WELD FATIGUE TEST

AREA A

\[ \log \frac{P}{A} = \log S_{nom} \]

N
COMPLEX STRUCTURE

$S_{nom}$ DOESN'T EXIST!

Locally, the notch cares about stress and strain, not load.

A strain gage can't measure notch strain, but can measure off-notch strain.
<table>
<thead>
<tr>
<th>STRAIN CONCENTRATION:</th>
<th>GAGE MEASURES IT</th>
<th>GAGE GETS AS CLOSE AS YOU CAN GET WITH A STRAIN GAGE. NEED $k_f$ GAGE-TO-NOTCH. NEED $k_t$ IF CONCERNED WITH YIELDING.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATERIAL:</td>
<td>HOMOGENEOUS</td>
<td>HOMOGENEOUS</td>
</tr>
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<td></td>
<td></td>
<td>BASE METAL? WELD METAL? HEAT-AFFECTED ZONE?</td>
</tr>
</tbody>
</table>
AWS STRUCTURAL WELDING CODE (REF 7)
STEELS HAVING $\sigma_y < 100$ ksi
TUBULAR CONNECTIONS, BUT LOCAL
("HOT SPOT") STRAIN IS USED.
MEAN STRESSES ARE IGNORED

AWS "X" CURVE - 97% SURVIVAL
(X CURVE) * 7 IN LIFE - 50% SURVIVAL (REF 9)
(X CURVE) + 3 IN LIFE - DESIGN LINE FOR
NON-REDUNDANT MEMBERS

CRACK FORMATION LIFE, CYCLES
PREDICTED CYCLES TO CRACK BY AWS "X*7" (THE MEDIAN)

1a, 1b: MEDIAN SERVICE LIFE VS. TWO SAMPLES GAGED
2, 3, 4, 5: FULL-SCALE FATIGUE TESTS OF DIFFERENT COMPONENTS
6, 7: REPLICAS OF WELD FATIGUE TEST SAMPLES

ALL WELDS ARE FILLET WELDS, $\frac{1}{8}''$ TO $\frac{1}{2}''$

ACTUAL CYCLES TO CRACK FORMATION
A36 BASE METAL (REF 2)
\[ \varepsilon_f' = 0.271 \quad \sigma_f' = 1013 \text{ MPa (147 ksi)} \]
\[ C = -0.451 \quad E = 190 \text{ GPa } \left( 27.6 \times 10^6 \text{ psi} \right) \]
\[ b = -0.132 \]

\[ \Delta \varepsilon = 2 \varepsilon_f' (2N)^C + 2 \frac{\sigma_f'}{E} (2N)^b \]

(1) \( \Delta \varepsilon \)
(2) \( \Delta \varepsilon, K_f = 1.3 \)
(3) \( \Delta \varepsilon, K_f = 2.0 \)
(4) \( \Delta \varepsilon, K_f = 3.0 \)
(5) AWS "X*7"

GAGE-TO-NOTCH STRAIN CONVERSION (\( \Delta \varepsilon \rightarrow \Delta \varepsilon \)) IS BY NEUBER'S RULE

Cycles to Crack Formation
TESTS BY DIJKSTRA & DEBACK
TUBULAR T & X JOINTS. LIFE TO FIRST CRACK.
IN THIS FIGURE, FITTED LINES HAVE SLOPE OF
AWS "X" CURVE MIDSECTION
DIJKSTRA & DEBACK DATA
MEDIAN FAILURE LINES, USING AWS SLOPE

Cycles to Crack Formation

LIFE AT 1000 με
DIA. 6.5” 1.1 \times 10^6
DIA. 1.5” 1.5 \times 10^5
DIA. 3” 5.3 \times 10^4

AWS "X" 2.5% SURVIVAL
SLOPE FROM AWS "X" CURVE AND AWS "X×7" CURVE

$10^6$ CYCLES TO CRACK FORMATION

SHAPE PARAMETER ($\beta$)

PROBABILITY %

PERCENT FAILURES

CUMULATIVE HAZARD %

$10^6$
WEIBULL MODEL - "SERIES SYSTEM"
- "WEAK LINK SYSTEM"

SCALE PARAMETER WITH ONE COMPONENT = $\alpha$
SCALE PARAMETER WITH m COMPONENTS = $\alpha'$; $\beta$ IS UNCHANGED

$\alpha' = \frac{\alpha}{m^{1/\beta}}$

IF A GIVEN WELD IS ONE COMPONENT, WHAT IS TWO COMPONENTS?

ONE WELD, TWICE AS LONG?

TWICE THE SURFACE?

TWICE THE VOLUME?

LET $m = CD^X$

$\alpha' = \alpha(CD^X)^{-1/\beta} = C \cdot D^{-X/\beta}$

$\log \alpha' = \log C - \frac{X}{\beta} \log D$; then

$\log \alpha' \quad \text{slope} = -\frac{X}{\beta}$

$\log D$
SUPPOSE
TESTED 6.6" SAMPLE,
PREDICTED OTHERS
USING \( m \) PROPORTIONAL TO \( D^3 \)

<table>
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<tr>
<th>DIA.</th>
<th>TEST</th>
<th>PREDICTED</th>
<th>TEST</th>
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</thead>
<tbody>
<tr>
<td>6.6&quot;</td>
<td>1.1x10^6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18&quot;</td>
<td>1.9x10^5</td>
<td>1.5x10^5</td>
<td></td>
</tr>
<tr>
<td>36&quot;</td>
<td>5.6x10^4</td>
<td>5.3x10^4</td>
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CONCLUSIONS

(1) "HOT SPOT STRAIN" MEASUREMENTS ARE A VERY USEFUL TECHNIQUE FOR WELD FATIGUE LIFE PREDICTION

(2) WATCH TECHNOLOGY COMING FROM WORK ON OFF-SHORE DRILLING PLATFORMS

(3) THE AWS "X*7" IS ESSENTIALLY EQUIVALENT TO A NEUBER ANALYSIS WITH:
   - CYCLIC PROPERTIES OF ASTM A-36
   - $K_f = 2.0$
   - MEAN STRESS IGNORED

   BOTH HAVE CORRELATED WITH GE-ERIE DATA ON STRUCTURES USING 1/4" TO 1/2" NON-CONTOURED FILLET WELDS

(4) DIJKSTRA AND DEBACK EXPERIMENTS SHOW AN IMPORTANT SIZE EFFECT. MY ANALYSIS SUGGESTS THAT VOLUME OF HIGHLY STRESSED WELD IS THE "SERIES SYSTEM" PARAMETER FOR A WEIBULL MODEL
REFERENCES


