Adams, Fatigue crack growth studies on constant compliance specimen

111

20) Vogel, H., Physik. Z. 22, 645 (1921).

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Fatigue crack growth studies on constant compliance specimen

By N. J. I. Adams

With 6 figures in 7 details and 2 tables

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Symbols:

\( a \) crack length, ins.
\( a_0 \) initial crack length
\( c \) constant
\( e \) distance from wedge tip to line of load application, ins.
\( H_p \) depth of tapered split arm at load line ins.
\( K_I \) stress intensity p.s.i. \( \sqrt{\text{ins}} \)
\( K_{I\text{max}} \) maximum fatigue stress intensity p.s.i. \( \sqrt{\text{ins}} \)
\( K_{I\text{min}} \) minimum fatigue stress intensity p.s.i. \( \sqrt{\text{ins}} \)
\( N \) number of cycles
\( P \) load, lb.
\( R \) stress intensity ratio < 1.
\( \sigma \) stress p.s.i.

Introduction

The study of problems of fatigue crack growth has in the past been conducted on wide centre-cracked plates [1, 2]. The crack is grown from an initial starter notch, and as it extends so the crack tip conditions vary continuously. Such specimens require complex end fittings and high load capacity testing machines. The constant compliance specimen is a small compact form suggested for fracture toughness testing. It has the property of constant crack tip stress intensity for non-dimensional crack lengths \( a/W \), approximately equal to 0.25 to 0.5 and requires only a low load capacity machine for testing.

Specimen configuration and experimental set-up

Fig. 1 shows the details of the specimen used in the work which is reported. The dimensions are based on a quarter crack length to suit available crack growth recording gauges and the \( K_I \) calibration by (3) which gives

\[
\frac{K_I \sqrt{BW}}{P} = 14.2
\]

for

\[
\frac{H_p}{e} = 0.4, \quad \frac{W}{e} = 5 \quad \text{and} \quad \frac{W}{H_p} = 12.5.
\]

It was pointed out in (3) that forward direction crack growth was highly unstable and to overcome

Fig. 1a. Geometry of constant compliance specimen
Fig. 1b. Details of constant stress intensity specimen

this problem a side groove of 0.03 ins. depth was machined along one face.

The arrangement for testing the specimen is shown in fig. 2, axially of loading is maintained by two guide strips attached to the sides of the upper mounting block, whilst the lower is free to slide, being restrained from sideways motion.

The crack growth in terms of stress cycles is recorded using a crack tip sensing gauge linked to a digital printout unit (4). The rate of stressing was 500 cpm for all tests.

Experimental results

Results of crack growth rate against maximum stress intensity are obtained for values of $R = 0.1, 0.2, 0.3$ and 0.4 (tables 1 and 2), these are shown plotted for the two materials in fig. 3 and 4 indicating a linear relationship between $da/dN$ and $K_{I_{\text{max}}}$. In the case of the Maraging steel, tests at 48 ksi/vin result in plane stress conditions.

Table 1. Crack growth rates at various stress intensity ranges in Maraging steel

<table>
<thead>
<tr>
<th>$K_{I_{\text{Max}}}$</th>
<th>26</th>
<th>30</th>
<th>34</th>
<th>40</th>
<th>48</th>
<th>$10^{-6}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_{I_{\text{Min}}}$</td>
<td>2.6</td>
<td>3.0</td>
<td>3.4</td>
<td>4.0</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>$da$</td>
<td>$10^{-6}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$dN$</td>
<td>6.1</td>
<td>9.44</td>
<td>11.6</td>
<td>15.28</td>
<td>24*</td>
<td></td>
</tr>
<tr>
<td>$K_{I_{\text{Min}}}$</td>
<td>5.2</td>
<td>6.0</td>
<td>6.8</td>
<td>8.0</td>
<td>9.6</td>
<td>$R = 0.1$</td>
</tr>
<tr>
<td>$da$</td>
<td>$10^{-6}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$dN$</td>
<td>5.36</td>
<td>5.92*</td>
<td>8.8*</td>
<td>14.1*</td>
<td>15.1*</td>
<td>$*10^{-4}$</td>
</tr>
<tr>
<td>$K_{I_{\text{Min}}}$</td>
<td>7.8</td>
<td>9.0</td>
<td>10.2</td>
<td>12.0</td>
<td>14.4</td>
<td>$R = 0.2$</td>
</tr>
<tr>
<td>$da$</td>
<td>$10^{-6}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$dN$</td>
<td>3.89</td>
<td>5.93</td>
<td>7.95</td>
<td>10.86</td>
<td>13.74</td>
<td>$*10^{-4}$</td>
</tr>
<tr>
<td>$K_{I_{\text{Min}}}$</td>
<td>10.4</td>
<td>12.0</td>
<td>13.6</td>
<td>16.0</td>
<td>19.2</td>
<td>$R = 0.3$</td>
</tr>
<tr>
<td>$da$</td>
<td>$10^{-6}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$dN$</td>
<td>2.38</td>
<td>3.85</td>
<td>5.81</td>
<td>8.39</td>
<td>10.41</td>
<td>$*10^{-4}$</td>
</tr>
</tbody>
</table>

*) Repeat test.