Laser Scanning Weld Inspection System

Laser scanning weld inspection systems are the first major development in how weld inspection is conducted in nearly 50 years. Designed for use in the field to improve the reliability and speed of the welding inspection process, these systems can check part fit-up prior to welding to ensure that joint preparation is within procedure requirements, as well as inspect the final weld to a much higher precision than standard weld gages. When using laser scanners, a 3D scan of joints and weld beads is often evaluated for a variety of features including size, porosity, and undercut. These results can be augmented with a picture of the weld and recorded comments saved directly to the system—exponentially enhancing the efficiency of the overall process. Laser weld scanning systems allow inspectors to quantify the undercut, toe angle, and overall bead shape for improved fatigue properties.

Upon selecting a joint weld type and setting the tolerances in a laser scanning system, the quality of a weld can immediately be determined. The three images in Figure 1 are of a portable weld system, demonstrating the joint library, tolerance requirements, and final results.

Laser Scanners use 3D Laser Scanning Technology to be able to Measure and Inspect Welds

The resolution of the laser scanner in Figure 1 measuring capability is 0.1 mm (0.004 in.), based on the laser field of view and the number of pixels present. The accuracy of any single measurement will depend not only on the inherent resolution of the system but also the welded or unwelded joint geometry and surface condition itself. Neither of these encompasses the repeatability and reproducibility (R&R) of the system, which must be determined on real weld samples by having several people measure the same samples and then determining the R&R value. The R&R is typically the result that most companies’ gage control departments are required to record. Of course, it all starts with a fully calibrated system, which involves ensuring the optics have the resolution to

Figure 1. Weld system showing: (a) joint library; (b) tolerance requirements; and (c) final results.
measure a verification block accurately. This same verification block is then used by the operator to verify that the laser scanner continues to measure correctly.

Applications
Laser scanners can be used for a wide variety of industrial applications to improve weld quality and productivity. Using a laser scanner will reduce the subjectivity inherent today with human inspection; it is up to ten times faster and can in fact automatically take one inspection per second for the full length of the weld. A few of these applications will be reviewed in detail so one can better understand how to identify uses where the payback and benefits will be quickly achieved.

Wind Tower Joint and Weld Measurement
Wind turbines depend on a very strong tower structure to withstand the high loads and fatigue conditions they experience in operation. The towers are made up of several sections that are first longitudinally welded and then welded to each other using submerged arc welding. To get optimum performance, the joint must be fit within a tight tolerance prior to welding, and then the weld shape needs to conform to specific requirements to be acceptable. Oftentimes, a report is required to summarize all of the results and is subsequently sent to the customer purchasing the towers. Prior to using a laser scanner, this process was all done with a series of manual gages, which was slow and prone to error during both the measurement phase as well as the transposing of the results onto paper. Laser scanners can take numerous measurements in a fraction of the time, allowing for a consistent result that can generate reports automatically. Refer to Figure 2.

Auditing of Robotic Manufactured Welds
The trend of moving welds from manual welders to robots has been going on for over 30 years, but now it is accelerating and being taken on by small to mid-size companies rather than just large corporations. In the early years, there was a misunderstanding that merely putting a robot into the welding environment would automatically improve everything. This proved to be totally wrong because people quickly found out that major changes to upstream

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**Figure 2.** Laser scanner inspection report.

1. Name based on the search criteria
2. Unit selection drop list (mm/in.)
3. Language selection drop list (English, French, German, Japanese, Chinese)
4. Discontinuity recorded in continuous inspection (for example, id-22-5 represents the fifth discontinuity found in Inspection ID 22)
5. Click on the hyperlinks to get more information (images, comments, and so on)
operations are needed to feed the robot parts designed for automation. Another misconception was that the robot somehow magically would put in the right size weld with the quality required. A laser scanner has proved to be very helpful for auditing robot made welds to ensure the benefits planned for more consistent welds have actually been realized. This can be done by using it manually to audit robot welds once the parts are outside the cell, or the robot can in fact pick up the laser scanner and check its own welds. Figure 3 shows a laser scanner being held by a robot.

Resolving Disagreements between the Customer and Supplier

They say “beauty is in the eye of the beholder” and that is definitely true when doing weld inspection manually and using mechanical/manual gages. The variability between inspectors combined with the inherent error in using manual gages results in many cases where there is a disagreement between two parties. This can be the end customer and the supplier, or it could be the production and quality departments in the same company. The laser scanner has been able to act as a “third party referee” to resolve these differences of opinions. Once it is agreed that the laser scanner’s results will be accepted, the decision becomes easy. See Figure 4, showing how one sets the tolerances for each feature. Figure 5 shows the complete results for one weld.

Why ship parts to a customer or move welded parts to the next operation in a factory without ensuring that the requirements are met? See Figure 6, showing a large weldment being inspected before moving it to the next operation.

Improving Fatigue Life

The weld attributes affecting structural fatigue life are the very ones that are most difficult to accurately measure with manual gages. A laser scanner can provide consistent measurements for the following features.
Undercut: can be roughly measured by special gages, but they are inconsistent and do not calculate the depth per the American Welding Society definition. Traditional undercut measurements normally are too deep because they partially measure the weld bead instead of just the amount below the plate surface. Correct measurement is key to determining conformance to workmanship standards and also for the effect it has on fatigue life.

Toe entry angles: toe angles represent how well the weld metal has “washed/flowed” out onto the adjoining base metal. If the angle is below or near 90°, it reflects cold lap. Toe angles approaching 150° will provide optimum fatigue life and a nice aesthetic appearance.

Height/width ratio: many codes specify a requirement for the ratio of weld height to width to not exceed a certain value to help ensure the weld is not a stress riser. Instead of having to measure both height and width individually and then doing the math, the laser scanner automatically makes this calculation and compares the result to the allowable percentage.

With these accurate measurements automatically recorded, this information can be easily fed back to the product designers so an accurate determination of expected fatigue life can be made. This will help avoid the normal course of action, which is excessive safety margins, which just add cost without any real benefit.

Over Welding

It is a fact that there is a tremendous amount of over welding taking place in all industries and on all products. Over welding significantly contributes to excessive welding cost (AWS, 2001). While it is typically less a problem when the welding is automated, the amount of waste is substantial. One company found that if only 5% of the company’s welders were over welding just 1.6 mm (0.0625 in.) on a typical 6.35 mm (0.25 in.) fillet for 5% of the total weld length, that this would still add up to hundreds of thousands of dollars wasted per year. The historical problem with trying to get one’s arms around this problem is that most weld inspection is really no more than pass/fail with the use of gages and without any actual measurement data. With a laser scanning system, each weld can be precisely measured and the percentage of over welding can be calculated. The result is immediately visible to the welder, inspector, or supervisor, which allows for proactive action to be taken to improve.

Training

Currently, welder training instructor feedback is primarily subjective, which can lead to the welder not getting substantive assistance with which to improve. This applies to both initial training for people who have no previous experience and to existing company employed welders who simply need to improve due to problems meeting the company’s requirements for productivity or quality. A laser scanner can give specific feedback in the form of an actual grade with which both the instructor and student can work to improve.

Summary

A laser scanner can provide many benefits to companies required to do weld measurement and inspection, which will save substantial time and money. One does, however, need to look at the payback of buying this type of system by including the following elements: the purchase price plus the cost to train inspectors to use the system, plus the cost to develop quality assurance/quality control operating procedures. Experience shows that typical paybacks range from one to three years.

Conclusion

Laser scanning systems for weld inspection are definitely the instrument of choice for those who want to make dramatic improvements to both weld quality, and also to reduce wasteful practices such as excessive repair or product rejections.

Most weld inspection is done with gages that do not provide measurements, but only determine whether the weld is good or bad. While this prevents bad product from getting out the door it does not provide the opportunity to implement continuous improvement efforts.

Laser scanners use similar technology that numerous users are already comfortable using such as cameras, smart tablets, and other smart devices. This fact will allow for easier acceptance of the laser scanner system with a short learning curve.

Acknowledgment

For the purposes of this article, the laser scanner referred to in this text and pictures is the Servo-Robot, Inc. WiKi-SCAN welding inspection system.

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