UNDERWATER ULTRASONIC PEENING
OF WELDED ELEMENTS AND STRUCTURES

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Outline

1. Introduction

2. Principles, Technology and Equipment for Ultrasonic Peening (UP)

3. Application of Underwater Ultrasonic Peening (UUP) for Fatigue Improvement of Welded Elements

4. Summary
Fatigue Strength of Base Metal (BM) and Welded Elements
Technology and Equipment for Ultrasonic Impact Treatment or Ultrasonic Peening (UIT/UP)
Schematic view of transducers for UIT/UP using piezoelectric and magnetostrictive approaches
Replaceable working heads for different industrial applications
PRINCIPLE OF ULTRASONIC PEENING

The technique is based on the combined effect of:

1. High frequency impacts of the special strikers

2. Ultrasonic oscillation in treated material
MATERIAL/PART IMPROVED BY UP

<table>
<thead>
<tr>
<th>Zone</th>
<th>Description of zone</th>
<th>Penetration (distance from surface), mm</th>
<th>Improved characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Zone of plastic deformation and compressive residual stresses</td>
<td>1 - 1.5 mm</td>
<td>Fatigue, corrosion, wear, distortion</td>
</tr>
<tr>
<td>B</td>
<td>Zone of relaxation of welding residual stresses</td>
<td>15 mm and more</td>
<td>Distortion, crack propagation</td>
</tr>
<tr>
<td>C</td>
<td>Zone of nanocrystallization (could be produced at certain conditions)</td>
<td>0.01 - 0.1 mm</td>
<td>Corrosion, wear, fatigue at elevated temperature</td>
</tr>
</tbody>
</table>
Profile of weld toe improved by Ultrasonic Impact Treatment (UIT/UP)

- Width of groove: 2 - 5 mm
- Depth of groove: 0.2 - 0.4 mm
- R

Diagram showing the profile of weld toe with labels for width and depth of groove.
The view of the butt welds in as-welded condition (left side sample) and after application of UP (right side sample)
The view of the fillet welds in as-welded condition (left side sample) and after application of UP (right side sample)
Comparison of Ultrasonic Peening and Other Fatigue Life Improvement Methods

Data from IIW Document XIII-1817-00 on fatigue testing of welded samples made from steel WELDOX 420 (yield strength - 460 MPa, ultimate strength – 570 MPa)

Specimen for fatigue testing N, cycles 1e

Series 1 – as welded (m = -2,080 /);
Series 2 – UIT treated (m = -17,5413), 5 and 3mm pin diameter;
Series 3 – hammer peened (m = -8,3701);
Series 4 – shot peened (m = -8,1321);
Series 5 – TIG dressed (m = -6,5539);
Series 6 – TIG dressed and UIT treated (m = -6,2090);
Series 7 – UIT treated (m = -9,7799), additional series, 3mm pin diameter.
Effectiveness of UIT/UP applied after welding and 50% of expected fatigue life of welded elements

Three series of welded samples were subjected to fatigue testing:
1 – in as welded condition,
2 – UP was applied before fatigue testing,
3 – UP was applied after fatigue loading with the number of cycles corresponding to 50% of the expected fatigue life of samples in as-welded condition.

The general view of welded sample for fatigue testing
Fatigue Improvement by UIT/UP

Fatigue curves of welded element (transverse non-load-carrying attachment):
1 – in as welded condition,
2 – UP was applied before fatigue testing,
3 – UP was applied after fatigue loading with the number of cycles corresponding to 50% of expected fatigue life of samples in as-welded condition.
UIT/UP of High Strength Materials

The higher the mechanical properties of the materials – the higher the efficiency of UIT/UP

1 - in as-welded condition for all types of steel
3, 5, 7 and 9 - after application of the UP to Steel 1, Steel 2, Steel 3 and Steel 4
Rehabilitation of Welded Bridge (Indiana, USA) by UIT/UP

Total Length of UP Treated Welds - 500 meters
Number of UP Treated Welded Elements - 2500
Application of UIT/UP for Rehabilitation of Mining Equipment

UIT/UP of Fatigue Critical Welds of a Grinding Mill

Total Length of Treated Welds – 250 meters
Application of UIT/UP for Rehabilitation of Stamping Equipment

UIT/UP of a Welded Reinforcement Plate
Application of UIT/UP for Fatigue Improvement of Large Welded Aluminum Panels
The new system UltraPeen® with easy replaceable working heads for Underwater Ultrasonic Peening (UUP)
Testing of New System for Underwater Ultrasonic Peening (UUP)

Depth – 30 meters
Material and Samples for Fatigue Testing

Material: CCS E36 Steel Plate For Shipbuilding

Typical Applications:
CCS E36 marine steel plates are used in manufacturing hull, maritime oil extraction drilling platform, platform tube junction and other structural components

Chemical Composition and Mechanical Property:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Chemical Composition(%)</th>
<th>C≤</th>
<th>Mn</th>
<th>Si</th>
<th>P≤</th>
<th>S≤</th>
<th>Al(%)</th>
<th>Cu≤</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCS E36</td>
<td></td>
<td>0.18</td>
<td>0.90-1.60</td>
<td>0.10-0.50</td>
<td>0.035</td>
<td>0.035</td>
<td>0.015</td>
<td>0.35</td>
<td>CCS/E36</td>
</tr>
</tbody>
</table>

Ultimate Strength  576.7 MPA  Yield Strength 428.6 MPA
The process of underwater welding and Ultrasonic Peening by using UltraPeen® system
Underwater Ultrasonic Peening of Welded Element (automatic)
View of the welded plate after UUP
View of the welded samples for fatigue testing
(left – in as-welded condition, right – after UUP)
Fatigue testing of welded samples

Axial loading, R=0.1
Fatigue Improvement by UUP

\[ R_\sigma = 0 \]

\[ \sigma_{a, f} \text{ MPa} \]

as-welded condition

after UP
Summary

1. The fatigue testing of welded specimens showed that the UIT/UP is the most efficient improvement treatment as compared with traditional techniques such as grinding, TIG-dressing, heat treatment, hammer peening, shot peening or application of LTT electrodes.
Summary

2. The results of the fatigue testing showed that the developed technology and equipment for Underwater Ultrasonic Peening (UUP) provides significant fatigue improvement of welded elements similar to what is observed for UP in air. The fatigue life of welded samples increased under the action of UUP in 4-5 times depending on the level of applied stresses.
Thank you for your attention

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