7th ICBMFF

Proceedings of the Seventh International Conference on Biaxial/Multiaxial Fatigue and Fracture

June 28 - July 1, 2004
Berlin, Germany
## CONTENTS

### Keynote Lectures

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiaxial fatigue - methods, hypotheses and applications. An overview</td>
<td>3</td>
</tr>
<tr>
<td>H. Zenner</td>
<td></td>
</tr>
<tr>
<td>Present limitations in the assessment of components under multiaxial service loading</td>
<td>17</td>
</tr>
<tr>
<td>C. M. Sonsino, H. Zenner, F. Yousefi-Hashtyani, M. Küppers</td>
<td></td>
</tr>
<tr>
<td>Basic working principle of the advanced incremental crack initiation life prediction method for arbitrary multiaxial loading EVICD</td>
<td>27</td>
</tr>
<tr>
<td>H. Nowack, W. Ott, C. Baum, A. Buczynski, K.-H. Trautmann, G. Glinka</td>
<td></td>
</tr>
<tr>
<td>Challenges in developing a general constitutive relation for cyclic loading</td>
<td>33</td>
</tr>
<tr>
<td>F. Ellyin, Z. Xia</td>
<td></td>
</tr>
<tr>
<td>Estimation of notch stresses and strains under multiaxial non-proportional loading</td>
<td>45</td>
</tr>
<tr>
<td>O. Hertel, R. Döring, J. Hoffmeyer, M. Vormwald, T. Seeger</td>
<td></td>
</tr>
<tr>
<td>Energy models of fatigue life of steels and an aluminium alloy under non-proportional loading</td>
<td>57</td>
</tr>
<tr>
<td>T. Itoh, A. Karolczuk, C. T. Lachowicz, E. Macha</td>
<td></td>
</tr>
<tr>
<td>Analysis and synthesis of standardized multiaxial load-time histories for structural durability assessment</td>
<td>63</td>
</tr>
<tr>
<td>T. Bruder, P. Heuler, H. Klätschke, K. Störzel</td>
<td></td>
</tr>
<tr>
<td>Life prediction for notched components in non-proportional low cycle fatigue - experiment and FEM analysis</td>
<td>79</td>
</tr>
<tr>
<td>M. Sakane, T. Itoh, T. Susaki, Y. Kawazoe</td>
<td></td>
</tr>
<tr>
<td>Critical plane concept and energy approach in multiaxial fatigue</td>
<td>85</td>
</tr>
<tr>
<td>T. Palin-Luc, F. Morel</td>
<td></td>
</tr>
<tr>
<td>Multiaxial mixed mode cracking and small crack initiation and propagation</td>
<td>97</td>
</tr>
<tr>
<td>M. de Freitas, L. Reis, B. Li</td>
<td></td>
</tr>
<tr>
<td>Multiaxial fatigue assessment: Current state and future trends</td>
<td>109</td>
</tr>
<tr>
<td>G. B. Marquis</td>
<td></td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Low Cycle Fatigue</strong></td>
<td>Simulations of multiaxial cyclic stress/strain in smooth and notched specimens</td>
</tr>
<tr>
<td></td>
<td>B. Li, L. Reis, M. de Freitas</td>
</tr>
<tr>
<td></td>
<td>Multiaxial fatigue life predictions by using modified Manson-Coffin curves</td>
</tr>
<tr>
<td></td>
<td>B. Atzori, G. Meneghetti, L. Susmel</td>
</tr>
<tr>
<td></td>
<td>Design criteria for proportional and non-proportional low cycle fatigue</td>
</tr>
<tr>
<td></td>
<td>T. Itoh, M. Sakane, T. Hata</td>
</tr>
<tr>
<td></td>
<td>Low cycle fatigue life predictions using energy-life curves</td>
</tr>
<tr>
<td></td>
<td>H. Jahed, A. Varvani-Farahani</td>
</tr>
<tr>
<td><strong>High Cycle Fatigue</strong></td>
<td>Estimation of the crack initiation probability in high cycle multiaxial fatigue with a volumetric energy based criterion</td>
</tr>
<tr>
<td></td>
<td>T. Delahay, T. Palin-Luc, E. Ducasse, J.-L. Charles</td>
</tr>
<tr>
<td></td>
<td>Fatigue behaviour of a sharply notched carbon steel under combined traction and torsion loading</td>
</tr>
<tr>
<td></td>
<td>B. Atzori, F. Berto, P. Lazzarin, M. Quaresimin</td>
</tr>
<tr>
<td></td>
<td>A probabilistic two-scale model for high cycle fatigue life predictions under multiaxial loadings</td>
</tr>
<tr>
<td></td>
<td>C. Doudard, S. Calloch, A. Galtier, P. Cugy, F. Hild</td>
</tr>
<tr>
<td></td>
<td>Fatigue life and strength criteria based on loading non-proportionality measure</td>
</tr>
<tr>
<td></td>
<td>D. Skibicki</td>
</tr>
<tr>
<td></td>
<td>3D observation of transient stage I to stage II behaviour of surface crack growth in carbon steel and aluminium alloys under high cycle fatigue stressing</td>
</tr>
<tr>
<td></td>
<td>S. Harada, Y. Kuroshima</td>
</tr>
<tr>
<td></td>
<td>The modified Wöhler curve method for predicting the fatigue limit of notched components under multiaxial fatigue loading</td>
</tr>
<tr>
<td></td>
<td>L. Susmel</td>
</tr>
<tr>
<td></td>
<td>Fatigue life of AlCu4Mg1 aluminium alloy under constant amplitude bending with torsion</td>
</tr>
<tr>
<td></td>
<td>D. Kardas, K. Kluger, T. Łagoda, P. Ogonowski</td>
</tr>
<tr>
<td></td>
<td>Effect of the mean shear stress on the torsional fatigue strength</td>
</tr>
<tr>
<td></td>
<td>A. Bernasconi, M. Filippini, S. Foletti, I. V. Papadopoulos</td>
</tr>
</tbody>
</table>

Deutscher Verband für Materialforschung und -prüfung e.V.

viii
A new high cycle fatigue multiaxial model
C. A Gonçalves, J. A. Araújo, E. N. Mamiya

Modified Wöhler curve method and Eurocode 3: accuracy in predicting the multiaxial fatigue strength of welded joints
L. Susmel, R. Tovo

Initiation and Small Crack Growth

Fatigue lifetime under non-proportional multiaxial alternating loading and its modelling
M. Weick, J. Aktaa

Statistical analysis of microcrack growth in a 1015 SAE steel subjected to different types of cyclic loading
A. Schram, M. Glatzer

Experimental investigations on the deformation and damage behaviour of metallic materials under multiaxial non-proportional loading
J. Hoffmeyer, R. Döring, T. Seeger, M. Vormwald

Energy exchanges during plane stress crack growth in uniaxial and biaxial tension
V. P. Naumenko, A. G. Atkins

The frequency influence on fatigue crack growth in D16T Al-alloy subjected to biaxial cyclic loads at various R-ratios
A. A. Shaniovski

Fatigue damage of weld seams with and without postweld treatment under multiaxial loading based on a fracture mechanics approach
K. Rother, T. Nicak, E. Weiß, B. Postberg, J. Rudolph

A method for the prediction of the influence of flaws on the fatigue strength under biaxial loading
A. J. McEvily, M. Endo

Fatigue lifetime prediction based on a short crack growth model for multiaxial non-proportional loading
R. Döring, J. Hoffmeyer, T. Seeger, M. Vormwald

Mean stress effect on cyclic deformation and short crack growth behaviour in torsional fatigue of steels
X. Cheng, I. Ohkawa, M. Misumi

Constitutive Modelling

Hardening and lifetime prediction under biaxial low cycle fatigue
M. V. Borodii, V. A. Strizhalo
Ratchetting modeling of a duplex stainless steel: Model based on yield surface distortion
V. Aubin, S. Degallaix

On the efficiency of the integral approach in multiaxial fatigue
B. Weber, K. Ngargueuedjim, B. Soh Fotsing, J. L. Robert

The Ohno-Wang type kinematic hardening rules for multiaxial ratchetting simulation
X. Chen, R. Jiao, K. S. Kim

Constitutive modelling of non-proportional hardening, cyclic hardening and ratchetting
R. Döring, J. Hoffmeyer, T. Seeger, M. Vormwald

Consistent approach to multiaxial strength and fracture analysis of structures: concept, methodology, applications to integrity providing and reliability assessments of main gas pipelines
V. Aladinsky, V. Makhanev

A constitutive high cycle fatigue damage model based on the interaction between microplasticity and local damage
L. Flacelière, F. Morel, A. Dragon

Comparative study on the efficiency of algorithms for shear stress amplitude calculation
A. Bernasconi, I. V. Papadopoulos

Non-Metallic Materials and Composites

Near-application testing of ceramics under proportional and non-proportional loading
P. Scheunemann, D. G. Feldmann

Experimental research on the fatigue of natural rubber subjected to multiaxial loading
S. Dong, C. Bathias, K. Le Gorju, F. Hourlier, J.-F. Vittori

Fatigue crack nucleation and growth in filled natural rubber subjected to multiaxial stress states
W. V. Mars, A. Fatemi

Micro-mechanisms of crack initiation and multiaxial fatigue life prediction for a natural rubber
N. Saintier, G. Cailletaud, R. Piques
Variable Amplitude Fatigue & Lifetime Assessment

Lifetime assessment under multiaxial random loading - calculations and tests
F. Yousefi-Hashtyani 341

Adaptation of cumulative damage models to multiaxial fatigue
K. Ngargueudedjim, G. Anago, J. L. Robert 349

An analysis of the critical plane methods for combined bending/torsion loading fatigue
J. C. Balthazar, N. R. C. Vilela, J. A. Araújo 355

Critical plane approach for the assessment of the fatigue behaviour of welded aluminium under multiaxial spectrum loading
M. Küppers, C. M. Sonsino 361

Application of a criterion for lifetime prediction under multiaxial random loading
A. Carpinteri, A. Spagnoli, S. Vantadori 369

Numerical simulation of the fatigue behaviour of welding seams based on notch strains
G. Kepplinger, F. Ruprechter, G. Stangl, A. Dunst, M. Hofer 375

Applying energy based criteria for calculation of an equivalent local stress amplitude of welded aluminium joints under in- and out-of-phase bending with torsion
T. Łagoda, M. Küppers 381

Energy based fatigue life prediction under random loading
D. S. Tchankov 389

Verification of the advanced crack initiation life prediction method EVICD and the advantages of the engineering input section
C. Baum, A. Buczynski, W. Ott, K.-H. Trautmann, G. Glinka, H. Nowack 395

Lifetime prediction under multiaxial variable amplitude loading - further development of the shear stress intensity hypothesis
J. Liu 401

Local and non-local normalised equivalent strain functionals for cyclic fatigue
S. E. Mikhailov, I. V. Namestnikova 409

Lifetime calculation under multiaxial random loading with regard to the microcrack growth
A. Ahmadi, H. Zenner 415
A technique to reduce the duration of multiaxial fatigue tests under service loadings  
T. Palin-Luc, A. Banvillet, S. Lasserre, J.-F. Vittori

Mixed Mode Cracking

Multiaxial fatigue life prediction of two welded details subjected to local complex stress states  
L. Susmel, R. Tovo

Experimental determination of $K_i$, $K_{II}$, $K_{III}$ of internal cracks under mixed mode loading  
M. Guagliano, M. Sangirardi, L. Vergani

Influence of the loading direction on fatigue crack growth  
M. Sander, H. A. Richard

The CTOA-approach – a method for simulation of stable crack extension in thin walled structures under multiaxial loading  
K. H. Schwalbe, M. Schödel, J. Heerens

Fatigue crack propagation from hole under combined torsional and axial loading  
K. Tanaka, Y. Akiniwa, H. Takahashi

Investigation of crack turning phenomena to improve the damage tolerance behaviour of integral airframe structures  
H. Assler

The influence of phase difference on the fatigue strength of steel specimens containing a small hole under combined axial/torsional loading  
M. Endo, I. Ishimoto

Bidimensional stress analysis and SIF's assessment of a cracked aeronautic doubler-skin assembly by BEM and FEM  
A. Apicella, E. Armentani, R. Citarella, G. Coppola, R. Esposito

The effect of steady torsion in power shafts under rotating bending  
M. da Fonte, L. Reis, F. Romeiro, M. de Freitas

Mixed-mode fatigue crack growth and closure in aluminium alloys  
L. P. Borrego, F. V. Antunes, J. M. Ferreira, J. D. Costa

Application of Delta-J integral range for fatigue crack growth rate in mixed modes I and III  
D. Rozumek
Experimental investigations of 3D fatigue crack propagation  
M. Heyder, G. Kuhn

Coating interface fracture toughness test by combination of edge compression and slinging load  
M. Arai, Y. Okajima, K. Kishimoto

Mixed mode fatigue crack growth in welded rails  
H. Desimone, S. Bavila, D. Polidori, S. Beretta

Cyclic J-integral under non-proportional loading  
O. Hertel, R. Döring, M. Vormwald

Fracture toughness and crack growth behaviour of heat-treated 5% chrome steel under mixed mode loading  
H. G. Bong, K. S. Kim, J. G. Kim

Testing Methods and Facilities

Experimental simulation of multiaxial stress states in material testing  
R. Bardenheier, G. Rogers

Modelling and experimental verification of fatigue strength under multiaxial static pressure loading  
H.-P. Lüpfert, H.-J. Spies, P. Trubitz

Creation of a synthetic road for multiaxial fatigue limit simulation on automobiles  
A. Saathoff, F.-J. Stolze, H. Zenner

Thermal Fatigue & Creep

An attempt to analyse crack initiation under high cycle thermal fatigue on a mixing zone of auxiliary cooling system  
S. Taheri

Biaxial thermo-mechanical fatigue experiments with cruciform test pieces  
A. Samir, A. Scholz, C. Berger

Effects of stress state and specimen geometry on partitioned strainrange versus life relationships of 316LC steel at 1023K  
K. Tokimasa

Creep rupture of anisotropic tubes under complex stress state  
A. M. Lokoshchenko, D. O. Platonov
Biaxial thermomechanical fatigue on a 304 L type austenitic stainless steel
V. Maillot, G. Degallaix, S. Degallaix, A. Fissolo

Case Studies and Design

Influence of stress ratio on fatigue strength under combined bending and torsion
R. Pawliczek, D. Rozumek

Structural durability of a cast aluminium truck wheel under complex service loading
M. Küppers, C. M. Sonsino, G. Fischer, K. Störzel

Fatigue assessment of an ageing aircraft's wing under complex multiaxial spectrum loading
M. Bäckström, K. Koski, A. Siljander, S. Liukkonen, J. Tikka, G. Marquis

Approach to estimate fatigue damage of non-linear supported structures applied to multiaxial and non-proportional loading
K. Rother, H. Schüler

Elastic-plastic stress/strain analysis of notched components subjected to multiaxial dynamic loading
U. S. Fernando, S. Holt, G. C. Cockerham, J. Draper

Manuscript has not been submitted

Multiaxial fatigue behaviour of laser beam welded thin steel sheets for automotive applications
C. M. Sonsino, M. Küppers, M. Eibl, G. Zhang

An unusual fatigue failure
L. P. Pook

A statistical measure of the non-proportionality of stresses – investigations and applications
H. Dannbauer, C. Gaier, M. Steinbatz

Elastic-plastic stress/strain behaviour of notched shaft under non-proportional tension-torsion loading (Comparison of experimental and finite element results)
U. S. Fernando, N. T. Medagedara, D. E. Eaton

Manuscript has not been submitted

Contact and Fretting

Multiaxial fatigue of a railway wheel steel under combined out of phase torsion and pulsating negative axial load
A. Bernasconi, M. Filippini, S. Foletti, D. Vaudo
On the cycle fatigue limit for rolling contact fatigue 637
M. Ciavarella, H. Maitournam

Fretting fatigue: The use of high cycle fatigue multiaxial models 643
R. C. Vivacqua, A. T. S. Bernardo, E. N. Mamiya, J.A. Araújo

On ratchetting-based models of wear and rolling contact fatigue 649
L. Afferrante, M. Ciavarella

Prediction of fretting fatigue lives for flat on flat contacts using numerically derived sub-surface stresses 655
R. J. Green, U. S. Fernando

A 3D multi size finite element model of surface rolling contact fatigue crack 663
S. Bogdański, A. Kolakowski

Estimation of life in fretting fatigue with cylindrical contact 669
C. Navarro, C. Vallellano, J. Domínguez

Helix-shaped and transverse cracking of rotor shafts based on disk shrunk technology 675
B. Andrier, E. Garbay, F. Hasnaoui, P. Massin

Author Index