



ESISNewsletter # 41, January, 2005

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by Viggo Tvergaard

ESIS Officers

President

Prof Alberto Carpinteri
 Dept Structural Engg & Geotechnics,
 Politecnico di Torino
 Corso Duca degli Abruzzi, 24
 10129 - Torino, Italy
 E-mail: carpinteri@polito.it

Vice-President

Prof A Pineau
 Centre des Materiaux,
 Ecole Nationale Supérieure des Mines de Paris, BP 87
 91003 Evry cedex, France
 E-mail: Helene.Beaugendre@mat.ensmp.fr

Vice-President

Prof K-H Schwalbe
 GKSS, Postfach 1160,
 D-21494 Geesthacht, Germany
 E-mail: schwalbe@gkss.de

Treasurer and Secretary

Prof Giuseppe Ferro
 Dept Structural Engg & Geotechnics,
 Politecnico di Torino
 Corso Duca degli Abruzzi, 24
 10129 - Torino, Italy
 E-mail: ferro@polito.it

Opening address by the ICF11 Chairman



On behalf of the Organising Committee of ICF11, I am very pleased to introduce the 11th International Conference on Fracture, to be held in Turin, Italy, on March 20-25, 2005. ICF11 has been organised under the High Patronage of the President

of the Republic of Italy, under the auspices of the Ministry of Infrastructures and Transportation of the Italian Government, and of the National Science Foundation of Italy (CNR), with the scientific support and sponsorship of worldwide leading Institutions in the fields of Fracture, Fatigue, Material Strength and Structural Integrity, like the International Congress on Fracture itself (ICF), the European Structural Integrity Society (ESIS), the American Society for Testing and Materials (ASTM), while the Italian Group of Fracture (IGF), the Politecnico di Torino and the Turin Academy of Sciences have taken the role of host organisations.

The conference is endorsed by a strong scientific programme and by the attendance of senior Scientists and younger Delegates coming from 53 different Countries. Besides the more traditional topics, the scientific programme will cover exciting and new developments such as scaling laws, nanomechanics, smart materials, biomechanics, geophysics and tectonics, infrastructure durability, damage and restoration of historical and monumental buildings.

12 Plenary Lectures will be delivered by well-known Speakers during the Opening, Plenary and Closing Sessions. 38 Keynote Lectures will be delivered by leading Scientists in the field of Fracture to characterise the topics of the Mini-Symposia, whereas nearly 1100 presentations are scheduled to take place during 228 Special and Contributed Sessions. This total is obtained by multiplying the 16 parallel sessions by the 14 working time periods of the conference, and adding four further events in the Auditorium. I would like to express my most sincere appreciation to the Organisers of the Special Sessions and Mini-Symposia as well as to the Referees of the papers.

The Lingotto Conference Centre, selected to host ICF11, is one of the largest in Europe, offering first-rate services. In addition, Turin - a very historic and artistic city but also a modern and dynamic one - is ready to receive you in the best way, as it will be for the Winter Olympic Games one year from now. I hope that you will also have an opportunity to visit other beautiful places and cities of Italy during your post-conference tours.

I wish you an enjoyable stay in Italy.
Very sincerely yours,

Alberto Carpinteri

WELCOME !



Dear colleague this is the second issue of the renewed ESISNewsletter. You will find here the report of some news very relevant for the future of ESIS: i) minutes of the Stockholm ESIS council including the situation of TC activities (p. 3); ii) a summary of the **editorial agreement with Elsevier** (p.3 and p.18); iii) a **calendar of future TC meetings** which is going to be published also on the the three Elsevier journals affiliated with ESIS (p.21).

Concerning the scientific content this issue contains the **invited paper** by Prof. Tveergaard. Unfortunately Prof. Mike Brown, even if he had warmly accepted the invitation, could not write his paper because of some familiar problems: we hope he can contribute to the next issues of the ESISNewsletter.

The ESIS website will have a renovated and more **modern appearance from next March**. The problem still remains **the few websites directly managed by TC's**: a more active contribution by TCs will help in keep the ESIS website updated.

Enjoy your reading and do not hesitate to send me your comments and remarks (stefano.beretta@polimi.it). Material for the next issue should be sent to me by **30th December 2005**.

Stefano Beretta

ESIS FINANCIAL SITUATION

Dear ESIS members, I would like to take the opportunity to inform you about our financial situation.

We received 84,000 euros from Past President (Prof. K.J. Miller). After 2 years, considering the Secretariat fees (secretariat, website hosting, Newsletter printing) and the incomes (memberships and Elsevier royalties), the ESIS deposit is now approximately 95,000 euros.

About the memberships only 8 Nations published material on ESIS web site: Bulgaria, Croatia, Czech Republic, France, Italy, Slovak Republic, Sweden, Ukraine. Only 3 Nations (Italy, Poland and Ukraine) have used 2/3 of ESIS Membership for national group organization.

So I would like to invite the National Groups intending to collect the 1/3 membership fees in their own Country for ESIS, keeping 2/3 for them, to send me their official Statute and the name of the Elected National Responsible to the ESIS Secretariat.

Giuseppe Ferro

ESIS 2005 Membership

good reasons for renewing your ESIS membership:

- ◆ a free copy of an ESIS procedure;
- ◆ a paper copy of ESISNewsletter;
- ◆ access to TC documents and activities;
- ◆ your support to ESIS.

how to renew ? see page 27-28

ECF16 Conference

<http://ecf16.civil.duth.gr>

Deadline for abstracts:

May 31, 2005

ESIS Website

www.esisweb.org

New graphical aspect and contents from March 2005 !!

ESIS COUNCIL MEETING 10th August 2004, 17.30 – 19.30

Lindstedtsvagen, 3
Lecture Room E31
STOCKHOLM, SWEDEN

AGENDA

1. Introduction and Communications
2. Publication Policy
3. Revision of ESIS Statute
4. ESIS Membership
5. National Groups
6. Financial Report
7. Technical Committees
8. ECF16 (Greece)
9. ECF17 (Organiser/Location to be decided)

ATTENDEES

Fifteen Countries were represented at Council, which was composed of 24 Members, these being either a National Representative, or a Representative of an ESIS Technical Committee. A full list of attendees is given at the end of these Minutes.

1. INTRODUCTION AND COMMUNICATIONS

This Council Meeting was held during the week of the 15th EUROPEAN CONFERENCE ON FRACTURE (ECF15), in Stockholm.

The President of ESIS, Professor Alberto Carpinteri, chaired the meeting and informed about the decisions and proposals of the Executive Committee. He informed that during the last two years the following activities have been organized or co-organized by ESIS:

- ESIS TC2/TC3 Meeting on "Accumulation of Fatigue Damage", Seville, May 26-30, 2003
- 8th International Fracture Mechanics Summer School (IFMASS), Belgrade, June 24-27, 2003
- ESIS TC3 Meeting on "Fatigue Crack Paths", Parma, September 10-12, 2003
- 9th Portuguese Conference on Fracture, Setubal, February 18-20, 2004
- 17th Italian Conference on Fracture (IGF17), Bologna, June 16-18, 2004
- Materials Structure & Micromechanics of Fracture, Brno, June 23-25, 2004
- ESIS TC3 Meeting on "Biaxial and Multiaxial Fatigue", Berlin, June 28-30, 2004
- 15th European Conference on Fracture (ECF15), Stockholm, August 11-13, 2004
- FESI Conference on "Integrity for Life - Structural Integrity Assessment for Life Cycle

Management", Manchester, October 20 – 21, 2004

- 11th International Conference on Fracture (ICF11), Torino, March 20-25, 2005
- Third International ASTM/ESIS Symposium on Fatigue and Fracture Mechanics, Reno, Nevada, May 18-20, 2005

The President postponed further communications to the following specific points.

2. PUBLICATION POLICY

The President reminded that copy of the proposed contract with Elsevier was sent by e-mail in July, together with the convocation to all the Members of the Council. He explained the difficulties fronted to arrive at this text and explained the most important points, that are reported below:

Elsevier will publish, under ESIS' editorial control, Technical Committees' Special Technical Publications as special issues of **Engineering Fracture Mechanics**, **Engineering Failure Analysis** or **International Journal of Fatigue** (subject to peer-review).

Elsevier will ensure that at least 33% of the International Editorial Boards of **Engineering Fracture Mechanics**, **Engineering Failure Analysis** and **International Journal of Fatigue** are made up of members working in Europe.

Elsevier will carry the ESIS logo on the outside front cover of the journals alongside the wording "Affiliated with the European Structural Integrity Society".

The calendars of **Engineering Fracture Mechanics**, **Engineering Failure Analysis** and **International Journal of Fatigue** will contain an ESIS Events section (with ESIS logo), where news and meetings of the TCs are announced.

Engineering Fracture Mechanics, **Engineering Failure Analysis** and **International Journal of Fatigue** will contain two pages per year dedicated to reporting information about ESIS Prize Winners: photographs, prize motivation and a short biography.

Engineering Fracture Mechanics, **Engineering Failure Analysis** and **International Journal of Fatigue** will publish ESIS documents and procedures as Appendices and make provision for reprints. Elsevier, where agreed with the local Organising Committee, will organise and support ESIS-hosted symposia and conferences.

Elsevier will make a single payment to ESIS of EUR 5000 on publication of each STP as a special issue of the host journal. Elsevier will pay ESIS an annual honorarium of EUR 10 000 payable on the first day of January.

After the presentation, Professor Taylor and Professor Williams showed their congratulations for the contract. The Council approved the contract unanimously.

The final text of the Contract is reported in Appendix A (see it at: www.esisweb.org).

3. REVISION OF ESIS STATUTE

The President reminded that copy of the revised version of the Statute was sent by e-mail to all the National Representatives and to all the TC Chairmen. The revision has been already approved by the Executive Committee. The President illustrated the revision commenting the principal variations. The Assembly approved the new ESIS Statute unanimously. Copy of the new Statute is reported in Appendix B.

4. ESIS MEMBERSHIP

The Secretary, Professor Ferro, reported the figures of the ESIS Members who sent the membership form to the registered office during the last two years. For the year 2003 only 105 forms were received, while for the year 2004 146 memberships have been registered up to now.

The Assembly invited the Secretary to ask the National Representatives to collect the Membership fees for their own Country, according to the new Statute.

5. NATIONAL GROUPS

The Secretary informed the Council about the situation of the National Groups.

Only 8 Nations published material on ESIS web site: Bulgaria, Croatia, Czech Republic, France, Italy, Slovak Republic, Sweden, Ukraine. Only 3 Nations (Italy, Poland and Ukraine) have used 2/3 of ESIS Membership for national group organization.

The National Groups intending to collect the 1/3 membership fees in their own Country for ESIS, keeping 2/3 for them, were kindly invited to send the official Statute and the name of the Elected National Responsible to the ESIS Secretariat.

6. FINANCIAL REPORT

The Treasurer, Professor Ferro, informed the Council about the financial situation of the Society.

The figures are the following (in Euro):

Transferring from Prof. Miller	84.257,21
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EXPENSES

Postal delivery	1645,29
Secretariat	3707,00
Web site	1570,00
Newsletter	2344,83
Total expenses	9267,12

INCOMING

ESIS Membership 2003	2998,00
ESIS Membership 2004	2600,00

Royalties Elsevier	14047,50
Total incoming	19645,50
New ESIS Deposit	94635,59

The new ESIS' Portfolio consists of 94635,59 €. The Assembly approved the report unanimously.

7. TECHNICAL COMMITTEES

Professor Beretta, ESIS Newsletter Editor, presented to the Assembly the situation concerning the TCs activity.

Three Calls for existence were addressed recently: i) the first was a letter from Professor Carpinteri dated on November 2003; ii) the second was a letter asking for TC report activity sent to all the TC Chairmen in December 2003; iii) eventually the ESIS Newsletter itself.

The result of the check is the following:

- **TC1** (Elastic Plastic Fracture Mechanics): *very active*;
- **TC2** (Micromechanisms): *no sign of activity*;
- **TC3** (Fatigue of Engineering Materials and Structures): *very active*;
- **TC4** (Polymers and Polymer Composites): *very active*;
- **TC5** (Fracture Dynamics): *very active*;
- **TC6** (Ceramics): *very active*;
- **TC7** (FM Nomenclature): *dormant*;
- **TC8** (Numerical Methods): *very active*;
- **TC9** (Concrete): *active*;
- **TC10** (Environmentally Assisted Cracking): *active*;
- **TC11** (High Temperature Mechanical Testing): *very active*;
- **TC12** (Probabilistic Interpretation of Mechanical Property Data): *no sign of activity*;
- **TC13** (Education & Training): *very active*;
- **TC14** (Smart Structures): *no sign of activity*;
- **TC15** (Structural Integrity of Wires, Ropes and Cables): *no sign of activity*;
- **TC16** (Surface Treatments): *no sign of activity*;
- **TC17** (Metal Forming Fracture): *no sign of activity*;
- **TC18** (Structural Integrity Electronic Components): *no sign of activity*;
- **TC19** (Structural Health and Integrity Monitoring): *no sign of activity*;
- **TC20** (Inclusions): *very active*;
- **TC21** (Residual Stresses): *no sign of activity*;
- **TC22** (Structural Integrity of Pipelines): *no sign of activity*;
- **TC23** (Optical Methods): *no sign of activity*;
- **TC24** (Integrity of Railway Structures): *very active*.

More in particular, we can affirm that the following TC's were never launched: TC14, TC15, TC17, TC18, TC22 and TC23. Therefore these TCs can be considered as extinguished.

On the other hand, for TC2, TC7, TC12, TC16, TC19, TC21, a new Chair or new activities are perhaps needed in order to re-vitalise the Committees.

The Assembly approved the above decisions with the request to TCs to maintain a Webpage with the same format of www.esis.ewb.org.

8. ECF 16 (GREECE)

Professor Gdoutos presented the organization of ECF 16 to the Assembly.

The 16th EUROPEAN CONFERENCE ON FRACTURE (ECF16) with the title "Failure Analysis of Nano and Engineering Materials and Structures", will be organized by the Democritus University of Thrace in Alexandroupolis, Greece, on July 3 - 7, 2006.

The web site of the conference is: <http://ecf16.civil.duth.gr>.

The Conference venue is the Thraki Palace Hotel.

The tentative programme is the following:

- *Sunday, July 2:* Registration and Welcome Reception;
- *Monday, July 3:* Plenary Talks, Sessions;
- *Tuesday, July 4:* Plenary Talks, Sessions, Banquet;
- *Wednesday, July 5:* Plenary Talks, Sessions;
- *Thursday, July 6:* Plenary Talks, Sessions;
- *Friday, July 7:* Plenary Talks, Sessions, Closing Remarks;
- *Saturday, July 8:* Daily excursion to the island of Samothraki.

The conference is divided into two Tracks:

Track 1 -Nanomaterials and Nanostructures

Track 2 - Engineering Materials and Structures

Approximately 160 experts in Fracture Mechanics have already accepted to be Members of the Scientific Advisory Board.

The Registration fee is 550 Euro (600 Euro for late registration). For PhD Student a fee of 300 Euro is considered (350 Euro for late registration). Registration fees for participants and students include: a) Admission to all sessions; b) Name badge and carry bag; c) Book of abstracts; d) CD Roms and bound volumes of the papers; e) Lunches; f) Coffee breaks; g) Welcoming reception; h) Banquet.

The Assembly approved the proposal unanimously.

9. ECF 17 (ORGANISER/LOCATION TO BE DECIDED)

The President informed that two Nations (Czech Republic and Norway) manifested the intention to organise ECF 17, to be held in 2008. During the meeting, also Professor Sedmak manifested the intention to organise ECF 17 in Serbia. The ESIS Secretariat will be in contact with the Representatives of the three National Groups in order to prepare a detailed proposal. The final decision will be taken at the next ESIS Council Meeting, to be held in Turin during ICF 11.

The meeting closed at 18.30 hours.

ATTENDEES AT COUNCIL MEETING

<i>Austria</i>	Otmar Kolednik
<i>Czech Republic</i>	Jaroslav Pokluda
<i>Finland</i>	Kim Wallin
<i>France</i>	André Pineau
<i>Germany</i>	Hellmuth Klingelhofer, Meinhard Kuna, Wolfgang Dietzel
<i>Greece</i>	Emmanuel Gdoutos
<i>Ireland</i>	David Taylor
<i>Italy</i>	Alberto Carpinteri, Giuseppe Ferro, Stefano Beretta, Andrea Spagnoli, Michele Carboni
<i>Netherlands</i>	Ad Bakker
<i>Poland</i>	Andrej Neimitz
<i>Russia</i>	Robert Goldstein
<i>Serbia</i>	Stojan Sedmak
<i>Slovenia</i>	Nenad Gubeliak
<i>Sweden</i>	Fred Nilsson, Erland Johnson
<i>UK</i>	Gordon Williams, Bhushan Karihaloo

Next ESIS Council ICF11 Conference, 23rd March 2005

**Wednesday, March 23, 2005, 6:00-7:30 p.m.
Lingotto Conference Centre (Via Nizza, 280-
-Torino), Madrid Room**

Topics to be discussed:

1. Introduction and Communications
2. ESIS Membership
3. National Groups
4. Financial Report
5. Technical Committees
6. ECF16 (Greece)
7. ECF17 (Organiser/Location to be decided)

TC ACTIVITIES

Reports from technical committees :

- TC1 – Elastic plastic fracture mechanics
- TC3 – Fatigue of Engineering Materials and Structures
- TC4 – Polymers and Polymer Composites
- TC5 – Fracture Dynamics
- TC6 – Ceramics
- TC8 – Numerical Methods
- TC9 – Concrete
- TC10 – Environmentally Assisted Cracking
- TC11 – High temperature mechanical testing
- TC13 – Education and Training
- TC20 – Role of Defects and Inclusions
- TC24 – Integrity of Railway Structures

ESIS TC1 “ELASTIC PLASTIC FRACTURE MECHANICS”

TC1 has worked in strong connection with TC8 in the last two years (last joint committee meeting had been held 9-10th December 2003, see ESISNewsletter 40, 2004).

The current work item of SC 1.4 is to produce a comprehensive fracture mechanics test method P3 covering the present state of the art of quasi-static fracture mechanics testing. In fact, P3 is an update and extension of the previous method P2. P3 is now in a very mature condition and its latest development has been the object of a meeting held in Stockholm on 10th August 2004. Attendees to the meeting were: Schwalbe, Joyce, Kolednik, Wallin.

The topics discussed had been: i) the discussion of some editorial changes in P3; ii) the new Editorial Agreement with Elsevier will result in a more wide diffusion of P3 as well as in the problem of clearly indicating the authors of the new ESIS procedure. TC1 members had been invited to send their comments about P3 to Schwalbe by **September 2004**.

Next TC1 meeting will be a joint event with TC8: it will be held on 2021 April 2005 at Serco Assurance, Risley, UK.

ESIS TC3 “FATIGUE OF ENGINEERING MATERIALS AND STRUCTURES”

1. ACTIVITIES DURING PAST TWO YEARS (2002-2004)

- (a) Professor Les P. Pook (London) : **Guest Editor of a Special Issue** of the **International Journal FFEMS**, under the title

“Biaxial/Multi-axial Fatigue”, Vol.26, No.6, 2003. Associate Guest Editors : Professor K. Dang Van (École Polytechnique, Palaiseau, France) and Professor Cetin Morris Sonsino (Fraunhofer-Institute für Betriebsfestigkeit, LBF, Darmstadt, Germany).

- (b) Professor Andrea Carpinteri (Parma), Professor Manuel de Freitas (Lisbon) and Dr Andrea Spagnoli (Parma) : **Editors of an ESIS Special Technical Publication (STP)** entitled “Biaxial/Multi-axial Fatigue and Fracture”, published by Elsevier Science Ltd (ESIS STP 31, 2003).
- (c) Professor Andrea Carpinteri (Parma) and Professor Les P. Pook (London) : **Chairmen of an ESIS International Conference on “Fatigue Crack Paths” (FCP 2003)** held in Parma, Italy, 18th to 20th September, 2003. Such a conference has drawn together the different strategies that designers and failure analysts face in relation to 3-dimensional stress-strain fields, projected fracture paths, critical plane approaches, and the fundamentals of Stage I (shear) and Stage II (tensile type) cracks. Physicists, metallurgists and fracture mechanics experts have all been required to solve some long-term problems presenting high quality papers.
- (d) Professor Cetin Morris Sonsino (Darmstadt) : **Chairman of the Seventh International Conference on “Biaxial/ Multi-axial Fatigue and Fracture” (ICBMFF 7)**, held in Berlin, 28th June to 1st July, 2004. Co-Chairmen : Professor P.D. Portella (Berlin) and Professor H. Zenner (Clausthal-Zellerfeld). Aims of the conference: to display the substantial international progress achieved in understanding of multi-axial fatigue and fracture behaviour during the past years, and to illustrate how research results apply to industrial practice.



ICBMFF 7 Conference: Prof. Zenner and Prof. Sonsino

- (e) Professor Andrea Carpinteri (Parma) and Professor Les P. Pook (London) : **Guest Editors of a Special Issue** of the

International Journal "Fatigue and Fracture of Engineering Materials and Structures" (FFEMS), under the title "Fatigue Crack Paths", with 25 papers selected from those presented at the Conference held in Parma in September 2003. Such a Special Issue of FFEMS will be published as Issue 1/2, Volume 28, 2005.

2. FUTURE ACTIVITIES (2005-2007)

- Professor Andrea Carpinteri (Parma), Professor Les P. Pook (London), Professor Cetin Morris Sonsino (Darmstadt) and Professor H. Zenner (Clausthal-Zellerfeld) : **Editors of an ESIS Special Technical Publication** under the title "Multiaxial Fatigue and Fracture", with 25 papers selected from those presented at the 7th Conference ICBMFF, held in Berlin in June 2004.
- Professor Andrea Carpinteri (Parma) and Professor Les P. Pook (London) : **Chairmen of a Mini-Symposium on "Numerical Approaches to Fatigue" at ICF 11** (11th International Conference on Fracture, Turin, Italy, March 20th to 25th, 2005).
- Professor Andrea Carpinteri (Parma) and Professor Les P. Pook (London): **Chairmen of an ESIS International Conference on "Crack Paths"** to be held in Parma, Italy, Thursday 14th to Saturday 16th September, 2006 (see the ESIS website <http://www.esisweb.org>).
- Dr Uful Fernando (Sheffield Hallam University, Sheffield): **Chairman of the Eighth International Conference on Multiaxial Fatigue and Fracture (ICMFF 8)**, to be held in Sheffield in June 2007.
- Professor Andrea Carpinteri (Parma) and Professor Les P. Pook (London): **Chairmen of the Ninth International Conference on Multiaxial Fatigue and Fracture (ICMFF 9)**, to be held in Parma in June 2010.

ESIS TC4 "POLIMERS AND POLYMER COMPOSITES"

1. ONGOING ACTIVITIES

ESIS TC4 continues to meet twice each year (in May and October) at their usual venue of Les Diablerets in Switzerland. In 2002 three TC4 work areas had been completed leading to the publication of three ISO standards. Ongoing work areas include mode I delamination of cross-ply and z-pinned composites, mode II delamination in composites, mode II fracture of structural

adhesive joints, J-crack growth resistance testing of polymers, high rate testing of polymers at greater than 1m/s, the essential work of fracture method, peel testing of flexible laminates, impact testing of short fibre composites and an impact plastic work dissipation method for polymers (inverse Charpy).

2. PUBLICATIONS

The proceedings of the conference 'Fracture of Polymers, Composites and Adhesives II' held in Switzerland in September 2002 were published by Elsevier Science as ESIS Publication 32 in November 2003 (editors B.R.K Blackman, A. Pavan and J.G. Williams). The proceedings contain 47 peer-reviewed papers selected from those presented at the 3rd ESIS TC4 conference. The book "The Application of Fracture Mechanics to Polymers, Adhesives and Composites" (edited by D.R. Moore) was completed and published by Elsevier Science as ESIS Publication 33 in December 2003. This book contains 37 articles on applications of fracture mechanics to polymers, adhesives and composites. The topics are discussed either in terms of performance or in terms of design for these materials. Authorship was by a wide multi-national group of scientists with connections to ESIS TC4. The call for papers for the 4th International ESIS TC4 Conference (to be held in Sept 2005) closes in November 2004.

3. Future meetings

- 25th-27th May 2005: Regular ESIS TC4 committee meeting.
- 11th-15th September 2005 (provisional): 4th International ESIS TC4 Conference (All to be held in Les Diablerets, Switzerland.)

For any further information on meetings or activities, please contact the committee secretary Bamber Blackman (b.blackman@imperial.ac.uk).

ESIS TC5 "FRACTURE DYNAMICS"

Activities 2004

This very active committee has around 80 members and normally meets twice every year in different European locations. Current major activities include development of a standard method for instrumented pre-cracked Charpy testing, and conducting round-robin tests on impact compression and dynamic sheet metal tensile testing of aluminium, two steel and two magnesium alloys. We maintain close contacts with Euro Dymat and with ASTM committees E08 and E28. Draft 18 of the Precracked Charpy method is now available as a pdf file.

The committee held 2 meetings during 2004. The first was on 23rd April at HSK/PSI Institute, Wurenlingen, Switzerland, and included detailed discussion of initial results from 7 laboratories on dynamic sheet tensile, and an overview of Swiss nuclear safety activities given by Dr Phillip Tipping of HSK/PSI. About 16 people attended and the minutes are available.

The second meeting was held on 19th November at Imperial College London. The progress of the two round robins was reported, and presentations were made by Bradley Leier of National Crash Center, Washington DC on rubber testing and simulation, Uwe Meyer of MPA Stuttgart on plastics tensile testing, Richard Keyte of Innoval Technology on aluminium cylinder crushing, and Alberto Regidor of CIDAUT on damping procedures. Sources of EU or other funding for high-rate research work and development of contacts with EuroDymat were also discussed. About 21 people attended the meeting, which concluded with an evening visit to the Kirkaldy Testing Museum at 99 Southwark Street.

Meetings in 2005 are planned at CIDAUT, Vallodolid, Spain on Friday 22nd April [date to be confirmed] and at TU Vienna, Austria in September/October. New members are welcome.

ESIS TC6 "CERAMICS"

1. Activities

The 22th meeting (2-3 December 2004) in Teddington UK was hosted by Dr. Roger Morrell from the National Physical Laboratory, Teddington, Middlesex, United Kingdom. 10 participants from 7 countries attended the scientific sessions.

Six scientific presentations were given on the topics of "Modulus measurement" and of the "Impact measurement"

Modulus measurement

- Roger Morrell, NPL, "Extending the impact excitation method for modulus measurement"
- Nicolas Evano, NPL, "Modulus measurement in NPL's nanotest machine"
- Giles Aldrich/Smith, NPL, "Measurement of modulus via indentation techniques"

Impact measurement

- Maria Maros and N Kaulics, University of Miskolc, Hungary, "Some aspects of dynamic fracture of Si_3N_4 ceramics during instrumented impact testing"
- Mark Gee, NPL, "Impact testing using an instrumented drop-weight impact tester"
- Ján Dusza, IMR SAS, "Impact testing of brittle materials"

RMTP - ESIS TC6 Reference Material Testing Program

Information was given by professors R. Danzer and J. Dusza concerning the **RMTP - ESIS TC6 Reference Material Testing Program**, about the new results and the about the future experiments. Up to now 9 publications have been published as the partial results of the RMTP. A keynote lecture at the ICF 11 symposium "Mechanical Reliability of modern Ceramic Materials" and at the "European Ceramic Society Conference" will be given about the RMTP.

Other ESIS TC6 activities

According to the information of the ESIS TC6 chair the number of the papers offered by the researchers working in the field of ceramics was not enough for a special issue on "Ceramic materials" for the Journal of the *Fatigue and Fracture of Engineering Material Structures*.

The papers prepared by Dr. T. Fett and Prof. H. Peterlík will be published in the normal way in the mentioned Journal.

Next Meetings etc.

The next (23rd) ordinary meeting will be hosted by Prof. A. Krell and Dr. H. Klemm on 29-30. 9. 2005 at the IKTS, Dresden, Germany.

ESIS TC8 "NUMERICAL METHODS"

This Technical Committee 8 (TC8) is devoted to Numerical Methods in Fracture Mechanics. The TC activities can be subdivided in two main parts. The first one is devoted to the organisation of round robin which are either numerical or experimental inter laboratories exercises. This intends to be a platform to gather and exchange experiences, ideas to solve problems, all this contributing to improve the quality of the numerical procedures and analyses. The second part is devoted to writing of Technical Guidelines which reflect the state of the art at the conclusion of the round robin.

Eventually, these guidelines can be used as starting documents for normative committees such as EN or ISO.

Within the TC8, a round robin on finite element simulation of fracture mechanics specimens has been initiated by Prof. W. Brocks (Germany). The objective was to evaluate the ability of the micro mechanical models to describe the fracture process. The overall project was organised in 3 distinct phases:

* Phase I : Determination of local approach parameters for ductile tearing (Task A) and for cleavage (Task B) for a German pressure vessel steel.

* Phase II : Finite element simulations of ductile crack growth (Task A) and cleavage fracture (Task B) on CT specimens.

* Phase III : Finite element simulations of CT specimens in the brittle to ductile transition curve.

Year 2004 was devoted to the completion of the Phase III of the numerical Round-Robin on micromechanical models for fracture. The corresponding report (CEA DMN/SEMI/LCMI/NT/2003-035/A) was written by C. Poussard and has been issued at the beginning of 2005. It was distributed to the round robin participants as well as TC members.

The first part (Phase I) was organised between 1993 and 1995 and the results were published by Brocks in 1995. The material investigated in this work was the German 20MnNi055 RPV (Reactor Pressure Vessel) steel. This first round robin demonstrated the interest in applying the local approach models but the number of scientists being able to perform such computations was found small, these models being generally not available in commercial codes at the time. However, the results suggested the application of improved experimental techniques so that much more information could be extracted from tensile or fracture mechanics testing.

Then Phase II was organised. Because of the manifold experimental results obtained for the German 22NiMoCr37 RPV Steel within the European project Fracture Toughness of Steel in the Ductile to Brittle Transition Regime (Heerens 1999), it was decided that the numerical analyses for that second phase would be based on that material. Phase II A1 consisted in a numerical analysis of a standard smooth tensile specimen to characterise and identify critical damage parameters for ductile tearing at 0°C. The results of this was then used in phase II A2 to predict the ductile crack growth behaviour of a 1TCT specimen and the material JR curve by applying porous constitutive models. The results of this round robin have been published by Bernauer et al. In 2002. Phase II B1 on the identification of cleavage parameters at low temperature from notched tensile specimens was then organised and the results were summarised Bernauer in 2000. At the end of this round robin, it was decided that CEA Saclay would continue the organisation and Phase II B2 was initiated in 2000. This was round robin was accomplished in 2001 and the results have been published by Poussard in 2002.

Phase III was launched in 2003. As this was initially intended, this third phase is devoted to the prediction of the brittle to ductile transition curve

for the 22NiMoCr37 German RPV steel using local approach micro-mechanical models. In the final report for this Phase III, an outline of the specification is recalled in chapter 2. A total of ten laboratories including nine disseminated in Europe as well as one in Asia have contributed. Seven finite element codes have been used. The results are given in chapter 4, 5 and 6 for the three steps that were proposed to the participants. The transition curve computed with the models agrees very well with that determined experimentally although significant differences between the sets of damage parameters have been obtained. The comparison between the computed and experimental data is further improved when a temperature dependant critical cleavage stress is accounted for. The results will now be used in order to support an ESIS guideline document entitled Guidance on local approach of rupture of metallic materials, document that describes the state of the art to apply the local approach to crack components. Finally, in order to keep track of the work that was done, Appendices 1 to 7 give an outline of the reports, notes or remarks that were made by a number of participants. Also, the interpreted results are supplied to the participants on a CD so that further work may be done by those interested.

A future **combined meeting with TC1** is planned on April 20-21, 2005 at Risley, UK.

ESIS TC9 "CONCRETE"

After the meetings held in 2003 and 2004, the present aim of TC9 activity is to prepare a compendium of topics for which fracture mechanics alone can give a reasonable solution.

The topics chosen have been:

- relationship between modulus of rupture and tensile strength (F. Wittman);
- minimum reinforcement and materials instability (A. Carpinteri);
- tension stiffening (H. Mang);
- material design for microstructure (j. van Mier);
- retrofitting of damaged concrete structures (B. Karihaloo).

The timetable of the activity will be:

- first draft by **end of 2004**;
 - circulation to TC9 members by **January 2005**;
 - comments to authors before **20 March 2005**;
 - discussion during meetin at **ICF11**;
 - publication of a compendium.
-

ESIS TC10 “ ENVIRONMENTALLY ASSISTED CRACKING”

ESIS TC10 on Environmentally Assisted Cracking (EAC) and the Subcommittee on Hydrogen Degradation hold a joint workshop on 28/29 October 2004 at VeneziaTecnologie in Porto Marghera (Venice). The workshop was organized along the line of previous workshops on "Fracture Mechanics Approach to Corrosion Assisted Cracking" and aimed at discussing issues of EAC in high strength pipeline steels, in particular in the frame of the ENI strategic project TAP (Trasporto gas ad Alta Pressione – Gas Transportation in High Pressure Pipelines). It was attended by delegates from France, Germany, Italy, U.K. and Ukraine.

After a welcome address by L. Meregalli of VeneziaTecnologie a number of talks were presented, i.e.:

- Overview of the TAP Project (R. Bruschi, Snamprogetti)
- EAC studies in the TAP project (G. Demofonti, CSM)
- EAC studies in the TAP project (M. Cabrini, Bergamo University)
- Conference on super-high strength steels – Rome, 2-4 November 2004 (G. Demofonti, CSM)
- EAC problems in pipelines – the scope of the workshop (G. Gabetta, Eni E&P)
- Certification problems in pipeline corrosion (R. Hamann, Germanischer Lloyd)
- ESIS TC 10 – Development of EAC test procedures (W. Dietzel, GKSS)
- Corrosion and hydrogen embrittlement of pipeline steels (H. Nykyforchyn, Karpenko)
- Stress corrosion of welds in supermartensitic steels (W. Dietzel, GKSS)
- Activities on EAC at Bordeaux University (J.-M. Olive, Bordeaux University)
- Collaborative Research Work on mechanisms of cracking in high strength steels (J. Atkinson, Sheffield Hallam University).

In the opening talk by R. Bruschi of Snamprogetti an overview of the TAP Project was given and a number of issues raised pertaining to a possible advanced strategy for gas transportation using high pressures (10-15 MPa) and high grade steels (X80-X120 API 5L) for pipelines. In such a strategy, EAC could play the role of a “time bomb”, since the damage caused by EAC can often only be detected after many years of service and with only a short time interval remaining between the first detection of such damage and the final failure of the component or structure under concern, as pointed out by G. Gabetta (Eni E&P, Italy). According to R. Bruschi, the X100 steel grade is mature for industrial application, but

an economical risk still remains regarding long distance/high pressure gas transportation that requires further knowledge in order to cover the present lack of in-service experience.

Lectures presented by G. Demofonti (Centro Sviluppo Materiali, Italy) and M. Cabrini (Bergamo University, Italy) provided insight into the state-of-the-art of research on this high strength steel and showed perspectives of its future applications in gas pipelines. R Hamann (Germanischer Lloyd, Germany) made it clear that such facilities for gas transportation would, on the long run, have to account for corrosion problems. In an attempt to specify the resistance to EAC of such steels, the test and evaluation techniques which have been developed by ESIS TC10 over the past 15 years, presented by W. Dietzel (GKSS, Germany), could play an important role.

H. M. Nykyforchyn (Karpenko Institute, Ukraine) presented results of an investigation on corrosion-hydrogen degradation of oil pipeline and storage tank steels after about 30 years of service, showing that the presence of ground water can be a major factor for corrosion damage at inner surfaces of oil pipelines and tanks. In addition, J.-M. Olive (Bordeaux University, France) showed the hydrogen embrittlement as a “cumulative damage” problem in the case of oil and gas pipeline steels,



R. Bruschi, Prof. J.-M. Olive and J. Atkinson during the discussion.

J. Atkinson (Sheffield Hallam University, UK) opened the floor for the subsequent panel discussion by outlining possible directions for future research based on the fracture mechanics approach favoured by the TC to adequately assess high grade pipeline steels.

In the panel discussion following the presentations on the second day, ideas for collaborative research attempts, based on the problems outlined in this workshop, were collated and included in a strategic concept for the future work of the TC. One of the items agreed upon was that the future work of the TC be closely linked to ongoing activities of other groups, in

particular those of the Working Party on *Environment Sensitive Fracture* (WP5) of the European Federation of Corrosion, EFC, chaired by J.-M. Olive, and of the European Network FITNET.

ESIS TC11 " HIGH TEMPERATURE MECHANICAL TESTING"

Minutes of the meeting held on Monday 6th December 2004 at SERCO Assurance Risley, Warrington, UK

1-INTRODUCTION & WELCOME

The Chairman, Mr McCarthy opened the meeting and especially welcomed Dr Barnard, who was attending his first meeting.

2 -ATTENDANCE & APOLOGIES FOR ABSENCE

The business cards of the six members present and a list of apologies received was reported.

3 -ELECTION OF MEMBERS OF THE COUNCIL

The committee ratified the membership to the council of the following : a) Nick Olpin, (*Bodycote Materials Testing, Newcastle on Tyne*), b) Dr Peter Barnard (*Alstom Power, Rugby*), & c) Andrew Wisbey, (*QinetiQ, Farnborough*).

It was also agreed that a) all members of the council would be asked annually to confirm their wish to continue to be a member of the council, b) the formal election of council members on a rolling three year cycle would continue to be maintained, c) an attendance list would be circulated with the minutes, and absence from three consecutive meetings would generally be taken as resignation from the council. The Secretary also agreed to scan the Article of Association and ensure that they are circulated to new members.

4 -MINUTES OF PREVIOUS MEETING

The Minutes of the 47th meeting held on 22nd March 2004, at NPL were accepted as a corrected record and a vote of thanks was passed to Dr Peter Skelton for preparing them.

5 -MATTERS ARISING

a) Multiaxial Meeting: Copies of FFEMS Volume. It was reported that additional copies of the Special Issue had not been obtained since a satisfactory deal with the publisher was not achieved.

b) Two additional Notch Papers presented by M. S. Loveday at the Multiaxial Meeting had now been published in the Autumn issue of *Materials at High Temperatures*, (Vol 21 (3) 2004)

c) HTMTC Web Site www.htmtc.com

The web site is now live and will be updated with minutes and information about forthcoming meetings etc. The Google, Yahoo and other search engines need to be notified of the existence of the HTMTC web site & keywords so that it will be found by the browsers.

6 - ESIS MATTERS

a) The Secretary agreed to supply the ESIS Webmaster (Stefano Beretta) with details of forthcoming HTMTC activities .

b) It was agreed that the HTMTC would formally pay an annual subscription to ESIS as a corporate member, and request all the members of the council would be registered as members.

c) A number of members of the HTMTC attended the ECF15 meeting recently held in Stockholm, Sweden

d) Thanks were extended to Dr Klingelhoffer who represented the HTMTC at the ESIS Council Meeting, since the Chairman & Secretary were unable to attend the meeting in Stockholm.

e) It was noted that the Italian Secretariat are encouraging national fracture bodies to collect the ESIS membership subscriptions. It is understood that the UK do not have an agreed organisation which undertake this task, and there is no formal means of electing / nominating the National Representative to serve on the ESIS Council, and no report is fed back to ESIS members in the UK.

f) It was noted that ECF 16 will take place in Alexandroupolis, Greece on 3rd – 7th July 2005, and a meeting of the ESIS Council will be held in conjunction with ECF 16.

7- FUTURE HTMTC SEMINARS

7.1 Generation of HT Data for Design : Risley Dec 2004

Mr Bretherton reported that over forty people would be attending the Seminar which would be held at the Risley Conference Centre later in the day and during the following day. It is intended that copies of the Power Point presentations would be made available to those who attended and lodged on the HTMTC Web site. A reception had been arranged and delegates would have the opportunity to visit the testing facilities. The programme for the meeting is given in Annex 4 vote of thanks was passed to Mr Ian Bretherton and to Mr Brian Daniels of Serco Assurance for organising the event.

7.2 TMF Workshop , BAM, Berlin Sept 2005

The Secretary reported that the EU funded project 'TMF-Standard' was progressing well and that the project would finish at the end of September 2005. The project partners and project leader, Dr Peter Haehner, IE JRC, Petten, NL had agreed to organise an HTMTC Workshop / Seminar at BAM, Berlin, on Thursday 22nd & Friday 23rd September 2005. The local arrangements for the meeting

would be organised by Dr Hellmuth Klingelhofer and his colleagues at BAM. Consideration is being given to the publishing the proceedings of the meeting in an appropriate special issue of a High Temperature journal. The committee welcomed this initiative and passed a vote of thanks to the Dr Haehner, Dr Klingelhofer and the project partners.

7.3 Testing of Weldments, GKSS, Hamburg, Sept 2005

Prof B Dogan tabled the draft flier for the Meeting '**Welds 2005**', which will be held at GKSS, Hamburg, Germany on Thursday 8th & Friday 9th September 2005. The dates have been chosen so as to fit in with the Int. Conf. on *Creep & Fracture of H T Components* to be held on 12-14th September 2005, being organised by EC3 –ETD, at the Inst Mech. Eng, London, so that visitors from the other side of the globe could attend both events.

Welds 2005 would focus on Design, Testing, Assessment and Safety of Welded Structures and would include presentation of the Code of Practice produced by the HTMTC Weldment Working Group (see item 8.2, below) .

A number of administrative details relating to the meeting were discussed, including liaison with ESIS TC 1Fracture, and ISO TC144. Prof. Dogan was thanked for all his work in arranging the event. For further information and registration please see <http://welds2005.gkss.de>

7.4 Creep- Fatigue Interaction

The Chairman reported that he had been contacted by Mike Winstone, (DTSL, Porton Down), concerning a proposed meeting on Creep – Fatigue Interactions, jointly organised by the IOMMM Materials at High Temperatures Committee and the HTMTC. The committee took the view that a meeting in the Autumn 2005 would conflict with the other meeting mentioned above, and that Spring 2006 would be the earliest envisaged date, and that if would be preferable in Autumn 2006 (*September* ?). The HTMTC would be happy to participate in a joint meeting provided issues relating to an equitable sharing of the work load, expenses and profit could be resolved. The HTMTC could provide input into setting up the technical programme, identifying and contacting speakers, reviewing papers, chairing sessions etc. The registration fee should be kept low inline with other HTMTC Meetings. The Chairman agreed to maintain the dialogue with the IOMMM Group and would report back at the next meeting.

8- WORKING PARTY REPORTS

8.1 Overview of New Working Parties

The Chairman reviewed the discussions that had been held with various HTMTC members since the AGM concerning the establishment of new working groups. He had invited Howard Burt, Ian

Bretherton and Malcolm Loveday to convene Task Groups covering the following : a) Miniaturised Testing at High Temperature b) Crack Initiation & Measurement c) Temperature Measurement for HT Testing. The committee agreed to request the convenors to prepare a one/two page scope for each group for circulation with the minutes. ***Any one interested in contributing to the activities of the group should contact the Secretary or the Convenors of the Groups.***

Preliminary reports are given below:

- Miniaturised Testing at High Temperature

Howard Burt had reported that two separate groups were already addressing some aspects of Miniaturised HT Testing : a) a CEN Technical Workshop Agreement has been set up to move miniaturised punch testing toward an agreed Code of Practice as a precursor to a Standard, although many research workers felt methodology was still in need of validation; b) A DTI funded project led by NPL had also recently started investigating miniaturised testing. It is therefore proposed to maintain a watching brief on the activities of these two groups, and review the suggestion to establish an HTMTC Working Group at some time in the future.

- Crack Initiation & Measurement

This working group had not yet been convened, because work had been focussed on the Data Generation meeting, but a Scope statement was being prepared.

- Temperature Measurement for HT Testing

This working group also had not yet been convened, but some members had indicated their willingness to participate in the group. The recent work on temperature measurement within the TMF-Standard project is particularly relevant.

8.2 Weldment Working Group

Prof Dogan reported that good progress is being made towards the completion of a Code of Practice on Testing of Weldments, and the preparatory work for the meeting Welds 2005, see above.

9 - ISO TC164 Meetings, Beijing, China, October 2004

The Chairman & Secretary reported on the progress made at the series of sub committees concerning International Standards relating to mechanical testing of metals recently held in Beijing. Several members of the HTMTC attended some of the meetings as part of National delegations. Reports from the UK delegates have been circulated by BSI and are given for information in **website**.

ISO TC 164 committees will meet at NPL Teddington, UK 7th – 16th October 2005, and a number of UK Companies will be approached for

sponsorship to provide some hospitality for the delegates during their stay in the UK.

10 - NATIONAL MEASUREMENT AWARD

The Secretary reported that, in conjunction with the Chairman, an application had been submitted for an award for the HTMTC under Category 4 of the National Measurement Scheme. (see **Appendix 11**) . The Committee was short listed and invited to exhibit a display stand at the Ministerial Networking Event hosted by the DTI, held in September in London. The Secretary attended the event and was introduced to the Secretary of State for the DTI, Lord Sainsbury, and to the adjudicating committee. The HTMTC were runners-up, and were awarded a 'Pioneers of Measurement Award' Certificate.

11 - DATES OF NEXT COMMITTEE MEETINGS

- **49th Meeting (AGM) : Friday 29th April 2005 at 3pm**
Venue : Rolls Royce, Derby [*to be held in conjunction with meetings of the Working Groups*].
- **50th meeting: September 2005 in Germany**
[*Date & Venue to be confirmed.*
The meeting will either be held on Wednesday 7th September 2005, in conjunction with meetings of the Working Groups, prior to the Welds 2005 meeting in Hamburg, or on Thursday 22nd September 10.00am –12.30pm BAM, held prior to the TMF Workshop.

The members of the working groups will be canvassed by the WG Leaders , and the Secretary will canvas the Main committee to determine their availability / preference.

ESIS TC13 "EDUCATION AND TRAINING"

The next School (IFMASS 9) will be organised in Bulgaria. Please visit the Web-Site of <http://www.divk.org.yu> for more detailed information.

ESIS TC20 "ROLE OF DEFECTS AND INCLUSIONS"

The annual TC20 meeting has been hosted by Prof. Fred Nilsson at the Department of Solid Mechanics of KTH (Royal Technical University), Stockholm on 30th September 2004. Meeting began at 9.30 chaired by Prof. **Anderson**, who introduced himself and asked participants to introduce themselves.

After the introductions, it was agreed to discuss results of round-robin on 42CrMo4 steel supplied by Corus. A short presentation by **Beretta** about

sampling procedure of metallographic specimens sent to round robin participants preceded the presentation of extreme inclusions measurements.

Murakami showed results obtained at Kyushu University with control areas of 0.48 mm², in particular showing a comparison between the different LEVD estimators in ESIS P11-02 and also showing some polishing problems caused by the matrix hardness (280 HV). **Beretta** showed measurements carried out at PoliMI on areas of 100 mm² (recognition of largest inclusions were done manually): the data suggests a kink in the distribution of extreme defects. **Butler** showed that the same effect is also present in the measurements carried out at Corus: in particular measurements were carried out by image analysis on areas of 0.90 mm² and then the largest particle on areas of 90.96 mm² were picked out by adding up the results of 100 small areas. **Henault** pointed the attention on the need of manual polishing, manual recognition of extreme particles at x100 (control areas of 100 mm²) and finally defect measurement at x500: analysis showed that extreme particles are both sulphides and oxides and that there is a definite kink in probability plot for defects larger than 15 µm. The discussion then focused the need of precisely investigate the nature of largest particles.

In the final part of the meeting, future activities were discussed, with special emphasis in the completion of the Round-robin on 42CrMo4 steel and the launch of another Round Robin on a 100Cr6 steel supplied by Creas. In particular **Henault** has already prepared samples with an area of 200 mm² for observation in longitudinal direction: Murakami, Beretta, Klimt and Butler were given pieces for extreme particle measurements.

Anderson then summarises the activity needed to complete the round-robin and he introduces the discussion about the future TC20 activities. A brief summary of the agreed points is given in the next point.

SUMMARY of OPEN DISCUSSION:

1) Steps and duties for completion of first round-robin on 42CrMo4 steel:

- 1.1 Murakami will carry out extra measurements on 100 mm² control areas;
- 1.2 Butler will carefully analyse extreme particles;
- 1.4 Beretta will solicit a response from the other round-robin participants;
- 1.5 Butler will give Beretta information about thermal treatment needed to achieve an hardness of 500 HV;
- 1.6 Murakami and Beretta will carry our fatigue tests in order to obtain extreme defects.

2) Steps and duties for the second round-robin on 100Cr6 steel:

- 2.1 Henault will prepare a short document about metallographic specimens;
- 2.2 Beretta will ask other TC20 members if they want to participate;
- 2.3 Murakami will be given some extra material for carrying out torsional fatigue tests.

3) Presentation of round-robin results:

- 3.1 Beretta will circulate round-robin results via the Website;
- 3.2 Anderson and Beretta will prepare a summary of results;
- 3.3 Beswick will be asked of the possibility of presenting results of the first round-robin at the next 'Bearing Steels' Conference (May 2005);
- 3.4 TC20 members attending the Conference will present the results;
- 3.5 a next TC20 document summarising results of the two round-robins is expected for December 2005.

4) Next TC20 meeting will be in Milan on 9th September 2005.**ESIS TC24 "INTEGRITY OF RAILWAY STRUCTURES"**

No meeting was held in 2004, but the activity of TC24 has been devoted to try to give structural integrity concepts a wide diffusion within railway community. To this special aim a number of 'popular' papers about structural integrity had been planned in 2003 meetings. In particular a paper by M. Guagliano has appeared on *European Railway Review* (Vol.10, No. 4, 2004) about the structural integrity of wheels.

About other 2004 activities some TC24 members (Schwalbe, Zerbst, Smith and Beretta) have been involved in the organisation of the 'Railway Session' at ICF11 Conference.

In 2005 a special Issue of *Engineering Fracture Mechanics* on Fracture Mechanics in Railway Applications has been published as n. 2, vol. 72. This special Issue, edited by U. Zerbst & K. Madler, contains 9 invited papers about some of the relevant topics of the first TC24 meeting.

Next meeting will be held in GKSS, Hamburg, on 2-3 February 2005: the meeting will be focused on damage tolerance of axles.

ECF15 CONFERENCE

KTH (Royal Institute of Technology) in Stockholm hosted the 15th European Conference of Fracture during August 11-13, 2004. A total of 203 delegates from 34 nations participated. The technical programme consisted of one opening lecture, 5 invited lectures and 159 contributions. The latter were presented either orally or as posters. All manuscripts for the presentations can be found on the conference web-site <http://www.half.kth.se/forskning/ecf15/index.html> or <http://www.ecf15.org>.

Responsible for the arrangements was an Organising Committee that was chaired by Professor Fred Nilsson. A Scientific Committee aided the Organising Committee concerning the technical programme. The contributions spanned the entire field of fracture and fatigue for several different classes of materials. Both fundamental as well as applied research was presented.

In connection with the conference ESIS President Professor Alberto Carpinteri presented the ESIS Awards to the awardees. The Wöhler medal was awarded to Professor Les Pook and the Griffith medal to Professor Hans Richard. Professor Ad Bakker was selected for an Honorary Membership and Professor Keith Miller received the Award of Merit.

Fred Nilsson



ESIS Awards at ECF15 Conference (from left to right): Prof. Nilsson (ECF15 Chairman); Prof. Richard; Prof. Bakker; Prof. Carpinteri (ESIS President)

AWARDS AND PRIZES

In connection with the ECF-15 conference ESIS President Professor Alberto Carpinteri conferred the ESIS Awards to the awardees.

THE GRIFFITH MEDAL



Professor Hans Richard

Professor Hans RICHARD is awarded the Griffith Medal for his outstanding research in the field of mixed mode fracture of materials an in numerical modeling of complex fatigue crack growth paths, on the occasion of ECF 15, Stockholm, 2004.

Hans Albert Richard was born in Brechen, Germany in 1949. He obtained a degree in mechanical engineering from the University of Kaiserslautern in 1974. From 1974 to 1980 he was a scientific assistant in the Institute of Engineering Mechanics, University of Kaiserslautern. In 1979 he was awarded a PhD by the University of Kaiserslautern. His thesis title is 'Determination of stress intensity factors from photoelastic determined notch stresses'. From 1980 to 1986 he was chief engineer in the Institute of Engineering Mechanics, University of Kaiserslautern. In 1984 he was awarded his postdoctoral lecturer qualification; the thesis title is 'Prediction of fracture due to overlapping normal- and shear loading as well as pure shear loading of cracks'. Since 1986 he has been Professor of Engineering Mechanics in the Faculty of Mechanical Engineering, University of Paderborn. From 1989 to 1991 Professor Richard was Dean of the Faculty of Mechanical Engineering and from 1991 to 1995 Rector of the University of Paderborn.

From 1985 to 1991 he led the German Working Group on Mixed Mode Problems, and from 1999 to 2003 he was President of the German Fracture Research Group. He has organised national and international Conferences ('Mixed-Mode-Fracture and Fatigue', Wien, 1991; 'Advances in Fracture and Damage Mechanics', Paderborn, 2003).

Professor Richard has over 170 publications in the fields of fracture mechanics and biomechanics. At the University of Paderborn Professor Richard's work has covered a wide range of topics including strength optimisation and fracture safe design of structures and components, biomechanical analyses of the human musculoskeletal system, new railway technology, product optimisation and new development in cooperation with industry, and failure analysis.

Professor Richard has a long standing interest in mixed mode fracture mechanics, dating back to the early 1980s, and this has developed into an interest in crack paths in complex three dimensional situations. Particularly noteworthy is his computer based theoretical prediction of crack paths where he has been able to obtain good agreement with experimental data determined under static and fatigue loading. His work is particularly notable for an innovative approach where he has not been afraid to challenge established wisdom.

THE WÖHLER MEDAL



Professor Les Pook

Professor Leslie POOK is awarded the Wöhler Medal for his outstanding contributions to the understanding of fatigue crack growth behaviour, especially those devoted to mixed mode loading, on the occasion of ECF 15, Stockholm, 2004.

Leslie Philip (Les) Pook was born in Middlesex, England in 1935. He obtained a BSc in metallurgy from the University of London in 1956. He started his career at Hawker Siddeley

Aviation Ltd, Coventry (HSA) in 1956. In 1963 he moved to the National Engineering Laboratory, East Kilbride, Glasgow (NEL). In 1969, while at NEL he obtained a PhD in mechanical engineering from the University of Strathclyde. Professor Pook moved to the Department of Mechanical Engineering at University College London (UCL) in 1990. He retired formally in 1998, but is still affiliated to UCL as a Visiting Professor, and remains active in research and teaching. Professor Pook has wide experience of both research and practical engineering problems involving metal fatigue, brittle fracture and fracture mechanics. In these fields he has published four books and over 100 papers. He is a Chartered Engineer, a Fellow of the Institution of Mechanical Engineers and a Fellow of the Institute of Materials, Minerals and Mining.

At HSA he worked in the Mechanical Test Laboratory (MTL) on the static and fatigue testing of aircraft and guided missile components and structures. Both constant amplitude and block loading were used in fatigue tests. By 1959 interest in the practical application of fractography was increasing and he was asked to investigate this technique. Due to his efforts the use of fractography as an adjunct to both fatigue testing and failure analysis rapidly became routine. Over the next four years he was involved in dozens of fractographic investigations.

His work at NEL covered a wide range of topics, including the following. Collaboration with Frost and Denton on the analysis of accumulated fatigue crack growth and threshold data in terms of stress intensity factors. The resulting paper, published in 1971, was very widely cited. Pioneering work on mixed mode fatigue crack growth thresholds resulted in a series of papers (1975-1991). He published a seminal paper on the application of fracture mechanics to spot welds in 1975. He made a major contribution to the development of standard load histories for fatigue testing relevant to offshore structures and this resulted in a series of papers (1976-1989); he published a seminal paper in 1978.

Work at UCL covered a wide range of topics, particularly noteworthy are series of papers on topics relevant to the fatigue of offshore structures (1990-1998) and on fatigue crack paths (1992-2003). To some extent this was a period of consolidation and he published two books, in 2000 and 2002. From 1990-1998 he was Editor in Chief of International Journal of Fatigue. In recent years he has been increasingly active in the affairs of the European Structural Integrity Society (ESIS), and he was co-chairman, with Professor Andrea Carpinteri, of the International Conference on Fatigue Crack Paths, sponsored by ESIS, held at the University of Parma, Italy in September 2003. He is a Guest Editor of a forthcoming Special Issue of

Fatigue and Fracture of Engineering Materials and Structures which will contain extended versions of selected papers from the Conference. Since formal retirement in 1998 he has maintained his enthusiasm for fatigue but has also found time to pursue interests in horology and in recreational mathematics.

AWARD OF MERIT



Professor Keith Miller

Professor Keith MILLER is awarded the Award of Merit for his outstanding contributions to the field of fatigue and for his work devoted to the advancement of the European Structural Integrity Society, on the occasion of ECF 15, Stockholm, 2004.

The contribution of Keith Miller, ex-president of ESIS, to the study of engineering fatigue and fracture has been immense. A man of prodigious energy, drive and enthusiasm, he has led his university, his country and many international groups in the study of important effects in the failure of engineering mechanical systems. Short cracks and microstructural influences, notches, multi-axial behaviour, mixed mode effects, fretting, and creep-fatigue interactions are just some of the areas in which he has contributed. Having established an internationally recognised research team at Cambridge, he came to Sheffield, his base ever since. His team and influence there grew rapidly. He was a pioneer in recognising the importance of true interdisciplinary work, a major feature in his formation of SIRIUS (Structural Integrity Research Institute University of Sheffield), a research centre with strong collaboration between three separate university departments. He founded the international journal Fatigue and Fracture of Engineering Materials and Structures early in the life of SIRIUS and was its editor for 22 years. He has been a strong and active

supporter of ESIS from the beginning, with special contributions to its publications activities. His efforts in the development of ESIS finally led to a presidency.

He was one of the first into China when it opened its doors to outsiders, and he began a rich and continuing stream of research collaborations between Chinese and European engineers and scientists. But his travels have also been driven by his other great love, exploration and mountaineering. He organised and led expeditions all over the world, Greenland, Iceland, Antarctica, the Karakorum included. From this came his contributions to the study of continental drift and the properties of ice.

HONORARY MEMBERSHIP



Professor Ad Bakker

Professor Ad BAKKER is awarded the Honorary Membership for his many valuable contributions to the field of fracture mechanics and for his work devoted to the development of the European Structural Integrity Society, on the occasion of ECF 15, Stockholm, 2004.

Ad Bakker has been involved with ESIS and its predecessor, EGF, for many years. He was Secretary-General of EGF, and later of ESIS, from 1984 to 1998 under the presidencies of Harry van Elst, Hannes Larsson, Ian Milne and Dominique François. He was organiser or co-organiser of several major conferences (ECF6, Amsterdam, 1986, ICM7, The Hague, 1987). Professor Bakker was Initiator and Editor of the EGF (later ESIS) Newsletter from 1987 to 1997, a total of 31 issues. He had to stop active participation in ESIS in 1998 because of health

problems, but since then he has acted as consultant to the Executive Committee of ESIS (now the Council) on various occasions.

General Secretary is a poor description of Professor Bakker's position: he was also responsible for the finances of ESIS, the membership, the Newsletter, printing and circulation of ESIS reports and documents, attending to external requests, and maintaining external contacts. In replying to external requests and suggestions he was unfailingly courteous. His contribution to EGF and ESIS has been immense, and it is no exaggeration to say that ESIS as it is today is very much a creature of his design. In earlier days, he was more than just General Secretary, but as right hand man to Harry van Elst he did all the leg-work.

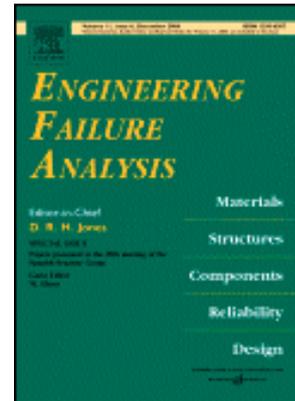
There are many examples of how Ad Bakker managed the affairs of ESIS beneficially. An important one is that he ensured that ESIS was registered as a non-profit organisation in The Netherlands, thus avoiding the payment of tax. ESIS also benefited from being run within his department at Delft University of Technology, so that many of the costs of the ESIS operation were covered not only directly, but also in kind (secretarial effort, typing the Newsletter, circulating it, etc.). His close involvement with the operation was essential in the drafting of the first edition of the ESIS rules and bye-laws, which followed the change of name from EGF to ESIS. He also gave advice on the myriad of issues which would come up from day to day, and more significantly in the biennial Council meetings.

All this was in addition to being Head of Department, running a research team, and writing some significant papers. Just how much Professor Bakker had been doing for ESIS only became completely clear when, in 1998, the ESIS Secretariat was transferred from Delft University of Technology to the University of Sheffield, under Professor Keith J Miller, who also undertook the Presidency of ESIS for two years.

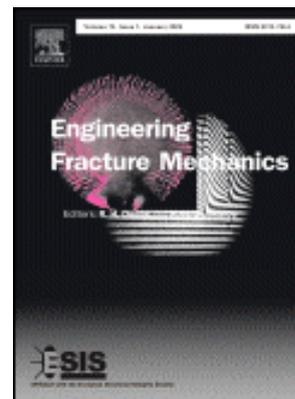
ESIS publishing agreement with Elsevier

- Elsevier will publish at its own risk and expense, under ESIS' editorial control, their Technical Committee Special Technical Publications (hereinafter called the STPs). These publications will be published as special issues of Engineering Fracture Mechanics, Engineering Failure Analysis and International Journal of Fatigue, subject to peer-review.
- Elsevier will ensure that at least 33% of the International Editorial Boards of Engineering Fracture Mechanics, Engineering Failure Analysis and International Journal of Fatigue are made up of members working in Europe.
- The calendars of Engineering Fracture Mechanics, Engineering Failure Analysis and International Journal of Fatigue will contain an ESIS Events section (with ESIS logo), where news and meetings of the TCs are announced.
- Engineering Fracture Mechanics, Engineering Failure Analysis and International Journal of Fatigue will contain two pages per year dedicated to reporting information about ESIS Prize Winners: photographs, prize motivation and a short biography.
- Engineering Fracture Mechanics, Engineering Failure Analysis and International Journal of Fatigue will publish ESIS documents and procedures as Appendices and make provision for reprints.
- Elsevier will publish at its own risk and expense for exclusive distribution, under ESIS' editorial control, their peer-reviewed European Conference on Fracture material (hereinafter called Proceedings), as a numbered volume and will be known as ESIS Publication nn. They will be part of the Series published in hard-bound book format, and optionally at Elsevier's sole discretion, on-line or any other media.
- Elsevier, where agreed with the local Organising Committee, will organise and support ESIS-hosted symposia and conferences. The services and terms are to be mutually agreed between Elsevier, ESIS and the local Organising Committee.
- Elsevier will make a single payment to ESIS on publication of **each STP** as a special issue of the host journal.

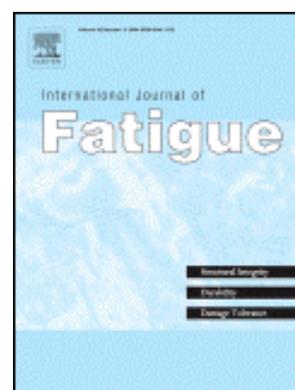
3 Elsevier journals are affiliated with ESIS



ENGINEERING FAILURE ANALYSIS



ENGINEERING FRACTURE MECHANICS



INTERNATIONAL JOURNAL OF FATIGUE

Calendar

<p>ICF11 INTERNATIONAL CONFERENCE ON FRACTURE Organisers: Prof Alberto Carpinteri</p> <p>20-25 March 2005 Turin, Italy</p>	<p>Further details from: Prof. Alberto Carpinteri ICF 11 Chairman C/o Centro Congressi Internazionale s.r.l. Via cervino, 60-10155 Torino, Italy. Fax: (39) 011 244 6900 E-mail: info@congressiefiere.com Website: http://www.ICF11.com</p>	<p>EUROMECH Colloquium 466 "COMPUTATIONAL AND EXPERIMENTAL MECHANICS OF ADVANCED MATERIAL 2005"</p> <p>20-22 July 2005 Loughborough, UK</p>	<p>Further details from: Prof. Vadim Silberschmidt, Wolfson School of Mechanical and Manufacturing Engineering, Loughborough University, Loughborough, Leicestershire LE11 3TU, UK. E-mail: v.silberschmidt@lboro.ac.uk Website: http://www.lboro.ac.uk/departments/mm/conferences/ec466/office.html</p>
<p>3rd INTERNATIONAL ASTM/ESIS Symposium on Fatigue and Fracture Mechanics Organisers: Prof Richard Link and Dr Kamran Nikbin</p> <p>18-20 May 2005 Reno, Nevada, USA</p>	<p>Further details from: Dr. Richard E. Link, United States Naval Academy, Annapolis, MD, USA. Tel: 410-293-6523 Fax: 410-293-3041 Email: link@usna.edu, or Dr. Kamran Nikbin, Imperial College of Science Technology and Medicine, London, UK. Tel: (44) 20-7594-7133 Fax: (44) 20-7594-7017. E-mail: k.nikbin@ic.ac.uk,</p>	<p>10th Conference on Fracture Mechanics</p> <p>Wisla (Poland) 11-14 September 2005</p>	<p>Further details: Prof. Ewald Macha Technical University of Opole Email: kmpkm@po.opole.pl</p> <p>Website: www.kmpkm.po.opole.pl</p>
<p>Mecmat 2005 MECHANICS & MATERIALS CONFERENCE</p> <p>1-3 June 2005 Louisiana, USA</p>	<p>Further details from: Dr. G. Voyiadjis Dept. of Civil & Environmental Engineering, Louisiana State University, Baton Rouge, LA 70803-6405, USA. E-mail: voyiadjis@eng.lsu.edu Website: http://www.lsu.edu/mcemat2005</p>	<p>4th INTERNATIONAL CONFERENCE ON Fracture of polymers, composites and adhesives Organisers: ESIS – TC4 with administration provided by Elsevier</p> <p>11-14 September 2005 Les Diablerets, Switzerland</p>	<p>Further details from: Claire Norris TC4 Conference Secretariat 51 Kestrel Way Wokingham Berkshire RG41 3HA, UK Tel: +44 (0) 118 377 4696 Fax: +44 (0) 118 977 6680 Email: tc4-conference@elsevier.com Website: www.tc4pca.elsevier.com</p>
<p>ICOSSAR '05 The Ninth International Conference on STRUCTURAL SAFETY AND RELIABILITY</p> <p>19-22 June 2005 Roma, Italy</p>	<p>Further details from: Prof. Ing. Giuliano Augusti Universita' "La Sapienza" –Facolta' di Ingegneria, Dipartimento di Ingegneria Strutturale e Geotecnica, Via Eudossiana 18, I-00184 ROMA, Italy. Fax: (+39) 06 488 4852 E-mail: giuliano.augusti@uniroma1.it Website: http://www.icossar2005.com</p>	<p>First International Conference on Mechanics of Biomaterials & Tissues</p> <p>11–14 December 2005 Waikoloa, Hawaii, USA</p>	<p>Further details from: Nina Woods ICMOBT Conference Secretariat, Elsevier, The Boulevard, Langford Lane, Kidlington, Oxford, OX5 1GB, UK. Tel.: +44 (0) 1865 843297 Fax: +44 (0) 1865 843958 E-mail: n.woods@elsevier.com Website: http://www.icmobt.elsevier.com</p>
<p>1st European Summer School of Fatigue & Fracture</p> <p>Zakopane (Poland) 19-26 June 2005</p>	<p>Prof. Ewald Macha, Chaiman Technical University of Opole Email: kmpkm@po.opole.pl</p> <p>Website: www.kmpkm.po.opole.pl</p>	<p>9th International Fatigue Congress—FATIGUE 2006</p> <p>14–19 May, 2006 Atlanta, USA</p>	<p>Further details from: Nina Woods, Fatigue 2006 Congress Secretariat, Elsevier Ltd, The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK. E-mail: n.woods@elsevier.com; Website: http://www.fatigue2006.com</p>

continues on page 21



ICF 11
11th International Conference on
Fracture
Turin, ITALY, March 20-25, 2005

The 11th International Conference on Fracture will be held in Turin, Italy, on March 20-25, 2005. ICF11 has been organized under the High Patronage of the President of the Republic of Italy, under the auspices of the Ministry of Infrastructures and Transportation of the Italian Government, and of the National Science Foundation of Italy (CNR), with the scientific support and sponsorship of worldwide leading Institutions in the fields of Fracture, Fatigue, Material Strength and Structural Integrity, like the International Congress on Fracture itself (ICF), the European Structural Integrity Society (ESIS), the American Society for Testing and Materials (ASTM), while the Italian Group of Fracture (IGF), the Politecnico di Torino and the Turin Academy of Sciences have taken the role of host organizations.

Papers for oral presentation will be welcome in all aspects of fracture. In particular **Special Sessions** or **Mini-Symposia** will be organised on the following topics:

1) Aeronautics & Aerospace	15) Failure Analysis	25) Inverse Problems	35) Plant Aging
2) Analytical Models	16) Fatigue	26) MEMS	36) Polymers
3) Biomechanics	17) Functionally Graded Materials	27) Metallic Materials	37) Railways
4) Ceramics	18) Geophysics and Tectonics	28) Micro- or Meso-scale	38) Reinforced Concrete
5) Composites	19) Glass	29) Mixed Mode	39) Reliability
6) Computational Mechanics	20) High Temperature & Creep	30) Nano- or Micro-scale	40) Scaling Laws & Size Effects
7) Concrete & Rocks	21) Historical and Monumental Buildings	31) Nondestructive Examination & Monitoring	41) Smart Materials & Structures
8) Corrosion	22) Hydrogen Embrittlement	32) Nonlinear Fracture Mechanics	42) Surface Treatments
9) Damage Mechanics	23) Impact & Dynamics	33) Oil & Gas Production and Distribution	43) Thin Films
10) Dams	24) Industrial and Architectural Sustainability	34) Physical Aspects	44) Welds
11) Debonding			45) Wood
12) Drilling, Cutting, Sawing			
13) Durability			
14) Electronic Materials			

ICF11 – Conference Timetable

	Sun 20	Mon 21	Tue 22	Wed 23	Thu 25	Fri 25
8. ³⁰ -10. ⁰⁰			Plenary session	Plenary session	Plenary session	Plenary session
10. ⁰⁰ -10. ³⁰			coffee break	coffee break	coffee break	coffee break
10. ³⁰ -12. ¹⁰		Opening Ceremony Honour Lectures				
10. ³⁰ -12. ¹⁰			Parallel sessions	Parallel sessions	Parallel sessions	Parallel sessions
12. ¹⁰ -14. ⁰⁰		lunch	lunch	lunch	lunch	lunch
14. ⁰⁰ -15. ⁴⁰		Parallel sessions	Parallel sessions	Parallel sessions	Parallel sessions	Parallel sessions
15. ⁴⁰ -16. ¹⁰		coffee break	coffee break	coffee break	coffee break	coffee break
16. ¹⁰ -17. ⁵⁰		Parallel sessions	Parallel sessions	Parallel sessions	Parallel sessions	Parallel sessions
18. ⁰⁰ -20. ⁰⁰	Registration & Welcome Reception			ESIS Council		Closing Ceremony
20. ³⁰ -				Conference Banquet		

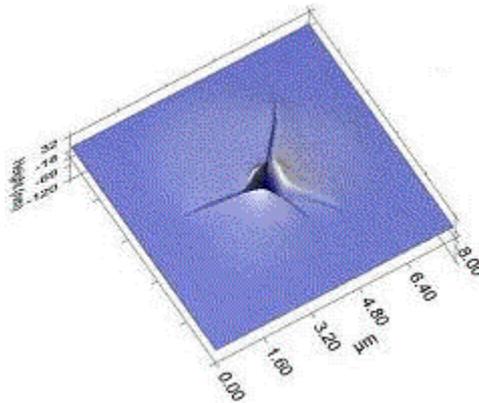
Calendar

<p>Structural Faults and Repair 2006</p> <p>13–15 June, 2006 Assembly Rooms, George Street, Edinburgh</p>	<p>Further details from: Conference Secretariat, ECS Publications, 46 Cluny Gardens, Edinburgh EH10 6BH, UK. Tel: +44(0) 131 447 0447 Fax: +44 (0) 131 452 8596 Website: www.structuralfaultsandrepair.com</p>	<p>ECF16 16th European Conference on Fracture Organisers: Prof. E.E. Gdoutos</p> <p>3–17 July 2006 Alexandroupolis, Greece</p>	<p>Further details from: Prof. E.E. Gdoutos School of Engineering, Democritus University of Thrace, GR-671 00, Xanthi, Greece. E-mail: egdoutos@civil.duth.gr Website: http://ecf16.civil.duth.gr</p>
<p>9th European Conference on NONDESTRUCTIVE TESTING (9th ECNDT)</p> <p>25-29 September 2006 Estrel Convention Center, Berlin, Germany</p>	<p>Further details from: Exhibition Sekretariat, Deutsche Gesellschaft für Zerstörungsfreie Prüfung e.V., Max-Planck-Strasse 6, 12489 Berlin, Germany Fax: +49 (30) 678 07129 E-mails: mail@ecndt2006.info Website: http://www.ecndt2006.info</p>		

Calendar of TC Meetings

TC1-TC8	20-21 April 2005	Joint TC1 and TC8 meeting	Serco Assurance, Risley, UK	TC1 Co-Chairman: warhelle@blueyonder.co.uk
TC4	25 th -27 th May 2005	Regular committee meeting	Les Diablerets, Switzerland	TC4 Secretary: b.blackman@imperial.ac.uk
TC5	22nd April 2005	Regular committee meeting	CIDAUT, Valladolid, Spain	TC5 Secretary: h.macgill@imperial.ac.uk
TC6	29-30th September 2005	Regular committee meeting	IKTS, Dresden, Germany	TC6 chairman : dusza@imrnov.saske.sk
TC11	29th April 2005	Regular committee meeting	Rolls Royce, Derby, UK	www.htmc.com
TC20	9th September 2005	Regular committee meeting	Politecnico di Milano, Milan, Italy	TC20 Secretary: stefano.beretta@polimi.it
TC24	2-3 February 2005	Special meeting on Damage Tolerance of Railway Axles	GKSS, Geesthacht, Germany	TC24 Chairman: Karl-Heinz.Schwalbe@gkss.de

ECF 16
16th European Conference of Fracture
Failure Analysis of Nano and Engineering Materials and Structures
Alexandroupolis, Greece, July 3-7, 2006



Conference Chairman:
EMMANUEL E. GDOUTOS
Democritus University of Thrace, Greece

16th European Conference of Fracture

Started in 1976, the European Conference of Fracture (ECF) is today the premier activity of the European Structural Integrity Society (ESIS) to promote world-wide cooperation among scientists and engineers concerned with fracture and fatigue of solids. It takes place every two years in a European country.

The 16th European Conference of Fracture will focus in all aspects of Structural Integrity with the objective of improving the safety and performance of engineering structures, components, systems and their associated materials. Emphasis will be given in the failure behavior of nanostructured materials and nanostructures.

The 16th European Conference of Fracture will comprise invited lectures together with contributed oral and poster presentations covering all aspect of fracture and fatigue.

ECF16 Conference Website:

<http://ecf16.civil.duth.gr>

Deadline for abstracts:

May 31, 2005

NUMERICAL MODELLING IN NONLINEAR FRACTURE MECHANICS

Viggo Tvergaard

Dept. of Mechanical Engineering, Solid mechanics
Technical University of Denmark

Nils Koppels Allé, Building 404, DK-2800 Kgs. Lyngby, Denmark

Abstract. Some numerical studies of crack propagation are based on using constitutive models that account for damage evolution in the material. When a critical damage value has been reached in a material point, it is natural to assume that this point has no more carrying capacity, as is done numerically in the element vanish technique. In the present review this procedure is illustrated for micromechanically based material models, such as a ductile failure model that accounts for the nucleation and growth of voids to coalescence, and a model for intergranular creep failure with diffusive growth of grain boundary cavities leading to micro-crack formation. The procedure is also illustrated for low cycle fatigue, based on continuum damage mechanics. In addition, the possibility of crack growth predictions for elastic-plastic solids using cohesive zone models to represent the fracture process is discussed.

Introduction

Many procedures for the analysis of crack propagation are based on using critical values of parameters characterising the crack-tip stress and strain fields, such as the stress intensity factor, the J-integral, the crack-tip opening displacement, or the crack-tip opening angle. Alternatively, the prediction of crack growth may be directly based on the fracture mechanism operating on the microscale, either by incorporating the failure mechanism in the constitutive equations for the material, or by representing the failure mechanism through a cohesive zone model of the fracture process zone. The present paper will give a survey of a number of investigations where the prediction of crack growth has been based on models of the actual fracture mechanism.

One of the most well known material models that accounts for the micromechanics of damage is the modified Gurson model [1,2], which models the evolution of ductile fracture by the nucleation and growth of voids to coalescence. Some of the analyses using this model to predict ductile crack growth will be discussed. Also for creep failure in metals at high temperatures material models [3] have incorporated the micromechanisms of diffusive cavity growth in grain boundaries, leading to open micro-cracks at grain boundary facets at a rate strongly affected by grain boundary sliding. Results on creep crack growth based on this failure model will be mentioned. The term continuum damage mechanics is used for constitutive relations, which are able to represent the effect of damage evolution on the macro level, by developing appropriate expressions in which free material parameters can be fitted to experiments, as in the case of low cycle fatigue [4]. As an example, predictions of micro-crack formation in a metal matrix composite, based on this material model, will be presented here.

Cohesive zone models have been used in recent years in a number of analyses of crack growth resistance in elastic-plastic solids [5]. Some of the

predictions obtained in these studies will be briefly mentioned here.

Material Models with Damage Evolution

When the failure mechanism is incorporated in the constitutive relations, the crack growth follows directly from the predicted loss of stress carrying capacity in one or more integration points in an element. Then it is natural to kill the failed elements, by using the element vanish technique [6]. This procedure has been used for the predictions of crack growth to be discussed in the following three subsections.

Crack growth by ductile failure

Much interest has been devoted to the development of elastic-plastic or viscoplastic constitutive equations that account for the effect of ductile damage development. The most well known model is that suggested by Gurson [1], which makes use of an approximate yield condition $\Phi(\sigma^{ij}, \sigma_M, f) = 0$ for a material containing a volume fraction f of voids, where σ^{ij} is the average macroscopic Cauchy stress tensor and σ_M is an equivalent tensile flow stress representing the actual microscopic stress-state in the matrix material. With some modifications to improve predictions of plastic flow localization [7] and of final failure by void coalescence [8] this yield condition is of the form

$$\Phi = \frac{\sigma_e^2}{\sigma_M^2} + 2q_1 f^* \cosh\left(\frac{q_2}{2} \frac{\sigma_k^k}{\sigma_M}\right) - \left[1 + (q_1 f^*)^2\right] = 0 \quad (1)$$

where $\sigma_e = (3s_{ij}s^{ij}/2)^{1/2}$ is the macroscopic effective Mises stress, and $s^{ij} = \sigma^{ij} - G^{ij}\sigma_k^k/3$ is the stress deviator. This material model accounts for the growth of the void volume fraction f due to plastic flow of the

material around voids and due to the nucleation of new voids, and final failure is directly predicted when f reaches the critical value, at which the yield surface has shrunk to a point.

This material model has been applied in a number of numerical studies of crack growth, including some studies where two populations of void nucleating particles are modelled; large weak particles that nucleate voids at relatively small strains and small strong particles that nucleate voids at much larger strains. For an edge cracked specimen under dynamic loading [9] results of a plane strain analysis are shown in Fig. 1, where contours of constant void volume fraction define the predicted crack growth path in a case of a random distribution of the larger inclusions ahead of the initial crack-tip. Also a full three dimensional analysis has been used to analyse this type of specimen [10]. Here the computer requirements were much larger, but the advantage is that more realistic spherical shapes of the larger inclusions can be accounted for, and that 3D modes of growth are accounted for, such as tunnelling and shear lip formation. Continuations of the 3D fracture study have been carried out recently in analyses that do not directly focus on crack growth, e.g. the failure of a metal matrix composite [11] or of a Charpy V-notch specimen cut through a weld [12].

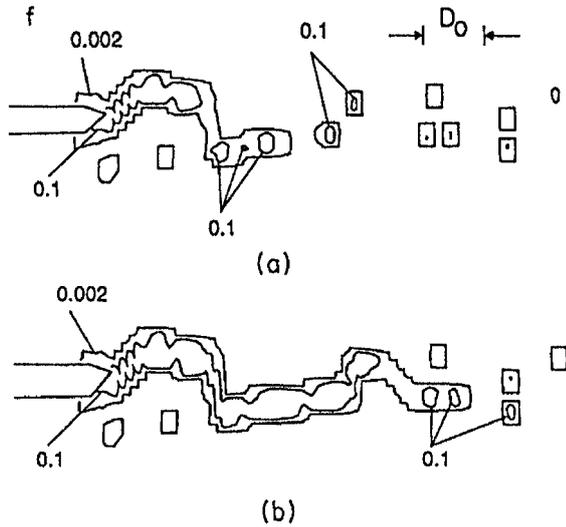


Fig. 1: Crack growth indicated by contours of constant void volume fraction, f , for random distribution of larger particles. (a) $t = 1.5 \mu s$, $\Delta a = 0.09 \text{ mm}$; (b) $t = 1.6 \mu s$, $\Delta a = 0.27 \text{ mm}$. (From [9]).

Some attempts to include a damage dependent material length scale in this constitutive model have been carried out by Leblond *et al.* [13] and Tvergaard and Needleman [14], using an integral condition on the rate

of increase of the void volume fraction. The expressions used in [14] are

$$\dot{f}(y^i) = \frac{1}{W(y^i)} \int_V \dot{f}_{\text{local}}(\hat{y}^i) w(y^i - \hat{y}^i) d\hat{V} \quad (2)$$

$$w(y^i) = \left[\frac{1}{1 + (z/L)^p} \right]^q, \quad W(y^i) = \int_V w(y^i - \hat{y}^i) d\hat{V} \quad (3)$$

where $L > 0$ is the material characteristic length, $z = \sqrt{g_{ij} y^i y^j}$, and $p = 8$, $q = 2$. The usual local formulation corresponds to the limit $L \rightarrow 0$, and it has been shown, as for other non-local continuum models, that the mesh dependence of numerical solutions in a softening regime are removed by taking $L > 0$. This nonlocal damage model has been applied by Needleman and Tvergaard [15] to predict ductile crack growth in the edge cracked specimen under dynamic loading also analysed in [9,10].

Creep crack growth

High temperature failure leading to crack growth has been modelled in terms of continuum damage mechanics (Hayhurst *et al.* [16]), where damage parameters are fitted to material behaviour on the macro level. The micro-mechanisms of creep failure in polycrystalline metals involve the nucleation and growth of small voids to coalescence; but here diffusion plays an important role, and the cavities occur primarily on grain boundary facets perpendicular to the maximum principal tensile stress (e.g. Ashby and Dyson [17]), where a creep constraint on the rate of cavitation is often a dominant mechanism. Cavity coalescence on a grain boundary facet leads to a micro-crack, and final intergranular failure occurs as such micro-cracks link up. Grain boundary sliding is an important mechanism that further complicates the analysis of creep failure. A micromechanically based constitutive model for creep failure in a polycrystalline metal has been proposed (Tvergaard [3,18]), in which the macroscopic creep strain rate is given by the expression

$$\dot{\eta}_{ij}^C = \dot{\epsilon}_0 \left(1 + C \dot{\epsilon}_e^C \right) \left(\frac{\sigma_e}{\sigma_0} \right)^n \left[\frac{3}{2} \frac{s_{ij}}{\sigma_e} (f^*)^n + \rho^* \left\{ \frac{3}{2} \frac{n-1}{n+1} \frac{s_{ij}}{\sigma_e} \left(\frac{S^* - \sigma_n}{\sigma_e} \right)^2 + \frac{2}{n+1} \frac{S^* - \sigma_n}{\sigma_e} m_{ij}^* \right\} \right] \quad (4)$$

Here, n is the creep power, $C > 0$ represents substructure induced acceleration of creep, and expressions for other parameters are determined by

axisymmetric cell model studies for a grain with a cavitating facet and sliding boundaries [3]. If there is no sliding, f^* is unity, ρ^* is the density of cavitating facets m_{ij}^* is a direction tensor for cavitating facets, and $S^* - \sigma_n$ is the difference between the maximum principal stress and the normal stress on a cavitating facet. The material model has been used to predict crack growth [18], by applying the element vanish technique when cavity coalescence was predicted on a grain boundary. For a double edge cracked panel under tension Fig. 2 shows the predicted damage near the crack-tip at two stages of time, where the damage parameter a/b is the cavity radius divided by the cavity half spacing on a facet, and vanished triangular elements are painted black.

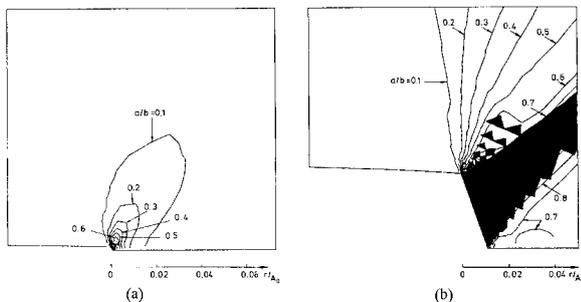


Fig. 2: Distributions of creep damage ahead of a crack-tip. Continuous cavity nucleation, no grain boundary sliding, and $C = 40$. (a) $t/t_f^0 = 0.064$. (b) $t/t_f^0 = 0.686$. (From [18]).

Plane strain multi-grain cell models for a polycrystalline aggregate have been used by van der Giessen and Tvergaard [19] to study the final creep fracture process, as microcracks formed at grain boundary facets link up. Such analyses are however limited by the unrealistic grain geometry and the reduced constraint on sliding. But a great advantage is that large grain arrays can be analysed if a crude mesh is used within each grain, and this allows for direct modelling of intergranular crack growth in a plane strain multi-grain aggregate (Onck and van der Giessen [20]).

Fatigue cracking

Among the many applications of continuum damage mechanics [4], studies of failure by low cycle fatigue are an important example, where a material model directly based on the micro mechanics of failure has not been developed. As the development of fatigue fracture depends strongly on the plastic strain range in each cycle, an accurate cyclic plasticity model is needed (e.g. Ohno and Wang [21]), with damage mechanics incorporated. The scalar damage parameter D is taken to be zero initially, but when the

accumulated plastic strain p reaches a threshold value p_d , it is assumed that damage starts to develop according to the evolution law

$$\dot{D} = \frac{Y}{S} \dot{p} \alpha(p), \quad \alpha = \begin{cases} 1, & \text{if } p \geq p_d \\ 0, & \text{if } p < p_d \end{cases} \quad (5)$$

Here, S is a material parameter describing the energy strength of damage, the strain energy release rate is given by $Y = \sigma_e^2 R_V / (2E(1-D)^2)$, and the expression for R_V depends on the mean stress $\sigma_{kk}/3$, so that fatigue develops more rapidly under tensile stresses. When the damage parameter reaches a critical value D_c , this is taken to represent such a high density of microcracks that coalesce into a macrocrack occurs. In a finite element analysis this failure event is represented in terms of the element vanish technique, such that the model can be used to predict the growth of a macroscopic crack. This type of numerical study has been carried out in [22] for a metal matrix composite, where the fatigue crack growth occurs in the metal matrix around short brittle fibres.

Modelling by Cohesive Zone

As an alternative to the continuum models discussed above, a number of crack growth analyses describe the fracture process separately in terms of a traction separation law for the crack surface, while the inelastic deformations around the crack are accounted for by standard plasticity without damage. This gives an attractive possibility for separating effects of fracture process parameters from effects of the material parameters determining inelastic deformations, e.g. in relation to determining crack growth resistance curves. Thus, analyses of this type determine directly the ratio between the remote fracture toughness and the local fracture toughness determined by the assumed cohesive model.

In [5] a rather general case of crack growth along the interface between an elastic-plastic solid and a rigid solid was studied. Here, a cohesive zone model was needed that accounts for both normal and tangential separation, or mixtures of these, not only in order to study effects of remote mixed mode loading, but also because of the oscillating elastic singularity resulting from the elastic mismatch across the interface, which gives varying mixtures of normal stress and shear stress along the interface. This work has been continued in a number of different studies of interface debonding, for different types of material systems. Thus, in [23] resistance curves have been determined numerically for crack growth along an interface joining two elastic-plastic solids, or an elastic-plastic solid to an elastic substrate. The steady-state value $|K|_{ss}$ of the

remote fracture toughness is found when the resistance curves reach their maximum, which depends on the local mode mixity ψ_0 near the crack-tip. As an example Fig. 3 shows such steady-state values for a case with an elastic substrate, where the elastic modulus E_2 in the substrate is twice that in the elastic-plastic solid. The angular measure ψ_0 is near 0° for mode I loading and would be near 90° or

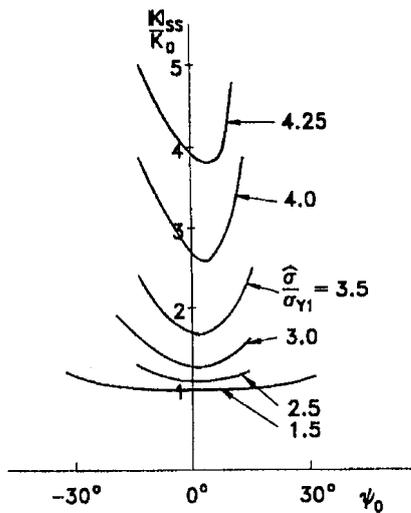


Fig. 3: Steady-state interface toughness as a function of the local mixity measure ψ_0 , for $\sigma_{y1}/E_1 = 0.003$ and $\sigma_{y2} \approx \infty$, considering different values of $\hat{\sigma}/\sigma_{y1}$, $E_2/E_1 = 2$. (From [23]).

-90° for mode II loading. The steady-state toughnesses are normalised by the value K_0 corresponding to a purely elastic solid, for the separation energy assumed in the traction separation law. The different curves correspond to different values of the peak stress $\hat{\sigma}$ for the traction separation law, normalised by the initial yield stress. The curves show two typical features of such results, that the fracture toughness level is very sensitive to small increases of the peak stress, and that the curves have minima for near mode I conditions at the crack-tip.

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