CYCLIC DEFORMATION AND CRACK INITIATION
IN TUBES UNDER MULTIAXIAL LOADING

B. Windelband, B. Schinke, D. Munz

Institut für Zuverlässigkeit und Schadenskunde im Maschinenbau,
Universität Karlsruhe (TH)
Institut für Materialforschung II, Kernforschungszentrum Karlsruhe

Abstract

A new test facility for multiaxial testing of tubes, specimen geometry and material data of tubes are presented in this report. First results from preliminary tests of this tubes, made from AISI 316 (LN) austenitic steel, are compared with data from uniaxial tests.

Introduction

Components used in engineering applications are subjected mostly to complex multiaxial loads. Typically, multiaxial loads occur in the notch root, but also in components subjected to thermal cycling, such as the first wall of a fusion reactor. Failure characteristics in these cases frequently are extrapolated from uniaxial tests conducted under comparable loads. However, these methods are not fully backed experimentally, especially where high and complex multiaxial loads are involved.

Some facilities for multiaxial testing of tubes (tension-compression combined with torsional and/or circumferential load) are described in /1-6/. Different types of tubes are used with a wall thickness mostly lower than 1 mm.

A facility is presented in this report which allows any biaxial stress condition to be achieved in tubes under isothermal
conditions. This is to simulate equi-biaxial load conditions typical of cyclic thermal loads in the austenitic AISI 316 L(N) type steel. Crack initiation and crack growth is examined.

The load is composed of a controlled cyclic axial load (tensile and compression loads) and a circumferential load (controlled internal and external pressures). Torsion has been envisaged as an additional possibility. Some first results obtained in experiments and preliminary tests are presented.

**Material and Specimen Geometry**

The specimen material is a specially specified batch of the austenitic AISI 316 L type of steel (material No. 1.4909) with a higher nitrogen fraction (Fig. 1), which is used as a material for the first wall of a fusion reactor. Micrographs of material specimens indicate a homogeneous structure with approx. 1% of band-shaped 8-ferrite inclusions in the longitudinal direction of the tube. The grain size is 5-6 according to ASTM.

![Micrograph of material specimen](image)

**Fig. 1:** Longitudinal microsection through the tube, and chemical composition.

<table>
<thead>
<tr>
<th>Chem. Element</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>Co</th>
<th>Cu</th>
<th>Nb + Ta + Ti</th>
<th>B</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random analysis melt 1.4909</td>
<td>0.26</td>
<td>0.37</td>
<td>0.169</td>
<td>0.010</td>
<td>0.003</td>
<td>0.1734</td>
<td>0.241</td>
<td>0.1235</td>
<td>0.029</td>
<td>0.048</td>
<td>0.025</td>
<td>0.0015</td>
<td>0.053</td>
</tr>
</tbody>
</table>

The test specimens are made of solid hot drawn tube (60x5). In order to achieve the surface qualities required for fatigue experiments, the tubes were subsequently finished and polished; their dimensions in the test cross-section now are 58.6x3.45 (Fig. 2). The specimen cross section increases to-