FATIGUE '99

PROCEEDINGS OF THE SEVENTH INTERNATIONAL FATIGUE CONGRESS

8-12 June, 1999
Beijing, P. R. China

Volume 2

EDITORS
Xue-Ren Wu
and
Zhong-Guang Wang

Organized by
Beijing Institute of Aeronautical Materials
Institute of Metal Research
Fatigue Society – C-MRS

Sponsored by
C-MRS, NSFC

Under the auspices of
International Fatigue Congress

HIGHER EDUCATION PRESS
Contents

The role of interfaces in fatigue behaviors and interfacial design resistant to fatigue in materials 645
Z. R. He

Microstructural investigation for loading sequence effects on fatigue lifetime 651
C. Fukuoka, Y. G. Nakagawa and S. T. Rosinski

The influence of metallurgical parameters on the fatigue behavior of aluminium alloy 6005A T5 657
G. Wante, C. Robin, P. Flahaut and D. Zakrzewski

Author Index

VOLUME II

Modeling and Simulation of the Fatigue Behavior

Keynote Lecture
Fatigue research topics in the EU 665
M. Steen

Dislocation modelling of stage I fatigue crack growth 673
Angus J. Wilkinson and Steve G. Roberts

On the correlation between high and low cycle fatigue behaviors of a 7050-T74 aluminum alloy 679
G. Costa, Junior, F. A. Darwish and H. H. El-Sharawy

Three-dimensional strip-yielding modelling for constraint factors 685
W. Guo, F. Rose and C. -H. Wang

New concept of the fatigue fracture of high strength materials 691
O. M. Romaniv

Computational simulation of self-heating generation in cyclic loading process 699
X. Y. Tong, D. Y. Ye and L. J. Yao

Finite deformation analysis of cyclic elastoplastic crack-tip fields and implications for fatigue fracture 705
J. Toribio and V. Kharin

Cold work energy during fatigue process 711
J. Kaleta.

To the analysis of self-affinity and self-similarity of the fractal surfaces of fatigue cracks 717
V. S. Ivanova and A. A. Shaniavski
Contents

An incremental fatigue damage model
Yanyao Jiang and Shenghong Yang 723

A nonlinear fatigue damage cumulative model
D. G. Shang, W. X. Yao and D. J. Wang 729

Prediction of fatigue failure in cast aluminum alloy components using the crack modelling method
G. Wang, D. Taylor, A. Ciepalowicz and J. Devlukia 735

Energy dissipation structure during fatigue process
L. J. Yao, X. Y. Tong and D. Y. Ye 741

Energy method of fatigue damage accumulation for structural materials
T. Topoliński 747

The description of the cyclic properties with trip under multiaxial stress state
G. Zietek 753

Continuum damage model based on material ductility and fatigue damage evolution for GH150 at 450°C
G. X. Cheng and J. Z. Zuo 759

Mechanisms of fatigue fracture in Metals
N. V. Tumanov 765

Research on the intelligent method for analyzing material fatigue property
Jia Li, An Ping, Hao Guo and Dengjun Wang 771

Generalized S-N surface of fatigue behavior
C. L. Yan and Z. T. Gao 777

New functions for description of fatigue curves and their advantages
J. Kohout and S. Véchet 783

A research on relation between two formulae for calculating fatigue safe factors
Chuanxiao Mao and Zuzhao Li 789

Fatigue Life and Life Prediction Methodology

Keynote Lecture
On cumulative fatigue damage rule and life prediction models
X. L. Zheng 797

Keynote Lecture
Life prediction of composite materials in severe-service environments
Scott W. Case and Howard G. Halverson 805
Contents

**Keynote Lecture**
Fatigue life prediction of 2-D problems by anisotropic damage mechanics
Xing Zhang, Deyu Cui and K. M. Khalid

Theory and applications of FeMFAT-a Fe-postprocessing tool for fatigue analysis
Ch. Gaier, B. Unger and J. Vogler

Fatigue life prediction of 3-D problems by damage mechanics-finite element additional load method
Iqbal Rasool Memon, Deyu Cui and Xing Zhang

The development of a total fatigue life approach accounting for nucleation and propagation
P. Laz, B. A. Craig, S. M. Rohrbaugh and B. M. Hillberry

Numerical investigation of fatigue crack growth under complex loading
H. A. Richard and M. Schöllmann

Prediction of fatigue life of carbon steel using only the tensile strength
X. S. Wang, N. Kawagoishi, S. W. Yu, H. Nisitani and M. Goto

Requirements for a new generation of multiaxial fatigue prediction methods
H. Nowack, W. Ott and K. H. Trautmann

A modified two-term fatigue life prediction model for mean stresses in steel
Sharon Peles and Menachem P. Weiss

Fatigue life calculation with stress field intensity (SFI) method
X. H. Yang and Y. L. Chen

A new method to predict the remaining fatigue life of plain concrete
Lin Yanqing and Ou Jinping

**Multi-Axial Fatigue and Mixed-Mode Crack Growth Behavior**

**Keynote Lecture**
Measurement of mode-II threshold stress intensity factor range $\Delta K_{th}$ for various steels and the threshold condition of biaxial fatigue crack growth
Y. Murakami

Fatigue crack propagation behavior under cyclic mode I or mode II with superimposed static biaxial mode loading
Yong-Hak Huh, Jun-Hee Hahn, Kyung-Jin Yoon and Jin-Young Kim

Effects of friction and threshold stress intensity factor on mixed-mode I and II fatigue crack growth behavior
Jin Qian and Ali Fatemi
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear mode fatigue crack propagation study in steel</td>
<td>899</td>
</tr>
<tr>
<td>Xiaobo Yu and Andras Abel</td>
<td></td>
</tr>
<tr>
<td>Effect of mean stress on fatigue under out-of-phase axial and torsional loading</td>
<td>905</td>
</tr>
<tr>
<td>I. Ohkawa, M. Isobe and M. Misumi</td>
<td></td>
</tr>
<tr>
<td>Mechanical behaviour and microstructural evolution of alloy 800H under biaxial cyclic loading</td>
<td>911</td>
</tr>
<tr>
<td>P. D. Portella and W. Österle</td>
<td></td>
</tr>
<tr>
<td>Non-proportional low cycle fatigue under multi-axial loading for 316L stainless steel</td>
<td>917</td>
</tr>
<tr>
<td>G. Q. He, Ch. Shu. Chen, Q. Gao, X. F. Sun and J. H. Zhang</td>
<td></td>
</tr>
<tr>
<td>Multiaxial fatigue-a probabilistic analysis of initiation in cases of defined stress cycles</td>
<td>923</td>
</tr>
<tr>
<td>A. Ekberg, R. Lindqvist and M. Olofsson</td>
<td></td>
</tr>
<tr>
<td>Elastic-plastic fatigue crack propagation in stainless steel under torsional and axial loadings</td>
<td>929</td>
</tr>
<tr>
<td>Keisuke Tanaka, Yoshiaki Akiniwa and Huichen Yu</td>
<td></td>
</tr>
<tr>
<td>A non-local theory for the assessment of multiaxial high cycle fatigue failure</td>
<td>935</td>
</tr>
<tr>
<td>B. Sjödin</td>
<td></td>
</tr>
<tr>
<td>Fatigue criterion for out-of-phase combined bending and torsion</td>
<td>941</td>
</tr>
<tr>
<td>D. Skibicki and J. Sempruch</td>
<td></td>
</tr>
<tr>
<td>Branched crack initiation and propagation under inclined loading for an austenitic stainless steel</td>
<td>947</td>
</tr>
<tr>
<td>H. J. Shi and L. S. Niu</td>
<td></td>
</tr>
<tr>
<td>An incremental multiaxial fatigue damage calculating method</td>
<td>953</td>
</tr>
<tr>
<td>C. C. Chu</td>
<td></td>
</tr>
<tr>
<td>Critical plane-strain energy density criterion of multiaxial low-cycle fatigue life</td>
<td>959</td>
</tr>
<tr>
<td>X. Chen, Sh. Y. Xu and D. X. Huang</td>
<td></td>
</tr>
<tr>
<td>Assessment of long-life time under biaxial random loadings with the energy parameter on the critical plane</td>
<td>965</td>
</tr>
<tr>
<td>T. Lagoda and E. Macha</td>
<td></td>
</tr>
<tr>
<td>Stress intensity factors $K_1$ and $K_{11}$ for semi-elliptical surface cracks in round bars</td>
<td>971</td>
</tr>
<tr>
<td>M. A. da Fonte and M. M de Freitas</td>
<td></td>
</tr>
<tr>
<td>Uniaxial fatigue test of anisotropy material as a model of biaxial fatigue</td>
<td>977</td>
</tr>
<tr>
<td>A. Cichański and J. Sempruch</td>
<td></td>
</tr>
<tr>
<td>Complex loading influence on damage accumulation in high cycle fatigue</td>
<td>983</td>
</tr>
<tr>
<td>F. Morel and J. Petit</td>
<td></td>
</tr>
</tbody>
</table>
## Contents

**Fatigue Behavior under Variable Amplitude Loading**

**Keynote Lecture**  
Developments in variable amplitude prediction methods for light weight structures  
H. Nowack  
991

Improvement to crack retardation models using “interactive zone” concept  
Z. W. Chen and O. S. Lee  
1001

Fatigue crack propagation of an Al-Zn-Mg-Cu alloy under variable amplitude loading conditions  
J. O. Peters, A. Gysler and G. Lütjering  
1009

Fatigue crack propagation of surface crack bend and compact type specimen under different types of random loading  
J. C. Radon and K. M. Nikbin  
1015

Overload Effect on Fatigue Crack Propagation in 2024-Al Alloy  
K. Hussain, A. Tauqir, A. ul Haq and A. Q. Khan  
1021

The effects of plastic zones on delay after overloading  
X. Decoopman, A. Imad, M. N. Abdelaziz and G. Mesmacque  
1027

Using the parameter $K_{p}$ for life prediction in metals under variable amplitude loading  
Markus Lang  
1033

Integration of plastic zone and crack closure concepts-prediction of crack growth under variable amplitude loading  
J. W. Provan and M. S. White  
1039

Interaction between low cycle fatigue and high cycle fatigue in common metallic materials  
G. Wheatley, D. Bowman, Y. Estrin, X. Z. Hu and Y. Bréchet  
1045

Effect of mean stress on fatigue crack growth behavior of aluminum alloy under high-low two-step loads  
Y. Katoh, T. Tanaka and H. Nakayama  
1051

A new model for crack growth prediction under random loading  
Z. W. Chen and O. S. Lee  
1057

Fatigue crack propagation behavior under overload/underload loading sequences  
X. Y. Huang, M. Lang and X. R. Wu  
1063

Effect of overloading on fatigue crack growth retardation in a 7150 aluminum alloy  
A. F. Simões, M. Pereira and L. Godefroid  
1069

Establishment of the helicopter fatigue load spectrum  
Z. T. Mu, N. C. Ma and W. J. Chen  
1075
## Contents

### Fatigue Damage and Fatigue Design

- Presentation of a mechanical design tool with fatigue consideration  
  R. Akrache and J. Lu  
  1083
- A fatigue damage rule based on plastic strain  
  Yasushi Ikai, Takeshi Yamamura and Shao Qiang  
  1089
- Fatigue strength of 18-8 type austenitic stainless steel by dynamic strain aging pretreatment  
  K. -W. Qian, W. -Z. Chen and K. -P. Peng  
  1095
- Conditions for the validity of damage accumulation models  
  Thomas Svensson and Jacques de Maré  
  1101
- Probability failure accumulative method for predicting fatigue life under spectrum loading  
  Xiaoyang Zheng, Jilong Xie and Zuyi Yuan  
  1107
- Influence of small load cycle omission on fatigue damage accumulation  
  Z. Wang and Z. W. Chen  
  1113
- The role of fatigue in the optimum design of hydro-carbon transporting pipeline systems  
  K. Jármai and J. Lukács  
  1119
- A statistical cumulative damage model to predict the fatigue life of heterogeneous materials under cyclic loading  
  H. Z. Ding and X. S. Xing  
  1125
- Damage of concrete in fatigue  
  A. Alliche  
  1131
- Calculations to damage evolving rate under symmetric cyclic loading  
  Y. G. Yu and E. J. Zhao  
  1137

### Notch Effect in Fatigue

- Comparison of different multiaxial fatigue criteria for predicting the fatigue life of notched parts  
  R. Akrache and J. Lu  
  1145
- Evaluation of notch sensitivity of Inconel 718 at elevated temperatures  
  Q. Chen, N. Kawagoishi, H. Nisitani, M. Goto and E. Kondo  
  1151
- An equivalent strain rule for elastic-plastic notch fields under triaxial stress constraint  
  W. Guo  
  1157
- Fatigue crack propagation at sharp notches  
  B. Wurm, V. B. Pham and S. Sahn  
  1163
Contents

Study of fatigue crack kinking of a circular ring with internal notch 1169
Wei Wang and L. S. Niu

Effective stress range in fatigue initiation emanating from notch 1175
N. Kadi and G. Pluvinage

Cyclic elastic-plastic strain behavior ahead of notch during fatigue under plane bending 1181
K. Shingai, T. Hirasouzu and K. Matsuo

Fatigue and crack propagation in V-notched Al-Li plates 1187
V. Dattorna, A. Irace, F. W. Panella and C. Pappalettere

Study on fatigue crack initiation law of the notches on the threaded portion of superhigh pressure pipeline 1193
A. A. Wei, Sh. Y. Chen, X. D. Chen, Y. T. Li and D. W. Yang

A modelling of Zigzag-like cracks propagation at sharp notches 1199
S. Semenov, S. Sähn and V. B. Pham

Residual Stress Effect in Fatigue

The analysis of crack growth life from cold expanded holes using the distributed dislocation method 1207
M. R. Jones, D. N. Dai, R. Cook and D. B. Rayaprolu

Computational analysis of residual stress effects on fatigue crack growth under mode I, II and mixed-mode I/II loadings 1213
H. Wang, F. -G Buchholz and H. A. Richard

The effects of hard shot-peening on high cycle fatigue properties of SUS316L steel 1219
K. Masaki, Y. Ochi and T. Matsumura

Effect of expanded hole on the delay of arresting crack propagation for two aluminum alloys 1225
R. Ghiri, G. Mesmacque, A. Amrouche and H. J. Shi

The effect of residual stress field induced by cyclic loading on crack initiation in a cracked sheet 1231
Y. N. Radayev and L. V. Stepanova

Fatigue of Welds and Joints

Fatigue durability and damage tolerance verification of welded joints 1239
Tom Lassen

Stress intensity factors for surface cracks in welded T-plate joints with fixed ends 1245
Xin Wang and Stephan B. Lambert

XIV
Contents

Fatigue crack initiation at spot welds: fracture mechanics or strain life approach 1251
H. -F. Henrysson and B. L. Josefsson

A study of the fatigue strength of welded joints using parent metal HQ70 steel 1257

Fatigue life estimation of flux cored arc welded cruciform joints of Q&T steels containing lop defects 1263
V. Balasubramanian and B. Guha

Fatigue life prediction of spot welded structures 1269
A. Blarasin and T. Giunti

Fatigue life prediction of spot welded components 1275
Y. Zhang and D. Taylor

Fatigue life prediction of welded structures using quality category under non-constant amplitude loading 1281
X. Jin, Q. P. Zhong, Y. J. Hong, J. B. WANG and J. F. Tian

Mechanical behaviour of martensitic stainless steel welded by non-traditional processes 1285
G. Casalino, V. Dattoma and A. D. Ludovico

A research on structural detail design of welding frame in high-speed rolling stock bogie 1291
Zhiming Liu, Jilong Xie, Longxiu Miao and Qiang Li

An initiation life prediction model for fatigue cracks at the toe of welded joints 1297
Beigang Nie and Yves Verreman

Strain controlled fatigue of type 316L(N) base metal and 316SS weld metal elevated temperatures 1303
A. Nagesha, M. Valsan, K. Bhanu Sankara Rao and S. L. Mannan

Experimentally based method for fatigue life prediction of aluminum welded joints 1309
T. Piršic

Simple shear fatigue of solder joint 1315
Yukiyoshi Kobayashi, Tsuneshichi Tanaka, Hideaki Nakayama and Takatoshi Yoshida

Experimental studies on fatigue crack growth characteristics of X65 SSAW pipe 1321

Crack initiation and extension characteristics of ceramic/metal joint under cyclic loading 1327
Weiping Lin, Yoshio Arai and Eiichiro Tsuchida

Determination of fatigue life by the simple tensile test in bolted joints 1333

XV
## Contents

The influence of bond defects on the fatigue strength of adhesive bonded steel sheet 1339
Arne Melander, Jan Linder, Hanna Stensjö and Anders Gustavsson

### Fretting Fatigue

Fretting fatigue behavior of surface-treated aluminum alloys 1347
K. Kondoh, Y. Mutoh, M. Mabuchi and T. Kobayashi

High cycle fretting fatigue behavior of Ti-6Al-4Vc 1353
C. Lykins and S. Mall

Fatigue and fretting fatigue of austenitic and ferritic stainless steels in pseudo-body fluid 1359
K. Nakazawa, M. Sumita and N. Maruyama

Experimental investigation on fretting fatigue of a high strength steel at ultrasonic frequency 1365
Z. D. Sun, Q. Y. Wang and C. Bathias

Study on the contact fatigue property of 35CrMoA steel 1371
J. S. Zhang, G. X. Pang and W. Z. Song

### Author Index

#### VOLUME III

Fatigue of New Advanced Materials MMCs, CMCs and Intermetallics

**Keynote Lecture**
Characterisation, assessment and modeling of fiber reinforced TiMMCs under fatigue loading 1377
P. Bowen

**Keynote Lecture**
Life prediction of titanium matrix composites under thermomechanical loading 1385
W. S. Johnson, O. Jin and J. R. Calcaterra

Fiber strength degradation and its effects on fatigue crack growth in Ti MMCs 1393
J. Liu and P. Bowen

Transverse fatigue crack propagation in unidirectional fiber reinforced SM1140+/Ti-6-4 composites 1399
X. H. Wu and P. Bowen

Damage evaluation under fatigue loading in TiMMCs using acoustic emission 1405
S. Zamperini, H. Mori, H. C. D. Whitlow and P. Bowen

---

XVI