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Corrosion Damage Assessment Utilizing Special Ultrasonic Techniques

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CORROSION DAMAGE ASSESSMENT UTILIZING SPECIAL ULTRASONIC TECHNIQUES

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In the pulp and paper industry, most boiler tubing and piping systems are subjected to corrosive conditions, which cause accelerated deterioration, and on occasion, premature and unanticipated failure.

Conventional nondestructive examination techniques have proven unsuccessful in the accurate remaining thickness determination on piping systems in digesters. This is due, primarily, to geometric considerations, as well as to the capabilities and expertise of testing technicians. This paper discusses the development of an ultrasonic examination technique which uses both conventional pulse amplitude and satellite pulse response techniques to identify corrosion damage, and readily assesses the remaining wall thickness to within 0.050". It will detail the development process as well as application of the technique.

Introduction

Digester systems are subjected to highly corrosive service environments. Because of these corrosive service environments, many are manufactured from stainless steel materials. Carbon steel material is also used in some instances, to minimize costs. Black liquor digester piping, in particular, is an example of carbon steel piping that is subjected to a highly caustic environment. Areas in these piping systems which are most susceptible to corrosive attack are the welded connections.

The welded connections are most susceptible due to differences in microstructure which are produced during the welding process. The heat affected zone has a much courser grain structure resulting in a higher galvanic potential than the base metal. Although the difference in galvanic potential is small, it does produce a higher corrosion rate in the weld. The base metal is also subjected to corrosion, however, it occurs at a much slower rate.

Many factors contribute to the deterioration rate of these welded connections. The first is the normal operation of the systems. Due to the differences in the products, some digesters will operate in a more corrosive manner. Higher concentrations of caustics can accelerate the deterioration of the welds.
Another factor is the maintenance procedures followed by each mill. Most mills perform some form of acid cleaning during routine shutdowns to remove residual deposits from the system in order to improve production. The acid cleaning solution concentration,

temperature and cleaning time all contribute to the deterioration of the welded connections.

Another less obvious contributing factor is the quality of the original manufacturing. Conditions such as poor initial fit-up, or lack of penetration or burn-through during the welding process will create sites for accelerated corrosion. Although the quality of any existing system cannot be improved, quality control measures should be emphasized during any repair or replacement.

At many plants, this condition has caused leaks in black liquor piping systems, resulting in extensive unscheduled outages. The need to inspect, evaluate, and repair the systems is therefore evident. Ideally, the inspection technique chosen for this application would be fast, accurate, and inexpensive to accommodate short outages and minimal budgets. A discussion of the development and implementation of such a procedure follows.

Nondestructive Examination Techniques

Several options were considered to determine their feasibility. Visual inspection would have been the most accurate method of determining the wall loss of the piping. However, it required access to the internal diameter of the systems, and the cutting of holes in the existing piping system. Extensive repair welding would then have been necessary. This method was therefore determined to be time consuming and economically unfeasible.

Another alternative was to perform radiographic examinations of a representative sampling of the welds. Techniques have been perfected to allow accurate through-insulation testing thus eliminating costly insulation removal. However, radiation exposure problems would minimize, and in some cases, eliminate, consideration for any other maintenance activity. In addition, due to the extensive set-up and breakdown time associated with radiographic examinations, a very small sampling of welds would have been inspected. This would then not allow sufficient data to evaluate the entire system thoroughly.

The final method to be considered was ultrasonic inspection. Although this required the removal of the insulation around the welded connections, it had the advantage of speed and accuracy. It enabled the engineering company to collect sufficient data for accurate analysis.

Procedure Development

The key to development of any accurate ultrasonic inspection procedure is access to samples that accurately represent the condition to be evaluated. Thielsch Engineering has been involved with the failure analysis of liquor piping systems and has utilized their customer's extra samples for procedure development and testing.

The development of the inspection procedure involves three phases:

1) parameter optimization
2) inspection standardization and
3) personnel training.

Parameter optimization consists of selection of items such as transducer frequency, transducer size, scan angle, etc. This is done by trying a variety of different parameters on the test samples. By varying each parameter, the optimum inspection procedure can be obtained. Once the inspection parameters have been optimized, the procedure is standardized, including development of detailed calibration standards and inspection result documentation. Personnel training follows. Detailed instructions on the specifics of the inspection technique, as well as the nature of the condition to be inspected, are provided. Technicians are thus able to correctly identify conditions of concern.

A sketch of the general condition to be evaluated is provided in Fig. 1. It is used as a reference to explain the application of the examination technique.

Three items of information are collected, and used to determine the remaining wall thickness. The first is the thickness of the base metal adjacent to the weld, identified as distance BM. The second value is the thickness of the weld reinforcement, identified as distance WR. The final value is the depth of the corrosion as measured from the ID of the pipe identified as CD. The amount of remaining wall at the welded connection is determined by adding the values for the base metal thickness and the weld reinforcement, and subtracting the value of the corrosion depth.

A value of the base metal thickness is determined by the use of a standard straight beam ultrasonic thickness measuring device. The thickness of the weld reinforcement is physically measured using a standard weld measuring instrument. These two measurements are standard techniques used throughout the industry.

The depth of the corrosion is determined by the satellite pulse technique, as illustrated in Fig. 2. In this technique the ultrasonic beam is directed at the corner trap which represents the ID/corrosion interface. Sound is reflected and displayed on the ultrasonic instrument screen. While the ultrasonic beam is focused on the corner trap, sound is radiated from the bottom of the corrosion area. This signal is also received by the ultrasonic instrument and displayed on the screen. Known standards are used for instrument calibration such that the distance between the two signals represents the depth of the corrosion.

This technique was recently implemented and revealed several notable conditions. As most of the liquor piping would have been installed with little or no nondestructive examination, isolated defects such as slag entrapment, lack of penetration, or lack of fusion were expected. This inspection technique revealed several of these conditions. These, however, were not considered detrimental to the serviceability of the piping. The inspection also identified general corrosion extending approximately 1/8" into the weld metal. Subsequently, several samples were removed from the worst case locations and the results of the inspection were verified.

Summary

An evaluation of the corrosion damage of liquor piping systems can be done nondestructively, quickly, and at minimal costs by using ultrasonic examination techniques developed specifically for this problem. Suggestions for a complete evaluation include:

1) Detailed review of all available maintenance records which may identify areas that have been historically troublesome.
2) Ultrasonic inspection of approximately 25% of the welds in the system, selected at random locations throughout the piping system. This will allow sufficient data to be collected in order to determine the existence and extent of the condition.
3) Prepare recommendations addressing any corrective actions needed.

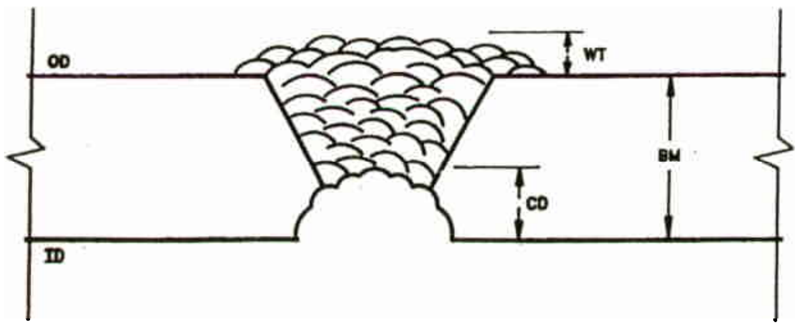

Figure 1. Condition of welded joints.

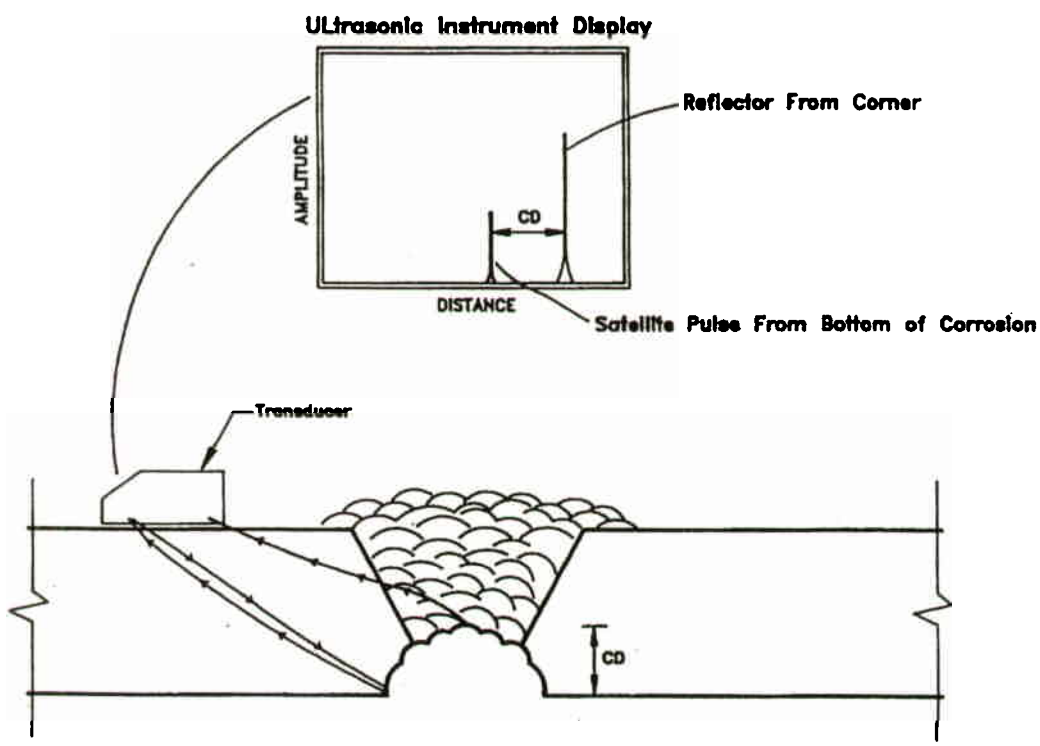

Figure 2. Sketch showing UT procedure.