Ultrasonic Inspection of Duplex Steel Joints Made by Laser Beam Welding

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Abstract. Austenitic steel welds exhibit a heterogeneous and anisotropic structure that causes difficulties in the ultrasonic testing (UT) understanding. Increasing the material knowledge has been an international large and long term research field. The main specificity of the weld material is its oriented grain structure which has to be described as an anisotropic and heterogeneous material. The description of the grain structure regularly progresses from simplified and symmetrical structures to more realistic descriptions. This paper report some result of the weld joints fabricated by laser beam welding, experimental investigation of the ultrasonic inspection of duplex steels. Experimental studies have concentrated on methods of improving signal to noise ratio in these steels and on relating properties such as attenuation to material structure.

Introduction

Austenitic welds usually have a strongly textured columnar grain structure and the special difficulties experienced in ultrasonic testing are due to their anisotropic properties which cause beam skewing and scattering of ultrasonic waves. Beam skewing does not occur in isotropic material such as ferrite weld metal, but scattering occurs in all polycrystalline materials, however it is far less severe in ferrite welds than it is in austenitic welds (1-4). For these reasons, austenitic welds will always be more difficult to examine than ferrite welds, but substantial improvements have been made in the inspection techniques employed for both types of welds in the last ten years. Thus there is reason to believe that careful choice of materials, geometrical factors and welding procedure at the design stage can permit a good sensitivity to be achieved for flaw detection, while very limited published data suggest that the time-of-flight diffraction technique can provide a good sizing capability in appropriate applications. The dependence of inspectability on detailed design and the welding procedure make it particularly difficult to codify the inspection procedures for austenitic welds or even to specify criteria by which their overall effectiveness may be satisfactorily tested (5-10). These factors are aggravated by the ultrasonic behavior of some components which have to be joined and it is also found that the inspection reliability is particularly sensitive to equipment variations. It must also be recognized that in addition to the special difficulties discussed in the review, austenitic weld inspection is also subject to the normal problems of ultrasonic inspection associated with access, surface finish and flaw characteristics. In view of the lower capabilities of ultrasonic techniques for austenitic welds by comparison with ferrite welds, it is probably necessary to accept a smaller factor of safety between the smallest flaw that can be reliably detected and the largest flaw that is tolerable on safety or economic grounds (11, 12).

Organization of the Text

For experimental programme was used sample from duplex steel SAF 2205. Dimensions of the sample was 200 x 200 x 5 mm. The weld joint was created by laser beam welding. The welding parameters were: laser power 4.7 kW, laser beam focusing +10 mm, welding speed 17 mm.s-1, gas type Arca F2, gas flow 15 l.min-1.
The detection of internal indications in weld joints was performed by ultrasound reflection method. It was used the ultrasound equipment Olympus Epoch LTC with 4MHz probe and angle of 70°.

As the second method was used Phased Array ultrasound testing method. The measurement was performed by Olympus OmniScan MX2 with 10 MHz probe PA10L16-A00 (Tab. 1).

<table>
<thead>
<tr>
<th>Probe frequency</th>
<th>4 MHz</th>
<th>10 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probe /Wedge angle</td>
<td>70°</td>
<td>40° - 60°</td>
</tr>
<tr>
<td>Gain</td>
<td>60 dB</td>
<td>66 dB</td>
</tr>
<tr>
<td>Sound Velocity</td>
<td>5900 m/s</td>
<td>3100 m/s</td>
</tr>
</tbody>
</table>

Calculation minimum defect dimension, which can be measured by Phased Array probe with a frequency of 10 MHz in homogeneous material with fine-grained structure:

\[
\lambda/2 = \frac{c/2}{10 \cdot 10^8 \text{ Hz}} = 0,31/2 = 0,155 \text{ mm}
\]  

(1)

Results

Testing of samples by using the Olympus UT Epoch LTC equipment with the probe of 70° despite a various changes of parameters, it was difficult to obtain the useful results.

![Figure 1. Olympus EPOCH LTC scan report.](image)

The problem is in the dimension of austenite grains, and when using the classical probe the ultrasound beam is breaking at the grain boundaries, to obtain a noise results due to the structure of the material (Fig. 1).

Based on this knowledge was used the Phased Array ultrasound testing method.

The sample was testing by using the angle PA probe at a frequency of 10 MHz. In the weld the internal defects was not found, also the testing by using the greater sensitivity probe no indicate the defects just the external defect was detected by the using a transverse ultrasonic waves of 3100 m/s and 40 dB amplification (Fig. 2.). Using of 10 MHz frequency probe during the testing shows the worse ratio of signal/noise ratio because the austenitic grain size.
Summary

As the experiment by conventional ultrasound inspection did not show 100% results, therefore was proposed Phased Array method, which has been shown in several experimental cases, as especially useful method with respect to the testing of duplex steels. Phased Array method use more types of scans at the same time, this is due to the fact that defects may lie outside the angle of the scan, or can be hidden for a larger echo. From this finding it is clear that in order to detect the defects, the use of multiple types of scans is necessary. Ultrasound scanning of duplex steels is problematic, as the two-phase structure of the material (austenite - ferrite). The austenitic welds scanning are generally quite problematic, causing the characteristics of the structure of austenite, that is, the structure of the material exhibits a relatively high loss, and a high level of noise. Significant influence is the speed of sound, which is different from the conventional steel, and may even vary along the path of ultrasound in testing. In this way, there may be so called "Folding" of the ultrasound way. Due to the high attenuation and a high level of noise is usually not possible to test the austenitic welding by the conventional ultrasonic probes of transverse waves, for the present case, the use angle sensor producing longitudinal waves. The Phased Array testing method is suitable for the weld joints defects detection in case of the shorter length of defects as the probe aperture. If the length of the defect aperture is shorter than the probe, it may be from a linear scan (no motion sensor) to detect a possible increase of the defect dimensions earlier and more accurately than manually by measuring the height and length of the defect from the probe move on the surface. The sectorial B-scan can be relatively easily on the basis of local color differences to identify even small defects and diffraction echoes that are in A-scan difficult to distinguish from noise.

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References


