Automated Ultrasonic Inspection Improves Quality and Benefits Economy in Welding Workshops

Ole OLSDAL 1, Steen Arnfred NIELSEN 1, Leif JEPPESEN 1

1 Sensor and NDE Innovation, FORCE Technology, Park Allé 345, 2605 Broendby, Denmark
Phone: +45 4356 7000, Fax: +45 4326 7011; e-mail: oo@force.dk, srn@force.dk, lej@force.dk

Abstract
Advanced automated ultrasonic systems coupled to intelligent developed scanners have proven to optimize on all important parameters within inspection, regardless if it replaces the manual process or replaces for example X-ray.
Replacing the manual ultrasonic inspection with automated equipment in manufacturing units, improves both the quality of the inspection and the quality of delivered products. At the same time, the automated inspection is a significant economical benefit for the manufacturer. As an example we will highlight the benefits for the manufacturer of wind turbine towers, usually producing many meters of weld per day. Time savings of 8 – 10 times compared to the manual examination work is possible, and at the same time the quality work is improved significantly.
The huge time saving achieved through automated ultrasonic inspection is possible with the most advanced automated ultrasonic systems on the market, controlling intelligent probe set-up including several transducers scanning simultaneous with TOFD and Phased Array techniques. Coupled to smart programmable scanner devices, scanning speeds of more than 100 m/hour is possible, even in welding workshops.
Unlike manual inspection, all parameters such as speed and data recording are precisely controlled with the automated inspection equipment. Advanced automated ultrasonic systems have also special features to lock parts of the software to avoid, that fatal human errors are introduced.
The manual inspections are controlled only by the inspector carrying out the inspection. Programming human beings to make movements of for example maximum 150 mm/sec with an overlap of maximum 10% is difficult, and most inspectors are confident that they can do inspections faster than that, and still perform excellent. In fact, directly asked, most inspectors admit that they perform inspections with minimum twice the speed dictated by the procedure.
Examination of a 15 m long and 80 mm thick circumferential weld takes about 12 minutes with the automated equipment, while it with conventional manual ultrasonic, according to EN 17640, should take the operator minimum about 128 minute.
This paper describes implementation of advanced automated ultrasonic inspection in the workshop, and highlights the technical, economical and human benefits achieved by replacing manual ultrasonic inspection with intelligent automated inspection equipment.

Keywords: Phased Array, Ultrasonic testing (UT), Automated Inspection, TOFD, Optimizing Economy

1. Introduction

The use of automated ultrasonic testing (AUT) systems are requested in many steel manufacturing industries to improve the quality of an object. In particular AUT is used in those industries that produces a high number of identical objects like for example steel pipes-, bars- and plates. AUT systems may also be an improvement due to the objects complexity either with respect to the shape or the material properties.
In traditional welding workshops however, the use of manual ultrasonic testing (MUT) equipments is still dominant. This is probably due to the various productions with different requirements to the extent of testing. In welding workshops manufacturing large pressure vessels though, automated ultrasonic inspection has been implemented for many years. Other welding workshops could also benefit more from the advantages of AUT, especially workshops producing many meters of weld every day, and require full inspection, like for example workshops manufacturing wind turbine towers, or similar large tubular products in large numbers.
This paper will demonstrate, that welding workshops delivering a product, verified by a reliable report issued on the basis of a comprehensive automated ultrasonic inspection, will achieve not only considerable economically advantages, but will also bring the quality of both the testing and the product to a new level, and will finally be awarded by their customers as well as their employees, for demonstrating a true interest in quality and employees well being.

The example is based on a welding workshop producing wind turbine towers. The ultrasonic technique is based on an advanced AUT-system with a combined phased array (PA) and Time-Of-Flight-Diffraction (TOFD) setup, and the full inspection of a circumferential weld in one single pass.

2. Achieved benefits moving from MUT to AUT

Companies with a production that requires the use of NDT, benefits in many ways by implementing automated inspection systems. The full package of advantages is achieved with a continuous production of geometrical identical objects, or in welding shops with daily production and inspection of many meters of weld. The benefits for the manufacturer are numerous, such as:

- Increased quality of inspection or Probability of Detection (POD)
- Results less dependent on subjective operator analysis
- Increased customer confidence
- Increased efficiency and inspection speed
- Increased employee work satisfaction
- Remarkable reduced inspection time
- Reduced costs per meter weld inspected
- Improved documentation of inspection
- Improved flaw localisation and sizing
- Better customer rating
- Reduced number of “false calls” benefits the final product and economy
- ISO 9712 or EN 473 level 1 personnel can be used for set-up and data acquisition.

The customer will benefit from:

- Increased reliability and detailed reporting
- Increased possibility for 3rd party inspection
- A better product for the same amount of money
- High repeatability.

The employee will benefit from:

- A more interesting job, due to work with advanced technology
- Extraordinaire possibilities for carrying out inspections according to specifications, every time
- Elimination of repetitive and monotonous work that can lead to musculoskeletal disorders

The increased POD is well documented through numerous tests and reports. Some of these reports also document the important False Call Rate (FCR) and thereby calculates the overall confidence of the applied technique [1].
Increased customer confidence can be evidenced by customer QA systems, which by means of a rating system favours the users of automated ultrasonic systems above those who have not yet calculated the economical benefits of the AUT technologies. They become the attractive “preferred suppliers” and may even save time due to a reduced number of customer audits.

Increased efficiency, reduced inspection time and reduced costs per meter examined weld, is easily demonstrated by simple calculations, as presented later in this paper.

Increased employee work satisfaction is a non documented statement so far, but interviews and customer feedback with qualified inspectors, highlights this important statement. It is however a fact that manual operators often gets problems with elbows and/or shoulders, caused by many years repetitive and monotonous work, which is totally eliminated by moving from manual to automated inspections.

The customer will benefit from the increased reliability and reporting level, which is due to the fact, that data are now stored digitally, and can be analysed using advanced software tools. The permanent digital storage also means that data are available for other than the operator, and can be analyzed at any time for example by the 3rd party auditor.

The better product received by the customer is a result of the minimized FCR and less unnecessary repairs with negative consequences on material and economy, and then of course also, the much higher POD.

Basically a win – win situation for all parties.

So why doesn’t everyone want to save time and money, and change to automated systems and get it implemented in the production? There is no simple answer to this question, but off course there are some considerations to do, before the decision is made

- Despite the below demonstrated large time and money savings, purchasing automated ultrasonic equipment is an investment, which often requires authorisation at top management level. As explained later, the huge savings can be difficult to explain to the management.
- Introducing new equipment and techniques, requires some additional efforts with respect to:
  - Upgrading of operator qualifications
  - Preparation of new test blocks
  - Revision of testing procedures

Relative small practical issues, which however can seem difficult to manage in a busy workshop, with limited number of people on all positions.

Furthermore, the implementation may have to be approved by the customers, and that is also sometimes a challenge, as the customer auditor or the responsible level 3 may not be familiar with automated systems, and as such unable to see the advantage of the new possibilities.
3. **Economical benefits for wind turbine tower manufacturers moving to AUT**

The following is an example from a wind turbine tower manufacturer in Europe. It demonstrates some of the main economical benefits of moving from MUT-systems to AUT-systems. Time savings after implementing an AUT-system and return of investment (ROI) is demonstrated by scanning circumferential butt- and flange welds with material thickness of 12 – 50 mm.

Weekly production of welds: 135 circumferential welds, or 1.793 meter

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<tr>
<th>Scanning technique</th>
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<td>MUT</td>
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<td>AUT</td>
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<td>1 or 2 TOFD set-up</td>
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Actual scanning time 1 weld

| Manual operator | 120 minutes |
| Automated scanning | 8 minutes |

Weekly hours necessary for manual inspection: 135 (circ. welds) x 120 (minutes) / 60 = 270 hours per week

Weekly hours necessary for automated inspection: 135 (circ. welds) x 8 (minutes) / 60 = 18 hours per week

**Time saving per week after implementation of AUT**

252 hours

Considering a hourly cost of EUR 35,00 per inspector, the ROI is approximately 18 weeks, or as presented in figure 1 below, after inspection of about 2400 welds.

![Figure 1. Inspection costs for AUT and MUT systems](image)
4. Frequently asked questions for AUT-systems

Looking at the above example, and at all the benefits mentioned as well, it should be easy to justify the implementation of new automated inspection equipment, and one would expect to see automated inspection carried out in many more workshops, than is the case today. So what are the objections?

One reason that automated inspection does not find its way into the workshops, are the manual inspection routines practiced in some workshops. Due to these routines it becomes difficult for the management to realize the entire range of benefits. Some frequently asked questions will clarify the benefits.

4.1 Compromise on inspection quality?

The management looks carefully into the economy, which should be an argument for investment in AUT-systems in a longer perspective. In a short perspective, however, a frequently asked question is: what is the price for examining a weld today, and what is the price for examining the same weld with automated inspection equipment?
In the above example the inspectors spend a reasonable amount of time on the inspection. They spend 2 hours carrying out 6 inspections of 13 meters of weld. In other words, they perform 6 x 13 m inspection in 2 hours, or 39 meters of weld inspection in 1 hour. The 6 inspections is 2 x lamination check, 2 x 60° and 2 x 45° scans.
However, in some workshops, the operators perform much better. They are actually capable of doing the same inspection up to 4 times faster, doing the same inspection in half an hour, which corresponds to 156 meter weld inspection per hour!
Obviously this is not possible, and no procedure for manual ultrasonic testing recommends such an inspection speed. So, how is that possible? First of all, it is quite common that the required lamination check is not performed at all. Then we have reduced the number of tests to 4, and the scanning speed is now 104 m per hour. This is still an extreme speed, even for very skilled manual operators. Such a high speed can only be achieved on the cost of quality, by moving the transducer much faster than the normally accepted speed of 150 mm/sec, and without any overlap, actually the opposite.

4.2 Conditions for scanning surface?

When implementing the automated inspection equipment in the workshop, some manual inspectors are quite surprised to experience that the scanning surface for automated inspection needs to be much better than for manual inspection. The truth is, that it doesn’t. The basic conditions are exactly the same for the two methods, and it has never been neither possible nor accepted, to perform test on a surface with loose scale. Nevertheless, that is done in some workshops today, and testing is performed with loose scale and weld deposits as the most natural thing in the world.
So preparing the scanning surface for ultrasonic inspection is actually considered an additional operation, and an additional cost, which will have a negative impact on the considerations about AUT.
4.3 Customers demand more of AUT-systems?

The third objection may emerge from customer requirements. For some reason there seems to be much higher requirements to automated inspections, than to traditional manual inspections, despite the fact, that the automated inspection in all significant ways performs better than the manual, and despite that the customer for sure will receive a better product requiring an automated inspection. It is even possible, based on collected data, to verify whether or not the scanning is performed correct, and that the required area is tested according to specification.

Figure 2 from the paper “Increase in Reliability in Advanced Ultrasonic Inspection Methods” [1] shows comparable result from a Round Robin test for the most common testing techniques applied to the same specimen, representing flaws in objects between 6 and 25 mm wall thickness. It proves, like other similar tests, very well that automated testing with TOFD or meander scan, is superior to all other testing techniques, and in particular to MUT. In this situation, it is assumed that the best manual operators have been selected and performed at their very best, as they have been aware that they did participate in a test. This assumption makes the above description of (too) fast manual testing in the workshop even more interesting, and makes one wonder how these tests would be ranked in the same scheme.

![Figure 2, comparison of different techniques for weld examination](image)

From the above figure the clear advantage of AUTover MUT can be seen, not only with respect to probability of detection (POD), but also the important parameter False Call Rate (FCR), which are the direct cause for many unnecessary repairs, which have negative consequences for the economy as well as the quality of final product. In total these two parameters proves the advantage of the automated inspection, in particular when the TOFD or meander scan testing techniques are applied.
5. Type of Automated Equipment

The automated equipment used in the above example consists of a P-scan system (the UT processor including scanner controller) and an AMS-41 lite scanner, which is dedicated to examination of large circumferential welds.

The P-scan system can be the PSP-4+ for carrying out TOFD combined with traditional pulse/echo transducers for additional coverage of the inner- and outer surfaces, or the P-scan Stack System for carrying out TOFD combined with Phased Array inspection, primarily for additional coverage of the inner- and outer surfaces. These equipments are shown in below picture 1.

![Picture 1](image1.jpg)

AMS-41 lite

P-scan 4+

P-scan Stack PA64

Picture 1, various P-scan equipments for automated inspection of large circumferential welds

Based on the electronically stored data, analysis and reporting is performed within the software packet that comes with the P-scan system. Reports can be generated directly in customer templates if required, and they can be extended to include also one or more pictures, general or detailed (picture 2), easily understandable for most readers of the report.

![Picture 2](image2.jpg)

Picture 2, reporting of scanning results
TOFD is carried out according to EN 583-6 [3], EN ISO 10863[4] and EN 15617 (acceptance levels) [5].

UT for the additional UT of inner- and outer surfaces is carried out according to EN 583-1 [6], EN 583-2 [7], EN ISO 17640 [8] and EN ISO 11666 [9].

Beside the national standards, specific procedures prepared by each wind turbine manufacturer have to be considered as well.

Under all circumstances, specific testing procedures are prepared, including verification scans on dedicated calibration blocks, to verify the sensitivity and detection of required defects with all applied methods.

6. Conclusion

The paper discusses the huge advantages achieved by replacing manual ultrasonic testing with automated ultrasonic testing. It highlights and documents the economically as well as the quality aspects of this change, and some of the benefits for the manufacturer, the customer and the employees.

An actual case is presented, making the advantages very clear.

Furthermore the problems related to NDT personnel not performing according to general accepted workmanship, and some of the possible negative consequences of such behaviour, are addressed. Implementation of AUT offers the possibility for more people to judge and verify inspections, and the relevance of that is addressed as well.

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