Effect of Plate Thickness on Fatigue Strength of Base Material and Butt Welded Specimens Made from EH40 Steel Thick Plates: Phase 1

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ABSTRACT
In large vessels, the thickness of deck plating has increased significantly during the last decade. Hence, it is not possible to ignore the effect of plate thickness on fatigue strength for these structures. To complement existing data and to establish the effect of plate thickness on fatigue strength, constant amplitude fatigue tests were carried out under tensile and bending loads for base material and butt welded specimens of various thicknesses made from high-tensile EH40 steel. Based on the fatigue test results and available literature, the thickness exponent was derived.

KEY WORDS: Fatigue strength; thickness exponent; fatigue tests; base material; butt welded specimen.

INTRODUCTION
“Container ships are increasing in size all the time, with the 10,000 TEU barrier finally having been broken. Nearly half of the container ship order book is comprised of ships with a capacity of greater than 6,000 TEU. With container ships of this size the owner and the builder will be particularly focussed on the reliability and performance of the hull structure over the course of the vessel’s transpacific trading life” - these are quotations from the article “Towards the ultra-large container ship” published in Lloyd’s Register technical news magazine “Horizons”, March 2005 issue.
Increase in container ship capacity inevitably leads to increase in size and thicknesses of hull structures. Hence it is not possible to ignore effect of plate thickness on fatigue strength of deck structures such as deck (hatch) opening corners. To estimate fatigue life of these structures, fatigue resistance data (S-N curves) for base material and butt welded specimens of various thicknesses are required.

Base material specimens were flame-cut and tested in the as-received condition. Specimens were tested under three-point bending in laboratory environment. Frequency varied from 1 to 25 Hz. Stress ratio was R=0.1.

Thickness exponent z was obtained using following equation:

\[ S_t = S_{ref} \left( \frac{t_{ref}}{t} \right)^z \]

where \( S_t \) and \( S_{ref} \) are fatigue strengths of the specimen of arbitrary and reference thickness at reference number of cycles to failure, \( z \) is the thickness exponent. Reference thickness of 22 mm was used, reference fatigue life is 10^6 cycles.

Thickness exponent \( z \) is given in Table 2.

LITERATURE REVIEW ON EFFECT OF PLATE THICKNESS

Base Material Specimens
An experimental investigation was carried out (Orjasaeter et al, 1987) to evaluate the fatigue properties of a low-carbon micro-alloyed steel, in plate thicknesses of 30 to 160 mm. Mechanical properties of the steel are given in Table 1.

<table>
<thead>
<tr>
<th>Plate thickness, mm</th>
<th>Yield strength, MPa</th>
<th>Ultimate strength, MPa</th>
<th>Elongation, %</th>
<th>Charpy energy at -40°C, J</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>368</td>
<td>490</td>
<td>33</td>
<td>282-352</td>
</tr>
<tr>
<td>70</td>
<td>340</td>
<td>486</td>
<td>36</td>
<td>339-364</td>
</tr>
<tr>
<td>100</td>
<td>341</td>
<td>491</td>
<td>37</td>
<td>189-348</td>
</tr>
<tr>
<td>130</td>
<td>320</td>
<td>476</td>
<td>36</td>
<td>268-348</td>
</tr>
<tr>
<td>160</td>
<td>302</td>
<td>473</td>
<td>38</td>
<td>218-368</td>
</tr>
</tbody>
</table>

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Table 2. Thickness exponent obtained at reference stress range of 10^6 cycles.

<table>
<thead>
<tr>
<th>Specimen type</th>
<th>Thickness, mm</th>
<th>Thickness exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base material</td>
<td>30-70-100-130-160</td>
<td>0.125</td>
</tr>
</tbody>
</table>