Pipe and Tube Weld Inspection Using Laser Vision Technology

Laser vision sensors can automate visual inspection of pipe and tube, help ensure the reliability of automatic ultrasonic testing, and make it easier to observe trends

BY JEFFREY NORUK

Pipeline welding requires the utmost attention to detail throughout every phase of manufacturing, starting with material preparation right through to final inspection. Although automation has entered this world in the form of mechanized welding systems and semiautomated radiographic and ultrasonic testing, the human factor is still very much a part of these operations. Two of the most important steps in the process are joint fitup and visual weld inspection. Laser vision sensing can help improve these operations.

Pipe/Tube Welding Requirements

Performance requirements for welded pipe and tube depend on their usage. Overland pipelines differ from underground spiral transmission (water, gas) pipe with respect to materials used and the anticipated failure modes. Likewise, tube used for offshore drill rigs is subjected to different stresses and corrosion requirements than that needed for onshore drilling. Two things, however, are common for all these applications:

- ◆ Quality and testing requirements are very demanding for both the initial qualification as well as for the actual fabrication.
- ◆ All codes (API, ASME, AWS) used in this industry require some level of visual inspection be done to augment other techniques such as magnetic particle (MT), ultrasonic (UT), and radiographic testing (RT). The visual requirements are normally quantitative in nature but there are certain cases where a specific feature is difficult to measure using standard tools. See Fig. 1A for a typical pipe inside groove weld, Fig. 1B for inspection variables, and Table 1 for actual results.

For the weld inspection results in Table 2, the bead width is fairly easy to measure, but the other measurements are difficult to make with either gauges or a borescope.

Table 1 — Results of an Inspection of a Typical Pipe Inside Groove Weld

Weld #1, Required measurements

Mismatch (mm)	0.47
Bead Width (mm)	5.22
Reinforcement Height (mm)	1.04
Toe Angle 1 (degrees)	150.3
Toe Angle 2 (degrees)	165.2

Fig. 1A — Pipe inside groove weld.

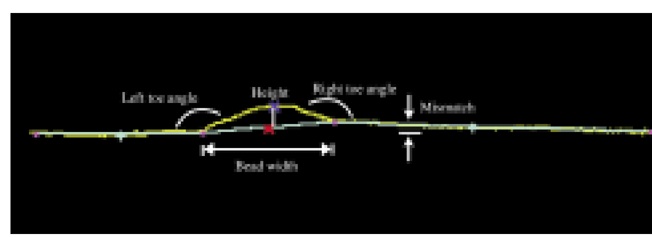

Fig. 1B — Inspection weld input variables.

What Is Laser Vision?

Using laser vision sensors for welding is not new, but their use for weld inspection is. Traditionally, this technology has been used for joint tracking and adaptive welding. Beginning in

Table 2 — Comparison of Weld Inspection Results

Defects and Measurement	Laser vision	Inspector using tools
Cracks	Not unless $\frac{1}{32}$ wide	Maybe
Porosity	Yes	Maybe, > $\frac{1}{64}$
Undercut	Yes	Yes, > $\frac{1}{32}$
Leg & throat size	Yes	Yes, within $\frac{1}{32}$
Width & height/reinf.	Yes	Yes, within $\frac{1}{32}$
Mismatch	Yes	Yes, within $\frac{1}{32}$
Toe angle	Yes	Maybe, within 5 deg

JEFFREY NORUK (jnoruk@wi.rr.com) is president of Servo-Robot, Inc., St. Bruno, Quebec, Canada.

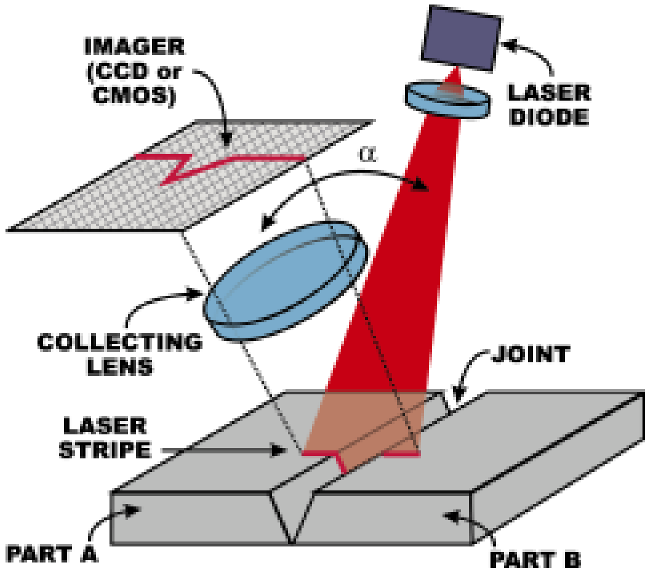

Fig. 2 — Explanation of laser vision.

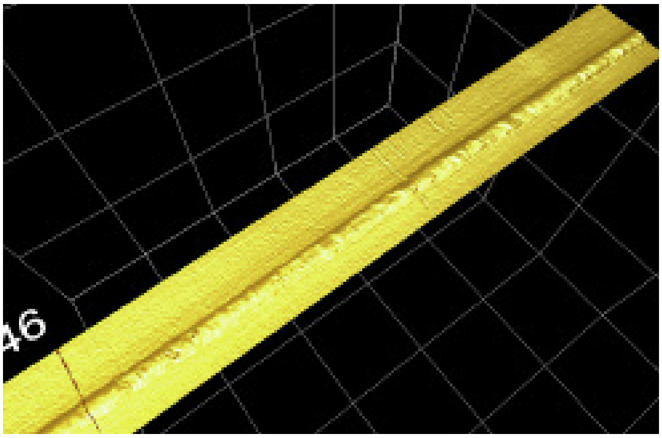

Fig. 3 — Three-dimensional image of the inside of a tube weld.

the mid 1990s, the technology was directed to developing the capability to measure pre-weld joint fitup as well as finished weld inspection. The early applications were in the automotive and mining/construction industries. Figure 2 schematically illustrates how laser vision works; Fig. 3 presents the 3-D image of a weld taken by a WeldSure laser vision system. The laser system is really a sophisticated profiler capable of geometric measurement as well as defect identification. Software library templates have been developed for unwelded joints, partially welded joints, and finished welds. The system is programmed by inputing the applicable weld standard (API 1104, AWS D1.1) requirements such as root openings and included groove angle for an unwelded joint and items like groove weld width, convexity, and toe entry angle for a completed joint.

Applications

Transmission Pipe. Transmission pipe for water, wastewater, gas, and other substances is typically either cast iron or welded steel/stainless steel. Welded spiral pipe is superior to either cast iron or standard welded length pipe with regard to performance and cost and is optimum for meeting today's increasing demands. This pipe ranges from about 12 to 150 in. in diameter with thicknesses from ¼ in. to more than 1½ in.

For certain customers, the welds need to be complete penetration per AWS D1.1, *Structural Welding Code — Steel*. Quality control requirements typically call for visual inspection by a CWI and ultrasonic testing either manually or in an automatic mode. Laser vision technology can be used to augment both NDE methods.

Spiral pipe is typically submerged arc welded with torches on both the inside and outside of the joint. After the slag is removed, the welds are ready to be inspected. A laser vision camera complete with two-axes slides can be programmed to track and inspect the welds for correct dimensions (convexity, bead width) and for the presence of defects. The output can be correlated to an exact location via the encoder on the drive system for the pipe. Automatic UT is efficient but, in practice, it can be difficult to keep the transducers properly positioned over the weld in order to get repeatable results. By using a track system in front of the UT system, precision positioning can be maintained via feedback to slides carrying the transducers.

Oil Drilling Tube. The search for oil reserves is leading companies to ever deeper ocean depths. These deepwater drilling facilities are now drilling at depths greater than 6000 feet. Much of the casual observer's attention goes into the huge above-ocean structure that houses all the equipment and people, but just as impressive is the drilling riser package consisting of a set of tubes extending to the ocean floor. These tubes house the drill itself as well as equipment to extract water and sediment. The tube housing the drill is typically made from heavy-gauge, large-diameter steel. It is made in sections and welded together utilizing double-V-groove joints to attain complete penetration. The testing for these welds includes VT, MT, UT, and RT and some testing is done more than once during the manufacturing cycle.

Visual inspection has typically consisted of a CWI with manual gauges on the outside and a semiautomatic manually rotated borescope viewing system for the inside. The borescope is okay for general measurements but the critical toe entry angles are tough to accurately measure. Also, the borescope does not provide a way to dynamically map inside the pipe a full 360 degrees and to automatically save the results. To overcome these limitations, laser vision inspection systems are now being employed for this task. These systems can be either used in a semiautomatic or fully automatic mode. The result is a faster, more accurate inspection with permanent data retention. Figure 3 shows a saved image from a typical tube weld.

Summary

Laser vision sensors can both automate the visual inspection process as well as ensure the automatic UT process is reliable. The noncontact nature of the sensor makes the process robust in this tough welding environment. This automatic inspection method removes the subjectivity inherent with any manual process and eliminates the arguments between production and quality control. The results speak for themselves and do not require any interpretation — one simply sets the tolerance limits and the system says "go" or "no go." The other advantage of automatic visual inspection is the ability to observe trends and implement targeted process improvement efforts. In addition, the inspection can examine 100% of the weld length and the results (both data and image) are archived digitally, thus eliminating paper.❖