transverse detecting transducer and offset it horizontally. Analyzing the geometry of this arrangement it was concluded that the angle of the transverse cut transducer has to be different from what is used for transverse defect detection. Also, the horizontal offset has to be done by a different table. Figure 4 shows the front view and side view of the transducer position for oblique defect detection.

Figure 3
Two kinds of transducers: for longitudinal defect detection on left and transverse on right.

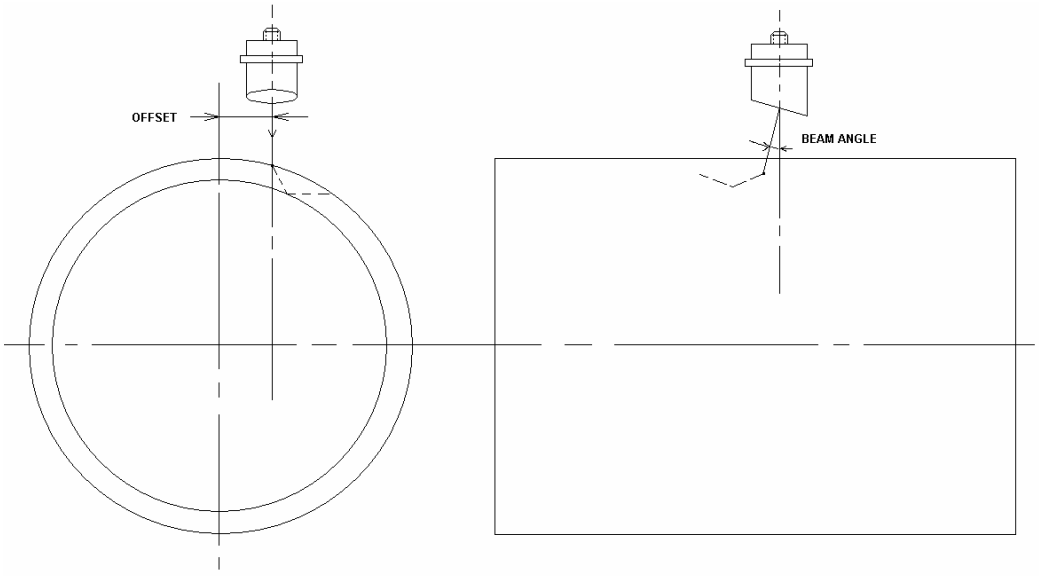

Figure 4
Oblique defect detection by rotary testers.

Conclusions

At Magnetic Analysis Corporation we have conducted tests using transducers made for transverse crack detection and offsetting them horizontally to generate shear waves which propagate in the 45 degree direction. We were able to detect 45 degree notches on both inside and outside surfaces of tubes. Precise alignment is very important and one transducer can only cover about 5 degrees to detect a notch in a reliable manner. This leads to the requirement to have more testing channels available in the rotary tester. The basic setup used to have five channels, clockwise and counter clockwise longitudinal, forward and reverse transverse crack detection and a wall thickness measuring channel. For oblique defects we need at least two more channels for clockwise and counter clockwise 45 degree channels. In case it is required to cover the range of 25-to-45 degrees of directions one channel has to be assigned to each five degrees of increments, adding five more channels in each direction. Rotary testers have a limited number of testing channels available and a large number of channels require longer changeover time from one size of tube to another. Fortunately, the occurrence of cracks in seamless pipe production is more likely in a specific direction depending on the manufacturing process. We have received a requirement from a customer for oblique detection capability adjustable to 35 +/- 10 degrees in two directions since the angle is known for all production pipes at point of production. In such case the number of testing channels required for longitudinal, transverse and oblique directions can be limited to six. For higher inspection speed or thickness gauging additional channels may be required.

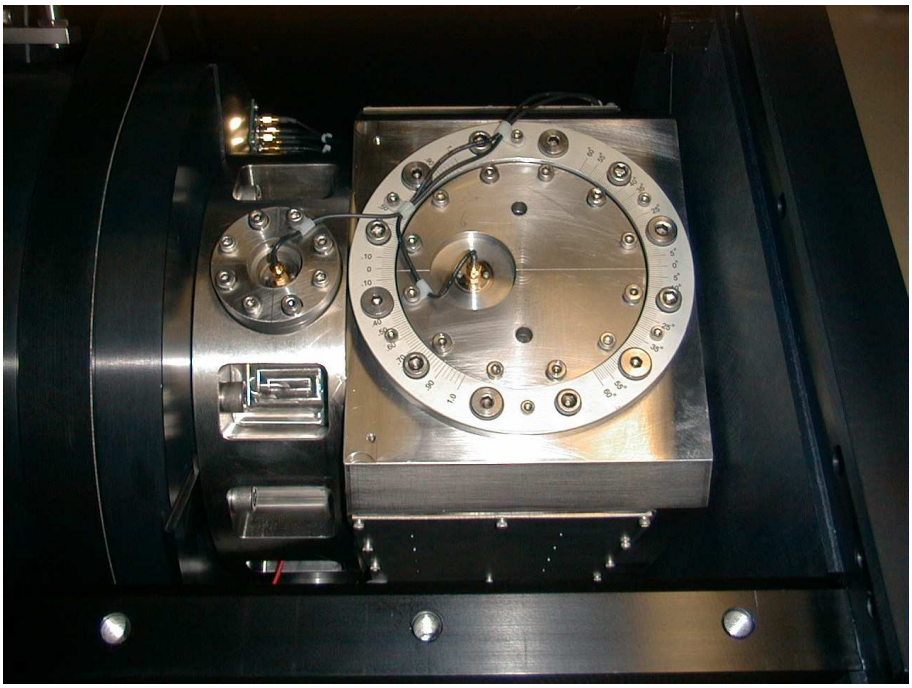

Figure 5
Transducer mounting on the rotary ultrasonic tester.

References:

1. K. H. Beck, “Ultrasonic Transducer Focusing for Inspection of Cylindrical Material”, Materials Evaluation, July 1991.