EGF Newsletter

Official Newsletter of the European Group on Fracture Nr. 9, Spring 1989

ASFM on the Road

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Until now EGF's Advanced Seminars on Fracture (ASFM) were always organized by the JRC in Ispra, Italy. Last year it was decided that the next, seventh seminar should be organized elsewhere. Hence, the Executive Committee had to make a choice regarding both scope and location for ASFM7.

Scope

Previous ASFM's were devoted to General Fracture Mechanics and Dynamics (1975), Elastic Plastic Fracture Mechanics (1979 and 1983), Sub-Critical Crack Growth due to Fatigue, Stress Corrosion and Creep (1981), Fracture of Non-Metals (1985) and Assessment of Cracked Components by Fracture Mechanics (1987). Consultation of the EGF Executive Committee and Consultants did not reveal a clear majority for one particular scope. It was then decided to choose that scope which was mentioned several times, which had not been treated in previous ASFM's, and which was expected to attract enough attendants from EGF's member countries, i.e.:

Numerical Methods in Fracture Mechanics.

Location and Time

Several attractive offers to organize ASFM7 were received, and hence also the location required a difficult decision. After a careful evaluation of the offers, it was decided to accept the offer received from the Polish Fracture Group and the University of Kielce to organize ***ASFM7 in Kielce, Poland***. Kielce is located at about 150 kilometers from Poland's capital, Warsaw, with an excellent railway connection with its international airport.

The additional consultation in connection with the change of

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1984 + 5 = Big Brother's 1st lustrum

When 1984 came and passed, a lot of people were relieved because we had managed to avoid Orwell's nightmare of "Big Brother watching us" to come true. Now, five years later, I have the feeling we were wrong....

In the seventies we faced an economical crisis. One of the results was that the society wanted a better control on expenses for education and scientific research. The solution came in the form of professional management. The tools of management are plans, figures and progress reports, and hence the staffs of educational and research institutes were asked to produce these. Before we knew, most of our efforts were devoted at writing proposals and progress reports explaining that our work was delayed because we were to busy writing down what we should have been doing. The real work was left to those happy few who managed without managers.

Measureing methods were developed to judge the quality and productivity of groups. First there were many protests, fighting the sense of the models based on output figures. However, under the device "bad or wrong figures are better than no figures" these were waved aside. That's when a strong underground movement developed. Groups started to find ways to report the same findings in as many ways as possible, shuffling around with co-authors and with maximum cross-referencing. Here we should also acknowledge the role of publishers and conference organizers; we could never have done it without the necessary printing capacity.

And we were proud. Proud, because we thought we had fooled our managers. But who do you think we are fooling? Do you also have that idea that it is impossible to keep pace with the literature? Did our actions prevent that management decisions were taken based on figures that were so successfully sabotaged by us? Just look around!

Still convinced that we managed to avoid Big Brother(s)? We even have special trainings for them!

an irritated researcher

EGF ADDRESSES

President
Dr. L.H. Larsson
CEC, D.G. XII/D-3
ARTS/LUX 3/39
200, rue de la Loi
1049 Brussels, Belgium
Tel. (32) 2-2354065
Telex comeu b 21877
Fax (32) 2-2362006

Secretary General & EGF Office
Prof. A. Bakker
Materials Laboratory
P.O. Box 5025
2600 GA Delft
the Netherlands
Tel. (31)15-785418
Telex 38151
Fax (31) 15-786730

ECF8 Organizer
Prof. D. Firrao
Politecnico di Torino
Instituto di Chimica Applicate e di Metallurgia
Corso Duca degli Abruzzi 24
10129 Torino, Italy
Tel.(39)11-5566763/5567777
Telex 220646
Fax (39)11-5566329

ASEM Organizer
Dr. L.H. Larsson
see President

Strengthening Committee
Chairman
Prof. L. Faria
CEMUL-IST
Avenida Rovisco Pais
1096 Lisboa, Portugal
Tel. (351)19-803580
Telex 63423 istutl p
Telefax (351) 1-899242

Publications Committee
Chairman/Editor FFEMS-Journal
Prof. K.J. Miller
University of Sheffield
Dept. of Mech. Engineering
Mappin street
Sheffield S1 3JD, UK
Tel. (44)742-768555 x 5160
Telex 547216 ugshef g
Fax (44)742-753671

Task Group EPFM
Chairmen
G. Angelino
CISE, Materials Department
P.O.Box 12081
2034 Milano, Italy
Tel. (39)2-2167 2413
Telex 311643 cise i
Fax (39)2-2167 2620

Prof. D. Firrao
see ECF8 Organizer

WP Numerical Round Robin
Dr. W. Schmitt
Fraunhofer Institut für Werkstoffmechanik
Wöhlerstr. 11
7800 Freiburg, FRG
Tel. (49) 761-5142 0
Telex 041-17761159 fhiwmfr
Fax (49) 761-5142 147

WP R-Curves and Tearing Instability
Dr. I. Milne
CEGB-CERL
Kelvin Avenue, Leatherhead
Surrey KT22 7SE, UK
Tel. (44)372-374488
Telex 917338

WP High Temp. Crack Growth Round Robin
Dr. Th. Hollstein
Fraunhofer Institut für Werkstoffmechanik
Wöhlerstr. 11
7800 Freiburg, FRG
Tel. (49)761-5142-121
Telex 041-17761159 fhiwmfr

WP Fracture Mech. Testing Standards
Prof. K.-H. Schwalbe
GKSS-Forschungszentrum
Max Planck Straße
2054 Geesthacht, FRG
Tel. (49)4152-87 2500/2501
Telex 218712 gkss-g-d
Telefax (49)4152-871618

WP on Local Approach
Dr. F. Mudry
Ecole des Mines de Paris
60, Boulevard Saint-Michel
75272 Paris Cédex 06
France
Tel. (33)1-42 34 90 14
Fax (33)1-43 25 94 95

Task Group Fracture Dynamics
Chairmen
Prof. J.F. Kalthoff
Ruhr University
Exp. Mechanics IA 2/26
4630 Bochum 1, FRG
Tel.(49)234-700-2471or 4598
Telex 0 82 58 60

Dr. Z. Bilek
Inst. of Physical Metallurgy
Czechoslovakian Academy of Sciences
Ziskova 22
61662 Brno, CSSR
Tel.(42)5-746 746 extn. 319

WP Crack Arrest
Dr. R.K. Gillot
MPA
Pfaffenwaldring 32
7000 Stuttgart 80, FRG
Tel. (49) 711- 6851
Telex 7-255 764 mpa d
Fax (49) 711-685 3043

WP Conventional Impact Testing
Dr. D.F. Cannon
British Railways Board
Research Division
London Road
Derby DE2 8UP, UK
Tel.(44)332-42442 extn. 2234
Telex 25860 ndr d

WP High Rate Impact
Prof. G. Pluvinage
Lab. de Physiques et Mécanique des Materiaux
Université de Metz
Ile de Saulcy
57045 Metz Cedex, France
Tel. (33)87 30 58 40

Task Group Fatigue
Chairman
Prof. K.J. Miller
see Chairman Publication Committee

WP Multiaxial Fatigue
Dr. M.W. Brown
University of Sheffield
Dept. of Mech. Engineering
Mappin street
Sheffield S1 3JD, UK
Tel. (44)742-768555
Telex 547216 ugshef g
Fax (44)742-739826

Task Group Micromechanisms
Chairman
Prof. W. Dahl
T.H. Aachen
Inst. für Eisenhüttenkunde
Intzestr. 1
5100 Aachen, FRG
Tel. (49)241-805782
Telex 832704 thac d
Fax (49)241-804413

Secretary
Dr. K.E. Hagedorn
Max Planck Institut für Eisenforschung
Postfach 140 260
4000 Düsseldorf 1, FRG
Tel. (49)211-67921
Telex 8586762

WP Stretched Zone Round Robin
Mr. A. Halim
T.H. Aachen
Inst. für Eisenhüttenkunde
Intzestr. 1
5100 Aachen, FRG
Fax (49)241-804413

WP Micr. Cleavage Fracture Stress Round Robin
Mrs. H.Dünnewald-Arfmann
T.H. Aachen
Inst. für Eisenhüttenkunde
Intzestr. 1
5100 Aachen, FRG
Tel. (49)241-805831
Fax (49)241-804413

Task Group Polymers and Composites
Chairmen
Prof. J.G. Williams
Dept. of Mech. Engineering
Imperial College of Science and Techn.
Exhibition Road
London SW7 2BX, UK
Tel. (44)1-589-5111
Telex 261503
Fax (44)1-584-7596

Prof. H.H. Kausch
Polymer Laboratory
École Polytechnique Fédérale de Lausanne
1007 Lausanne, Switzerland
Tel. (41)21-6932841
Telex 454478
Fax (41)21-6932935

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location required more time than expected. As a consequence it had to be concluded that it was not possible to have ASFM7 in 1989, as originally intended, but that the first half of 1990 is the earliest possible time. The definite date for the 5 days seminar is still to be fixed; this will be done in the next few weeks.

Programme

As all previous ASFM's, the high quality of the seminar should be guaranteed by a balanced programme with lectures by outstanding experts in the field. To achieve this, an international Advisory Committee was installed. Members of this committee are A. Bakker (Delft University, The Netherlands), Ph. Jamet (Centre d'Etudes Nucleaires de Saclay, France), M. Kuna (Academy of Sciences, GDR), A.R. Luxmoore (University College of Swansea, UK) and W. Schmitt (IWM Freiburg, FRG).

The definite programme, together with various other details about the seminar will be announced in the Summer issue of the EGF Newsletter, and in a seperate flier that will also be distributed this summer. ***We will keep you informed.***

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EGF Organizational Membership/Sponsorship Campaign

First results are promising

This winter we started a campaign to find organizations and industries willing to support EGF by becoming an EGF Member or Sponsor. This campaign must be seen apart from the EGF Personal Membership introduced before, which is intended primarily to create a technical forum for the future that may vote on technical issues, and to improve personal involvement in EGF's affairs.

By finding organizational members/sponsors EGF tries to secure its operations for the future. There is a still increasing pressure to increase the activities, but further growth is prevented by a lack of the required finances.

We are glad that we can now announce that the first EGF Organizational Members/Sponsors have registered. These pioneers are:

Gebrüder SULZER AG, Switzerland
Fraunhofer Institut für Werkstoffmechanik (FhIWM), FRG
STORK Boilers, The Netherlands
FRAMATOME, France
TNO-IBBC (Institute for Building and Construction), The Netherlands
HSK (Swiss Federal Nuclear Safety Inspectorate), Switzerland

If you feel that your organization belongs in this row, please contact EGF Office for details.

TASK GROUP FRACTURE DYNAMICS

Working Party "Crack Arrest"

Minutes of the 3rd meeting at MPA Stuttgart, FRG on March 16, 1989
Co-ordinator: R.K. Gillot

Introduction

The 3rd meeting of the working party "Crack Arrest" was held at MPA Stuttgart, FRG on March 16, 1989. Dr. Roos as the acting co-ordinator announced his withdrawal from the chairmanship in the group. His proposal to nominate Dr. Gillot from MPA Stuttgart as the new co-ordinator was accepted unanimously by the participants. Afterwards, Dr. Gillot took over and chaired the meeting.

Current Research

In the first presentation, Dr. Brickstad from the Swedish Plant Inspectorate in Stockholm described in great detail the experimental and numerical evaluation of instrumented crack arrest experiments conducted within the Nordic crack arrest project, the participating countries are Sweden, Norway, Finland, and Denmark.

The goals of this co-operative program are:

- to obtain information on the dynamic fracture properties, in particular crack arrest data, of the material A 533 B Cl. 1;
- to participate in benchmark analyses of the HSST wide-plate crack arrest experiments (dynamic FEM, elastic and viscoplastic);
- to develop simple methods for analyses of rapid crack growth and arrest;
- to perform analyses and predictions of rapid crack growth and eventually arrest in real structures.

In the experimental part, compact crack arrest specimens (dimensions: 400 x 400 x 100 mm^3) from a broken HSST wide-plate of series WP-1 were tested at temperatures slightly above $T_{NDT} = RT_{NDT} = -23°C$. Special effort was made to develop a reliable technique to measure the instantaneous crack-tip velocity, preferably not only at the specimen surface. The following test techniques were considered: ladder gages across crack plane, strain gages above crack plane, high speed camera, optical fibres, ultrasonic methods, and potential-drop method. Mr. Klemm and Böhme from IWM Freiburg referred to investigations conducted to locate the crack tip by monitoring the temperature increase in the vicinity of the crack plane. The first three methods only measure the crack tip position at or close to the surface of the specimen, while the last three ones are designed to locate the crack tip position at mid-thickness as a function of time. So far, it is not absolutely clear if the breakage of the optical fibres always coincides with the passage of the crack tip. A promising method seems to be the measurement of the crack tip position by ultrasonic transducers. In this case the waves are transmitted from one side of the specimen and are or are not received on the other side of the specimen, depending on the position of the crack tip. A high sampling frequency for a good resolution and a filter for stress wave signals are essential for assuring reliable results.

The goals of the analytical part are to perform an elasto-dynamic FEM-analysis in generation mode to determine the stress intensity factor as a function of crack speed and temperature, and to investigate the role of nonlinear effects by using elastic-viscoplastic material models. It is assumed that the split pins are in a fixed position during crack propagation, a gradual node relaxation according to the measured crack speed enables the FE-code to simulate crack growth. The dynamically evaluated K_{Ia}-results of the present study correspond to K_{Ia}-values from the Battelle Columbus Labs. determined by smaller compact specimens and tested according to the ASTM Standard E-1221.

In the second presentation Dr. Gillot reported on first results from tests with sub-sized crack arrest specimens. These

tests were conducted by Dr. G. Hedner from the Royal Institute of Technology, Dept. Solid Mechanics and Strength of Materials in Stockholm. In this case, standard sized Charpy V-notch specimens (10 x 10 x 50 mm^3) with a V-shaped crack plane to provide a decreasing stress intensity factor with crack propagation were used. The prefatigued specimens are loaded by slow three point bending, the evaluation was done by the dynamic FE-code VISCRK. First results are in good agreement to values from standard compact crack arrest specimens.

Mr. Gerscha from Siemens AG, UB-KWU in Erlangen proposed a method to determine K_{Ia}-values by standard Charpy tests. These investigations should be available at the next meeting.

Finally, questions related to the extension of the validity range to the upper-shelf regime of the Charpy V-notch energy were discussed. This topic will once again be raised in the next meeting, together with questions from the field of large scale testing.

Next Meeting

The 4th meeting of the Working Party "Crack Arrest" is planned for January 1990.

Working Party "Conventional Impact Testing"

Meetings of the Working Party have been arranged for 6 July 1989 at the Royal Military College of Science, Shrivenham (UK) and 25 October 1989 at the Welding Institute, London (UK).

Although the present title of the WP suggests an emphasis on impact testing the actual interests of the WP covers all types of conventional high loading rate testing.

Further information from:

Mr. D.F. Cannon *(Chairman)*
British Railways Board
Research Division
Railway Technical Centre
London Road
Derby, DE2 8UP, UK

or

Mr. B. Hayer *(Secretary)*
The Welding Institute
Abington Hall
Abington
Cambridge, CB1 6AL, UK
Telephone: (44) 223 891162

TASK GROUP ELASTIC-PLASTIC FRACTURE MECHANICS

Round-Robin on LOCAL CRITERIA

Co-ordinator: F. Mudry

Perhaps is it necessary to explain the three parts of the programme.

- First, a numerical round-robin on **one** specimen geometry : a notched round bar with a 2mm radius. The data for this calculation have been sent to the participants;
- Second, an experimental round-robin on ductile fracture involving **six** specimens of three different geometrics (notch radii 2, 4, 10mm) at 100 °C. The material will be provided by the MPA in Stuttgart;
- Third, an experimental round-robin on cleavage fracture involving **nine** specimens of three different geometries (notch radii 2, 4, 10mm) at -196°C. The material will be provided by KWU.

In the end, we have exactly 31 participants from the EEC and 7 outside EEC *(please note that one laboratory from Italy has been counted twice in our previous document and some laboratories outside EEC cannot be accepted because of the amount of material available).*

The funding from EEC is not official yet. It will cover the expenses of cutting and sending the blanks to the EEC participants.

We wait for an official contract before the beginning of the experimental round-robins.

EIGHTH EUROPEAN CONFERENCE ON FRACTURE

GRUPPO ITALIANO FRATTURA (IGF)

CALL FOR PAPERS

ECF8

European Group on Fracture

POLITECTICO DI TORINO
Torino Italy 1-5 October 1990

The European Conferences on Fracture have, since their first round in Compiègne in 1976, represented the major biennial European forum for engineers and researchers in the field of Fracture Mechanics and related scientific and technological areas. They constitute one of the most efficient means of the **EUROPEAN GROUP ON FRACTURE (EGF)** to fulfil its statutory objectives.

The 8th edition, **ECF8**, will be organized in Torino by the **GRUPPA ITALIANO FRATTURA (IGF)** on behalf of EGF from **October 1 to 5, 1990**. It will represent the occasion for an in-depth outlook to the 90's and to the global integrated challenge they will pose to Engineers and Materials Scientists.

The Conference will comprise Invited Plenary Lectures, presentation and discussion of Contributed Papers, as well as Poster Sessions about various themes centred on:

Fracture Behaviour and Design of Materials and Structures

Prospective authors are requested to submit a **300 word abstract** to IGF, signalling their preference for oral or poster presentation by **September 15, 1989**. A European Scientific Advisory Board will decide on the acceptance for presentation and publication in the proceedings. Authors will be advised upon acceptance by December 15, 1989. **Final manuscripts** have to reach IGF by **March 15, 1990** for incorporation into the **ECF8 PROCEEDINGS**.

IGF, c/o Prof. Donate FIRRAO
Politecnico di Torino, Dip. Scienza dei Materiali e Ingegneria Chimica
C.so Duca degli Abruzzi, 24
I-10129 Torino, Italy
Tel. (39) 11-556.7777/6763, Telefax (39) 11-556.6799/7990, Telex 220646 POLITO

Workshop on

Fracture Mechanics Characterization of Austenitic Steels

The **Working Party of Fracture Mechanics Testing Standards** is planning to hold a

Workshop on Fracture Mechanics Characterization of Austenitic Steels

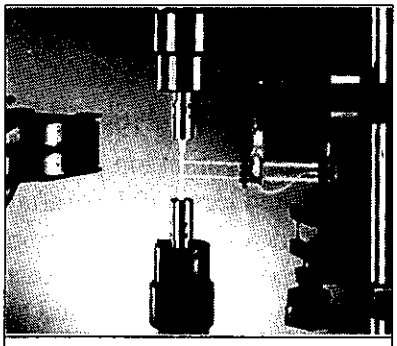
next spring or summer. The main emphasis is on issues like:

- applicability of existing or drafted standard test methods,
- experimental techniques, e.g. measurement of crack extension,
- size requirements,
- characterization in terms of J-integral versus CTOD.

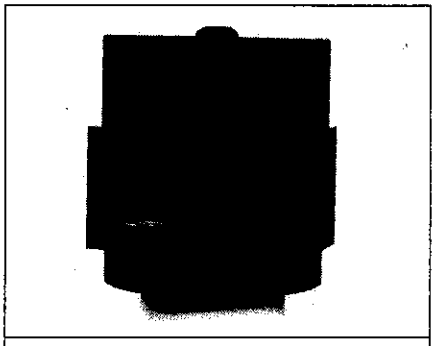
Those who wish to contribute actively are requested to contact

Prof. Dr. Ing. K.-H. Schwalbe, *address see page 2..*

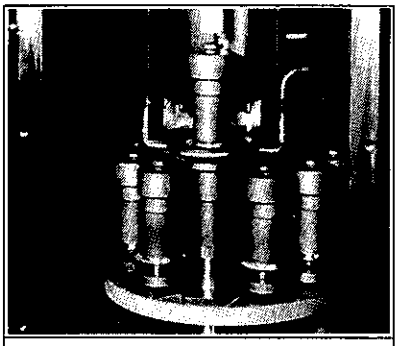
Total package capability for advanced ceramics testing



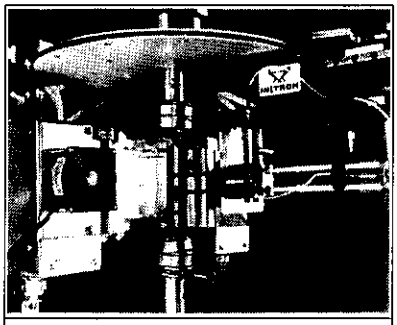
'Supergrip' tensile grips



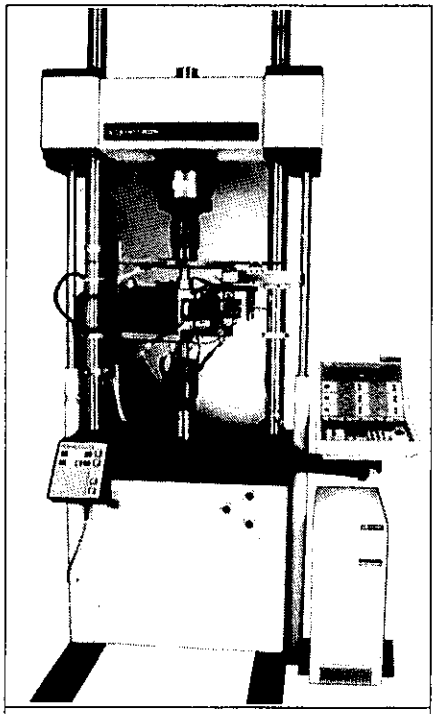
1500°C flexure testing



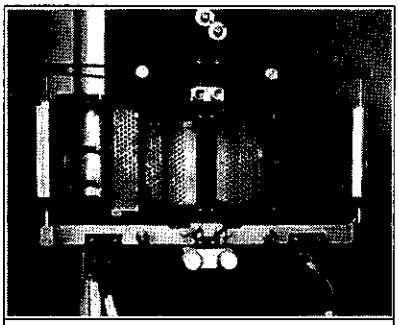
Automated 12-station multiple bend testing at 1650°C



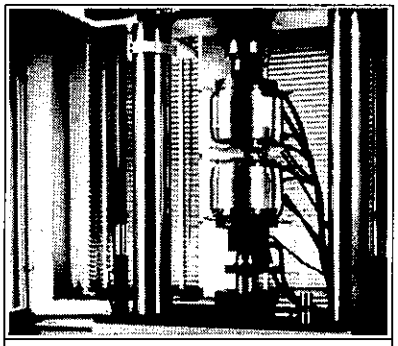
1600°C Short furnace and extensometry



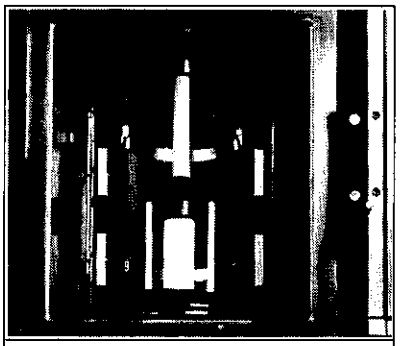
Digital tensile testing system for ceramic composites



Ceramic fibre-testing system



Tension/torsion testing of ceramic tubes



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The best test for any idea

Fifth Fracture Mechanics Summer School

Fracture Mechanics Application in Lifetime Estimation of Power Plant Components

Dubrovnik, Yugoslavia, June 26-30, 1989

The Fracture Mechanics Summer Schools, that have been organized regularly from 1980, have attracted large number of participants (63 in the first and 96 in the fourth) and the attention of well-known specialists from all-over the world, who served as lecturers. The published lecture-books after every School are the most effective references in fracture mechanics application for experts in Yugoslavia. The decision for the organization of the Fifth Summer School is based on growing interest and requirements of the Electricity Board-Belgrade. Accordingly, the next School will be devoted to the problem of life extension of power plants components and the application of the fracture mechanics approach to this problem. The large number of fractures and resulting consequences have attracted the attention of experts in electricity production to the problem of cracks of different origin, that could occur in materials applied for power plants components. The fracture mechanics approach offers a possibility towards a better understanding of the behaviour of loaded materials containing cracks under various severe environmental conditions. The aim of the Fifth Fracture Mechanics Summer School "Fracture Mechanics Application in Lifetime Estimation of Power Plant Components" is to bring together the experience of experts in fracture mechanics and operational problems that are met in power plant service regarding crack occurrence and development, including final fracture. A large number of invited foreign lecturers have already confirmed their participation with contributions devoted to their field of interest:

- **Dr. P. Agatonovic** *MAN Technology, BRD*
- **Prof. P. Albrecht** *University of Maryland, College Park, U.S.A.*
- **Dr. M. Bethmont** *Electricité de France, Paris, France*
- **Dr. A. Czeratzky** *Asea Brown Boveri, Baden, Switzerland*
- **Dr. E. Czoboly** *Budapest Műszaki Egyetem, Budapest, Hungary*
- **Dr. T. Hollstein** *Fraunhofer Institut für Werkstoffmechanik, Freiburg, BDR*
- **Dr. A. Jovanovic** *Staatliche Materialprüfungsanstalt, Stuttgart, BDR*
- **Dr. H. McHenry** *National Institute of Standards and Technology, Boulder, Colorado, U.S.A.*
- **Prof. B. Michel** *Academy of Sciences of GDR, Karl Marx Stadt, GDR*
- **Dr. J. Radon** *Imperial College of Science and Technology, London, U.K.*
- **Dr. D. Read** *National Institute of Standards and Technology, Boulder, Colorado, U.S.A.*
- **Prof. A.D. Truhnij** *Moskovskij Energeticeskij Institut, Moscow, USSR*
- **Dr. H. Weber** *Mannesmann Forschungsinstitut, Duisburg, BRD*
- **Prof. M. Wnuk** *University of Wisconsin, Milwaukee, U.S.A.*

The following Yougoslav experts are expected to give their contributions:

- **Prof. M. Berkovic** *Faculty of Sciences, Belgrade*
- **Dr. M. Butkovic** *Jugoturbina, Karlovac*
- **Dr. S. Jaksic** *TPK, Zagreb*
- **Dr. Z. Lukacevic** *Faculty of Mechanical Engineering, Slavonski Brod*
- **Prof. A. Radovic** *VTI, Belgrade*
- **Doc. I. Rak** *Technical Faculty, Maribor*
- **Prof. F. Vodopivec** *Metallurgical Institute, Ljubljana*

The lectures will be directed to explain following themes:

1. **DAMAGE AND FRACTURE**
2. **MATERIAL PROPERTIES AND BEHAVIOUR OF CRITICAL COMPONENTS**
   - 2.1. Basic mechanical properties
   - 2.2. Crack growth resistance
   - 2.3. Resistance against (stress) corrosion and erosion
   - 2.4. Fatigue
   - 2.5. Creep
   - 2.6. Influence of low and high temperatures
   - 2.7. Welding problems of steels for high temperature application
3. **LIFETIME ESTIMATION PROCEDURES**
   - 3.1. Lifetime estimation parameters and techniques
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   - 3.7. Influence of operational conditions
4. **LIFE EXTENSION OF COMPONENTS, SYSTEMS AND PLANTS**
   - 4.1. Technical aspects
   - 4.2. Regulatory aspects
   - 4.3. Economical aspects

The Fifth School will be held from 26th to 30st June 1989 in Dubrovnik. The lectures of foreign lecturers will be given in English. The lecture book will be published in English.

For further informations please contact:

Dr. Blagoj Petrovski
Faculty of Technology and Metallurgy
Karnegijeva 4
11000 Belgrade, Yugoslavia

TASK GROUP ELASTIC PLASTIC FRACTURE MECHANICS

Working Party "Fracture Mechanics Testing Standards"

The WP Fracture Mechanics Testing Standards is thinking of extending the present draft of the EGF Recommendations for Determining the Fracture Resistance of Ductile Materials to thin sections, i.e. to configurations which often occur in **Aerospace Applications.**

Thin sections are often outside the thickness requirements for size independent data. This new action would cover - among other items:

the introduction of centre cracked tensile specimens and the treatment of this configuration with elastic plastic fracture mechanics methods which at the present time is not addressed in an existing standard.

We are seeking for volunteers - in particular from industries or research organizations related to aerospace applications who are willing to actively contribute to a chapter in the EGF Procedure addressing thin sections.

Please contact **Prof. Dr.-Ing. K.-H. Schwalbe,** *address see page 2.*

Proceedings of the European Group on Fracture

BIAXIAL AND MULTIAXIAL FATIGUE (EGF 3)

Edited by M.W. Brown and K.J. Miller

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(c) Surface microstructural effects
(d) Models of surface defect growth
(e) New experimental techniques including acoustic microscopy for measuring surface features
(f) Mean stress effects
(g) The short-long crack transition
(h) Elastic-plastic finite element simulations
(i) Long-life prediction
(j) Short cracks at notches

Coference date

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Location

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All delegates will be expected to contribute to the discussion, for which ample time will be available. Consequently attendance will be by invitation only.

Further information

For further information please write to:
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FAILURE ANALYSIS

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BUDAPEST, HUNGARY, 1988

EDITOR E.Czoboly

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Remarks on the Note "Orowan and Irwin Exposed"

by R.N. Stevens and F. Gulu, EGF Newsletter Nr. 7, 1988

R. Labbens, Past President of the EGF, Paris

I believe the short comment of Prof. François about the absence of the dissipated energy in the balance is perfectly appropriate and sufficient. Differences of point of view do not matter when thermodynamics is violated. However I believe it useful to analyse the note with more details.

I- In any theory of fracture mechanics instability occurs when the sum of the change of the recoverable potential energy of the system (< 0 or driving) plus the change of the absorbed or resisting energy (>0) is zero, passing from positive to negative. In terms of generalized forces:

$$\Delta a\,[-G(a,\sigma) + R] = 0 \qquad (1)$$

$G(a,\sigma) = -\Delta P/\Delta a > 0$ *driving force*

$R > 0$ *resistance*

With Griffith $R = 2\gamma$, surface energy density, reversible ; in LEFM $R = 2p$ ($p >> \gamma$) non reversible, dissipated, property of the material: in large scale yielding R depends on the geometry.

In perfectly continuous materials voids or separations are impossible whatever the level of deformation is. In real materials they exist and change while the surrounding material is plastically deformed; at a certain level of deformation the ligaments are broken, and the crack extends absorbing an energy $R\Delta a$ ($p\Delta$a in LEFM) resulting from plasticity and rupture of ligaments. In this extension the plastic zone is translated and to a certain extent increased.

This resisting energy must not be confounded with the energy necessary for creating the plastic zone before the extension.

p or $R(a)$ cannot be calculated by a mechanical analysis of a continuous solid ; they must be measured by experimentation. Calculations have been attempted involving the breaking of grains, the formation and coalescence of voids, beyond the domain of continuous materials, and also, to my knowledge, beyond the domain of dislocations.

Let us look at the example of a semi infinite crack in an infinite plane in mode III with an imposed K_{III}. It is known [1,2] that in perfect plasticity the plastic zone is exactly a circle of radius $r_\gamma = 1/2\pi \ (K_{III}/\tau_\gamma)^2$. If the crack is extended by Δa, with two points of plane fixed, keeping the same K_{III} the size of the plastic zone is not changed, while it is evident that a volume of material has been swept by plastification with relaxation in certain places, and energy has been dissipated, work of a resisting force. In modes I and II, and LEFM, this solution is considered a sufficient approximation [3, 4, 2].

II- About definitions and notations, p. 10, under eq (1), the authors mention "*the plastic work term*" of Irwin and Orowan. I understand they give to p the hereabove significance, resisting energy density.

The authors mention their own paper (their ref. 4) and "*define clearly what is meant by plastic work ..... When dislocations are generated and move in a crystalline material under influence of some forces, the work done can be computed, in principle, by integrating the force per unit length on the dislocations with respect to displacement and total line length.*" This definition is very general, for LEFM and large scale yielding. They add a part dissipated as heat, and a small part, about 5%, is stored in the material as strain energy. I denote this plastic work W_{pl}.

W_{pl} is the energy necessary to the formation of the plastic zone before any extension. If it is calculated again after the extension, it yields the energy for the formation of the new plastic zone. The difference ΔW_{pl} is related to Δa, but is not the resisting force $2p\Delta a$, or $R\Delta a$.

In the hereabove example of a semi infinite crack in mode III, $\Delta W_{pl} = 0$ while there is a resisting force.

III- Energy balance

The authors give an expression of the "total energy change".

$$\Delta E_c + \Delta E_p + 2\gamma\,\Delta a + 2\alpha p\,\Delta a \qquad (2)$$

They write : "*The condition of unstable equilibrium with respect to crack extension is obtained by setting this total energy change to zero.*" This means that (2) equated to zero is the energy balance at instability.

1) "ΔE_c *and* ΔE_p *are the changes in the combined elastic plus mechanical energy of the system due to crack extension and to plastic deformation respectively.*" A more accurate definition would be useful. "*Elastic*" is likely for "*linear elastic*", and "*elastic energy*" for linear elastic strain energy. Does "*mechanical energy*" mean the potential energy of the applied forces, or minus the external work ($-W_{ext}$)? The definition of W_{pl} allows the consideration of non linear problems. In such problems, are ΔE_c and ΔE_p the recoverable parts of the changes of the potential energy of the system $P = U - W_{ext}$ (U, strain energy)? In LEFM they are total changes of I. What model have the authors in mind?

2) $2\gamma\Delta a$ is a Griffith's term, positive, resisting, but small and not significant for metals.

3) What is exactly $2\alpha p\Delta a$ (α likely 0,05)? In the authors' mind is it 5% of the resisting energy, then > 0 ? Difficult to understand. The authors write "*.... small fraction* α*, of plastic work,* $p\Delta a$*, stored in the material*". It might be $\alpha\Delta W_{pl}$, fraction of plastic work, as defined by the authors (see II) but not $2p\Delta a$. If $\alpha<0$, this fraction is driving.

4) The note does not make very clear what ΔE_p is. From the authors' paper (their ref. 4, fig. 3), I have understood they seem to believe the plastic zone, and the resulting increase of the compliance, is created by the extension. Actually the plastic zone results from the loading of the body and exists before any physical extension; after the extension it is translated and slightly modified. The authors should have placed a point C' related to $a + r_\gamma$; they would have found another shaded area under OA. The difference would have given ΔE_p negligible.

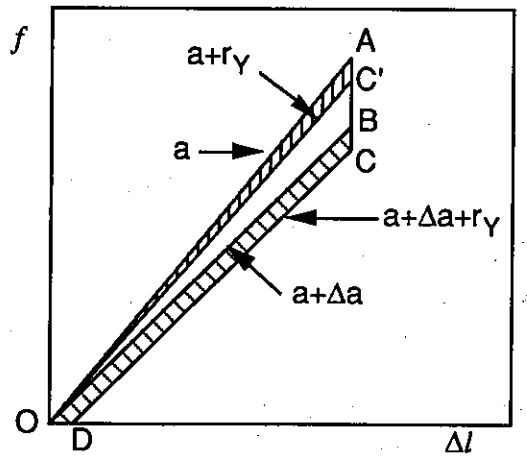

Fig. 3 of ref. 4 of the authors

The authors state rightly the unloading line does not pass by O. But a point in the elastic zone comes back nearly to its initial position; in the plastic zone the difference is higher, but as the zone is small the result is practically negligible in LEFM.

5) In (2), the Griffith term $2\gamma\Delta a$ is > 0, resisting, but small, unless the authors give another sense to γ; whatever its significance is, $2\alpha p\Delta a$ is small. A resisting, first order term is missing in (2). This is not astonishing since (2) results from an analysis in an ideally continuous material, while the resisting term results from another physical phenomenon as shown in I.
This is the major point. It makes that (2) equated to zero looks like an equilibrium equation without the reactions.

IV- Conclusion

My main remarks are:

1) The authors seem to have believed the plastic zone results from the extension while it results from the loading before any physical extension.
2) They have omitted the physical resistance to extension and the corresponding dissipated energy which cannot be evidenced by an analysis in a continuous material, even, to my knowledge, with the use of dislocations.

If I am wrong on this point, I expect the authors will show clearly where I am wrong, and the reason why they may omit a resistance to extension. The other points, right or wrong, are secondary.

My conclusion is that of Prof. François. There is no paradox, and no problem at all. Any opinion can be presented if it is clearly documented. The note is not very clear. It has not been improved by the use of such words as "erroneous and fallacious" near the names of Irwin and Orowan.

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3) G.R. Irwin, Plastic zone near a crack and fracture toughness, 7th Sagamore Conf. on Ordnance Materials Research, 1960
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Quantities versus Rates

Comment on reaction of F. Guiu, EGF Newsletter 8, page 5

C.E. Turner, Imperial College, London

This comment is not on the original article by Stephens and Guiu but on the point they make in their reply (*EGF Newsletter 8, p. 5*) "*that plastic deformation should make the crack growth rate easier*". It does! The "toughness" that increases as in a *J-R*-curve is a measure of the cumulative dissipation. The toughness that decreases is a rate such as (more or less) measured by *dJ/da*. For *COD* the value at the ***initial*** tip increases whilst a decreasing or perhaps steady rate is instanced by either the *COA* or the *COD* at the ***advanced*** tip. The *"falling R-curve"* of dissipation rate was in vogue in the 1950's by Boyd amongst others, only to be superseded by rising (cumulative) *R*-curve of Krafft, Sullivan and Boyle in the 1960's. The falling rate curve may yet come into vogue again with measurements of dissipation rate in e.g. [1], [2] and the scaling of [2] in [3] and of [1] in [4]. The *"two* COD*'s"* picture (not implying that *COA* might not also be a way to present the same data) is in [5] Fig. 2.71 and the Boyd-Krafft controversy in [5] Fig. 2.66. What (still) seems lacking is any wider recognition that *"toughness"* is a term loosely defined (in the scientific if not legal sense) to cover both quantity and rate (*d/Bda*). Thus, e.g. a Charpy measure is a quantity; the Griffith concept is a rate; the *J-R*-curve is a quantity; a falling of *dJ/da* and dissipation *dU/Bdu* curves (as in [1], [2], [3] and [4]) are rates. In LEFM this hardly matters since quantity and rate increase together. In EPFM, subsequent to initiation, the quantity increases but the rate decreases. In my own view the former controls initiation but the latter controls instability. However, confusion will continue until two distinct terms are used. So come on, Task Groups, - get some better scientific terminology circulating! I believe prior to circa 1900 creep strain and creep strain rate were similarly confused but can we not do better nearly 90 years later?

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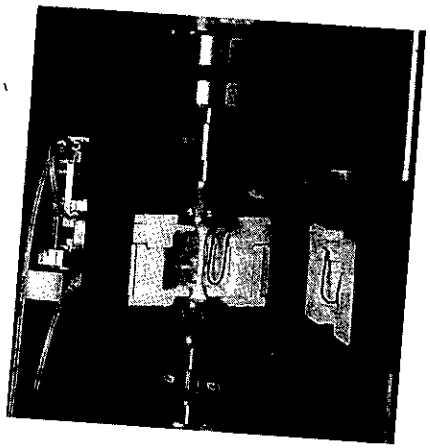

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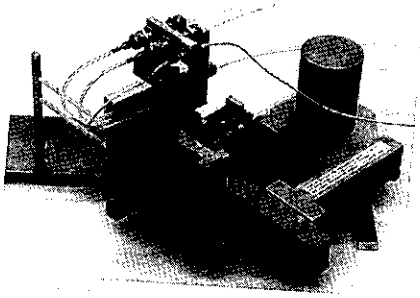

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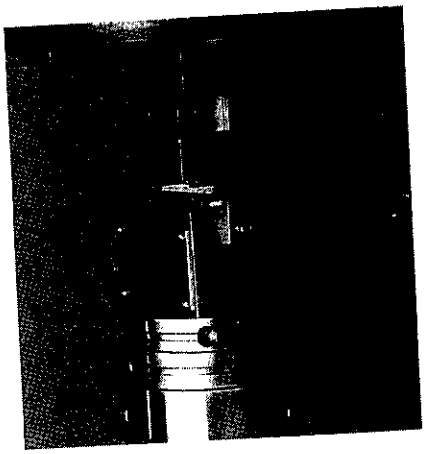

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Physical Mechanisms in Polymer Failure

Report on the results of the
20th Europhysics Conference on Macromolecular Physics/
3rd Lausanne Polymer Meeting

Lausanne, 26 - 30 Sept. 1988
H.H. Kausch/W.J. Cantwell

For the first time in its 16 years of existence, the Europhysics Conference on Macromolecular Physics was held in Switzerland. Following the tradition of the Lausanne Polymer Laboratory "Physical Mechanisms in Polymer Failure" had been chosen as the conference theme. This topic was viewed from all possible levels and directions, ranging from the molecular scale of small deformations to the macroscopic behaviour of fibre-reinforced composites.

The meeting opened with a welcome cocktail offered by the Head of the Department of Materials of the EPFL, Prof. B. Ilschner, in the aula of the Ecole Polytechnique Fédérale de Lausanne. This beautiful setting, the excellent facilities of the auditorium and the spacious poster hall overlooking a splendid park and the lake, the addresses of Prof. B. Ilschner, Prof. B. Crottaz, Vice-President of the EPFL and Prof. Baltà-Calleja, member of the Board of the Macromolecular Section of the Condensed Matter Division of EPS helped greatly to create a stimulating atmosphere facilitating the exchange of information and furthering progress by direct contacts.

The general theme was subdivided into seven topics:

- **Molecular Mechanisms and Theory of Deformation of Polymers**
- **Micromechanics of Crazing**
- **Crazing and Fracture**
- **Fracture and Degradation**
- **Highly Oriented Fibres**
- **Polymer Blends**
- **Fracture of Composites.**

Within these subject areas 30 invited lectures covered major recent developments, sufficient time was allowed for discussions. The powerful tool of the neutron scattering technique was detailed by M. Dettenmaier (Mainz) who showed that the deformation of a molecule (of polycarbonate) is an affined image of the macroscopic deformation at temperatures up to 120° C. The large molecular anisotropy, therefore, plays a specific role only close to Tg (at 149° C). B. Jasse (Paris) continued this theme and reported an unexpected finding : the first step in the plastic ***elongation*** of a sample at the yield point is a slight ***shortening*** of the chains by increase on the number of gauche bonds - interpreted as being due to a shift in thermal configurations equilibrium.

As opposed to the previous discrete molecular approaches, C. G'Sell (Nancy) derived continuum mechanical constitutive equations, linked however, to molecular interpretations. Noteworthy, was the definition of micro-shear domains enlarged by plastic cycling and which favour local molecular mobility. Such a model permits the quantitative description of "rejuvenation" and "physical aging" phenomena.

The above considerations concern molecular segments; they are generally restricted to the range of linear viscoelastic behaviour. All strength properties depend, however, on the nature of the interaction of whole chains, of their interdiffusion and entanglement. M. Tirrell (Minneapolis) treated the materials science aspects of these mechanisms (see his extensive report given in Ann. Rev. Mat. Sci., Vol. 19, 1988).

One of the most intriguing mechanical phenomena in glassy polymers is the formation of crazes. This subject was treated in detail at the meeting. Formation and breakdown on the fibrillar structure (E.J. Kramer, Ithaca; C.J. Plummer, Cambridge. W. Döll, Freiburg; H.R. Brown, San José) crazing and shear yielding (J.A. Sauer, New Brunswick; A. Pavan, Milan; M. Takemori, Schenectady; I. Narisawa, Yonezawa), and Crazing of blends (R.E. Cohen, Cambridge/Mass) were the essential subjects which will be reviewed by these authors in a new volume of the Advances in Polymer Science (Crazing in Polymers, Vol. 2, H.H. Kausch, ed. 1989).

It was generally regretted that G.H. Michler, (Halle), a well-known expert on high-voltage electron microscopy, had not been permitted to come to Lausanne to give his talk on "Electron Microscopical Studies of Craze Initiation". Thus an excellent opportunity had been missed to discuss his findings with most of the world's leading researchers in this sometimes controversial area. Instead Prof. J.A. Sauer (New Brunswick) was kind enough to present a superbly fitting lecture on the influence of molecular parameters on crazing.

Another important subject could be added to the conference programme, namely the fracture of polymers at low temperatures, (G. Hartwig, Karlsruhe). As the author pointed out, at low temperatures the strength of a polymer is increased whilst the fracture strain is decreased. Most mechanical and thermal properties at very low temperatures are rather independent of chemical structure but depend on morphology, i.e. crystallinity or cross-linking. Unexpected, certainly, was that some polymers (PE) at 77 Kelvin become remarkably tougher at strain rates above $de/dt = 103s^{-1}$.

On the third day, fracture, molecular structure and morphology were put into perspective. L.C.E. Struick (Geleen) chose the fracture mechanics approach and N.W. Gedde (Stockholm) a detailed analysis of the crystalline superstructure (including DSC and electron microscopy); molecular fracture events were studied by F. Szöcs (Bratislava) using ESR-technique; N.Ya. Rapoport (Moscow) drew attention to the generally neglected phenomenon that mechanical stresses can influence the kinetics of

chemical reactions (e.g. the oxidation, leading to microcrack formation and subsequent, stress-dependent failure). She also pointed out the anisotropy of diffusion of low molecular weight radicals in stretched polymers - and thus the anisotropy of the propagation of the reaction.

In an attempt to elucidate the importance of the different molecular fracture mechanisms and combining the possibilities of a large chemistry laboratory with that of an exploring physicist, M. Fischer (Marly) had prepared networks with tailored distances, L, between crosslinking points. The critical crack opening in these materials turned out to be a constant multiple (~350) of L; the fracture energy, however, was predominantly spent in the plastic deformation of the network up to such an extension.

J.T. Dickinson (Pullmann/Washington) discussed the application of fracto-emission analyses to determine failure processes in unfilled as well as filled epoxy resins. The technique can be used in a similar way as that of acoustic emission but offers considerably greater flexibility and precision. The fracto-emission technique has been applied to fibre-reinforced composites enabling the initial stages of matrix failure as well as fibre-matrix debonding to be assessed in detail.

The half way stage of the conference was marked by a scenic lake cruise to the Chateau de Chillon near Montreux. Here, all scientific discussions were curtailed for a few hours and superceded by a wealth of historical information about the splendid castle accompanied by some wine from the famous wineyards of the Lavaux. The visit was followed by a meal in the sumptuous ballroom of a traditional Montreux hotel.

Happily, almost all of the delegates managed to re-surface early the following morning in time for a series of presentations detailing the production and subsequent mechanical properties of highly oriented polymers and fibres. L.P. Mjasnikova (Lenningrad) employed a wide range of techniques in order to study the effect of varying the processing conditions on the morphology of ultra high oriented polyethylene (UHMWPE). She proposed that the motion of extended chain segments is the limiting mechanism in fibres produced from this material. This hypothesis correlates well with the recent work of Pennings (Groningen) where it was stated that the stress-induced solid-solid phase transition occurs at higher temperatures.

P.J. Lemstra (Eindhoven) continued this theme by considering the feasibility of inducing crosslinks during the processing of polyethylene fibres. Induced chemical crosslinks via electron beam irradiation can help to reduce the rate of creep deformation in UHMWPE. However, care must be taken since radiation of the gel-spun fibres may precipitate chain scission and therefore lead to poorer rather than better mechanical properties. Consequently, it is suggested that crosslinking should be induced either before or during the initial stages of draw.

A. Zachariades (San José) discussed the relationship between the tensile properties and the molecular draw ratio ultra-drawn UHMWPE in terms of the macrofibrillar dimensions. By developing a morphological model, the tensile properties of the polymer were predicted as a function of the fibrillar properties and dimensions; record values of fiber stiffness were reported i.e. 220 GPa at draw ratios of 200 to 300. Such enormous values had become possible through a clever "unzipping procedure" of UHMWPE monocrystals.

D. Prevorsek (Morristown) assessed the compressive properties of polyethylene fibres and composites. Interestingly, he pointed out that molecules with small cross-sectional areas generally offer good tensile strengths but poor compressive properties. He suggested that the strength of these oriented fibres will depend strongly upon the fibril diameter, fibril spacing as well as the interfibrillar strength. It was suggested that the last point represents perhaps the most effective means of enhancing the compressive properties of these fibres. I.M. Ward (Leeds) examined creep and stress relaxation effects in ultra-high modulus polyethylene and showed that it is possible to model the creep response of this material using a two-part thermally-activated model. Detailed analyses such as this are greatly needed since the long-term load-carrying capability of this material is still a great cause for concern.

The microhardness of polymeric materials was discussed in some detail by F. Balta Calleja (Madrid). Here, it was shown the hardness of a semi-crystalline polymer can be modelled using a simple parallel spring analysis taking account of the microhardness of the crystalline and amorphous regions. Using this type of analysis it was possible to assess the influence of varying parameters such as the crystal thickness on the hardness properties of the polymer. The latter stages of the conference dealt with a distinct two phase materials with a number of talks on rubber-toughened as well as fibrous systems. Bucknall talked on the principles and consequences of varying the size of the rubber particles on the fracture properties of a toughened nylon. He found that at low strain rates, the size of the rubber particles did not influence the toughness of the polymer whereas at high rates of strain matrices with larger particles tended to offer improved toughnesses. Bucknall (Cranfield) also discussed the feasibility of adding thermoplastics to epoxy resins in order to enhance their fracture toughnesses. It was stated that the short-term toughness of an epoxy can be increased by a factor of three by adding fifteen percent of poly-etherimide.

Local activities were presented by W.J. Cantwell and A.C. Roulin-Moloney, who reported on the considerable experience of the Lausanne laboratory in dealing with the fractographic analyses of pure and loaded resins in a wide range of strain rates and temperatures (See also A.C. Roulin-Moloney, Ed. "Fractography and Failure Mechanisms of Polymers and Composites", Elsevier Applied Science, Barking/1989).

Two quite surprising conclusions were drawn from this multitude of data:

a) The total energy available within a specimen determines the surface roughness
b) a crack clearly needs some time - and distance - in order to accelerate up to the limiting crack speed.

One of the most enlightening talks was given by Young (Manchester) on the subject of the application of Raman spectroscopy to the analysis of micro-

deformations in single fibres. Here, it was shown that the technique can be used in order to determine the magnitude of shrinkage stresses in fibre-reinforced composite materials. This is of particular importance since thermal stresses are often a cause of the premature failure of laminated composites. Young and his colleagues were also the first to determine experimentally the size of the critical transfer length in a high modulus fibre.

Another view into the future, the very promising subject of the behaviour of special three-phase composites, was treated by F.J. McGarry. (Cambridge/Mass.). The talk spanned in a short historical review the very first (and then successless) attempts of blending in the 40 s, the present role of a rubber phase in polymers and that of rubber-coated glass and carbon fibers. The latter treatment increases impact strengths by up to 8-fold while diminishing only slightly (10 to 30%) the transverse tensile strengths of the composite.

Important contributions to the conference theme also came from the exposed (54) individual contributions which very well accompanied and detailed previously mentioned subjects. Just to give an example, the invited paper on chain interdiffusion (Tirrell) was ably. supported by six posters on the dynamics of entangled polymer melts, and on adhesion, knit line formation, welding and fracture of different polymers. Eight posters dealt with crazing, showing e.g. interesting computer simulations, explaining the toughening effect of rubber particles (through geometrical interaction of the particles beyond a critical filling ratio of between 6 and 17%) or of ion-content (insulfonated polystyren). Each poster author gave a 2-minutes oral presentation of his main results and tried to attract the curiosity of his fellow participants. Extended abstracts of all contributions are found in Europhys. conf. abstracts, Vol. 12J (1988).

The congress was accompanied by a well-received exhibition of relevant books from most of the pertinent polymer publishing companies featuring work on general polymer physics, chemistry, mechanics and processing as well as, of course, a special selection of books on polymer fracture.

The conference was a great success attracting thirty well-known speakers, fifty four posters as well as 180 participants from eighteen countries including the U.S.A., Japan, Canada, Australia and of course most European countries. In concluding, the Chairman of the organizing Committee (H.H. Kausch) wishes to express his gratefulness to the invited speakers who assured the scientific value and success of the meeting, to the local political authorities and the President of the Ecole Polytechnique Fédérale de Lausanne for their assistance and encouragement, to the many sponsoring organizations and companies for their generous support which had permitted to invite as many speakers and student, and last but certainly not least, to all members of the Laboratory who through their tireless efforts contributed decisively to the smooth running and the enjoyable atmosphere of EPS20/LMP3.

AGENDA of Fatigue and Fracture Events

Agenda items are placed free of charge.
Inform the editor about any fatigue and/or fracture related meeting of interest for the readers of this Newsletter.

May 16-19, 1989
Course on High Temperature Component Life Assessment
Location : Imperial College, London, UK
Organizer : Imperial College
Inquiries : Dr. G.A. Webster
Imperial College, Mech. Engineering Dept.
Exhibition Road
London, SW7 2BX
Tel. (44)1-5895111, Ext. 6183
Telex 929484, Fax (44)1-5847596

May 16-18, 1989
Introductory Course on Computational Methods in Fracture Mechanics
Location : Southampton, UK
Organizer : Computational Mechanics Institute
Ashurst, Southampton, UK
Lecturers : Dr. M.H. Aliabadi/Dr. D.P. Rooke
Inquiries : Ms. Rosemary Barrett
Computational Mechanics Institute
Ashurst Lodge
Ashurst, Southampton SO4 2AA, UK
Tel. (042 129) 3223, Fax (042 129) 2853
Telex 47388 Attn COMPTECH

May 23-24, 1989
Symposium on The Application of Automation Technology to Fatigue and Fracture Testing
Location : Kansas City, Missouri, USA
Sponsor : ASTM Committees E-9 and E-24
Deadlines : Feb 1, 1989 - complete manuscripts
Inquiries : Arthur A. Braun
MTS Systems Corp.,Materials Testing Div.
Box 24012
Minneapolis, MN 55424, USA
Tel.(612)937-4045

May 24-26, 1989
Meeting of EGF Task Group on Polymers and Composites
Location : Les Diablerets, Switzerland
Organizer : EGF TG Polymers & Composites
Inquiries : Task Group Chairmen, addresses see p. 2

May 24, 1989
Symposium on Quantitative Methods in the Assessment of Structural Defects
Location : Kansas City, Missouri, USA
Sponsor : ASTM Committees E-9 and E-24
Deadlines : Feb 1, 1989 - complete manuscripts
Inquiries : A. P. Berens
University of Dayton, Research Institute
Dayton, Ohio 45469, USA
Tel. (513) 229-4475

AGENDA cont'd

May 29-June 9, 1989
DISORDER AND FRACTURE – Patters and Non-Linear Behaviour of Heterogeneous Materials
Location : Cargese (Corsica), France
Organizer : NATO Advanced Study Inst.
Panel on Chaos, Order and Patterns:
Aspects of Non-Linearity
Inquiries : Dr. J.C. Charmet
E.S.P.C.I.
10 rue Vauquelin
75231 Paris Cedex 05, France
Tel. 43-36-44-45, Fax 43-31-42-22

May 31-June 2, 1989
International Conference on "Structure and Fracture"
Location : Leoben, Austria
Sponsors : EHÖ, DGM, DVM, EGF
Languages : German/English
Deadline : Feb. 28, 1989- Short abstracts (max 70 w.)
Inquiries : Prof.Dr. Karl L. Maurer
Montanuniversität Leoben
Franz-Josef Straße 18,8700 Leoben, Austria
or
Prof.Dr.-Ing. Michael Pohl
Ruhr-Universität Bochum
Institut für Werkstoffe
Postfach 102148, 4630 Bochum, FRG

June 20, 1989
Course on Structural Integrity of Welded Components: Assessment of Risk - Defect Growth
Location : London, UK
Organizer : The Institute of Metals, London, UK
Inquiries : Ms. M.E. Blower (SIWC)
Conference Department
The Institute of Metals
1 Carlton House Terrace
London SW1Y 5DB, UK
Tel. 01-839 4071
Telex 8814813, Telefax 01-839 2289

June 26-30, 1989
Fith Fracture Mechanics Summer School
Location : Dubrovnic, Yugoslavia
Organizer : University of Belgrade *et al.*
Inquiries : Dr. Blagoj Petrovski
Faculty of Technology and Metallurgy
Karnegijeva 4
11000 Belgrade, Yugoslavia

July 10-12, 1989
Third Int. Conference on STRUCTURAL FAILURE. PRODUCT LIABILITY AND TECHNICAL INSURANCE
Location : Vienna, Austria
Organizer : TU Vienna, Austria
Deadlines : Oct 1, 1988 - abstract (300-1000w)
May 31, 1989 - full papers
Inquiries : Doz. Dr. H. P. Rossmanith
Inst. of Mechanics, Technical Univ. Vienna
Wiedner Hauptstraße 8-10/325
1040 Vienna, Austria

September 12, 1989
Course on Structural Integrity of Welded Components: Validation - Conservatism in Design and Assessment
Location : London, UK
Organizer : The Institute of Metals, London, UK
Inquiries : Ms. M.E. Blower (SIWC)
Conference Department
The Institute of Metals
1 Carlton House Terrace
London SW1Y 5DB, UK
Tel. 01-839 4071, Telex 8814813
Telefax 01-839 2289

September 14-15, 1989
International Symposium on Fatigue Aspects in Structural Design (on the occasion of the retirement of Prof. J. de Back)
Location : Delft, The Netherlands
Organizer : TU Delft, Faculty of Civil Engineering
Reg. fee : Dfl. 250,– before June 1, 1989
Dfl. 300,– after June 1, 1989
Inquiries : ir. J.H. Reusink
Delft University of Technology
Department of Civil Engineering
Structures and Mechanics Division
PO Box 5048
2600 GA Delft, The Netherlands
Tel. (31) 15-781373, Fax (31) 15-781855
Telex 38151 butud-nl

September 18-20, 1989
Int. Conference on Recent Developments in Fibre Reinforced Cements & Concretes
Location : Cardiff (Wales), UK
Organizer : Univ. of Wales College of Cardiff
Deadlines : Abstracts (300w) - Dec. 16, 1989
Full papers - May 1, 1989
Inquiries : Dr. B. Barr
School of Engineering
Univ. of Wales School of Engineering
Newport Road
Cardiff CF2 1XH, UK
Tel. (0222) 874000 extn. 5696/4826
Telex 498635 ulibcf g, Fax (0222) 371921

September 20-22, 1989
Int. Conference on Recent Developments on the Fracture of Concrete & Rock
Location : Cardiff (Wales), UK
Organizer : Univ. of Wales College of Cardiff
Deadlines : Abstracts (300w) - Dec. 16, 1989
Full papers - May 1, 1989
Inquiries : Dr. B. Barr
School of Engineering
Univ. of Wales School of Engineering
Newport Road
Cardiff CF2 1XH, UK
Tel. (0222) 874000 extn. 5696/4826
Telex 498635 ulibcf g, Fax (0222) 371921

AGENDA cont'd

October 9-11, 1989
European Symposium on Elastic-Plastic Fracture Mechanics: Elements of Defect Assessment
Location : Freiburg, FRG
Organizer : DVM, EGF
Deadlines : Oct 1, 1988 - Abstracts (500 words)
Jan 15, 1989 - Acceptance notice
Sep 1, 1989 - Full manuscripts
Inquiries : J. G. Blauel
Fraunhofer Institut für Werkstofmechanik
Wöhlerstraße 11
D-7800 Freiburg, FRG
Tel. (0)761/5142-101,fax (0)761/5142-147
telex 17761159 fhiwmfr

October 31-November 2, 1989
Euromech Colloquium 255: "Thermal Effects in Fracture of Multiphase Materials"
Location : Paderborn, FRG
Organizer : Paderborn University
Note : on invitation only
Inquiries : Prof.K.P. Herrmann/Prof.Dr. Z. Olesiak
Paderborn University
Laboratorium für Technische Mechanik
Pohlweg 47-49, 4790 Paderborn, FRG
Tel.(49)5251-602283,Fax(49)5251-602519
Telex 936776 unipb d

November 6-7, 1989
Symp. on Corrosion Testing and Evaluation
Location : Orlando, Florida, USA
Sponsor : ASTM Comm. G-1
Deadlines : May 1, 1989 - Abstracts (300-500w.)
Sep 1, 1989 - full manuscripts
Inquiries : Robert Baboian, Symp. co-chairman
Texas Instruments Inc.
Electrochemical and Corrosion Lab.
Mail Station 10-13
Attleboro, MA 02703, Tel. 508/699-1350

November 8-9, 1989
Symp. on User Experience with Elastic-Plastic Test Methods
Location : Orlando, Florida, USA
Sponsor : ASTM Comm. E-24
Deadlines : Jan. 1, 1989 - Abstracts (300-500w.)
Sep 1, 1989 - full manuscripts
Inquiries : Prof. James A. Joyce
Mechanical Engineering Dept., MS11C
U.S. Naval Academy
Annapolis, MD 21402, USA, Tel. 301/267-3188

November 15-17, 1989
Fourth Int. MECAMAT Conference on the Mechanics and Mechanisms of Damage in Composites and Multimaterials
Location : Saint-Etienne, France
Organizer : MECAMAT, GIS Composites
Deadlines : Abstracts (500w) - Feb. 1, 1989
Full papers - Aug. 1, 1989
Languages : English and French (simult. transl.)
Inquiries : UNIREC, Secrétariat MCM
Conférence MECAMAT 1989
B.P. 50, 42702 Firminy Cédex, France
Tel. 77 40 33 20 Telex 307 466, Fax 77 40 33 94

December 12, 1989
Course on Structural Integrity of Welded Components: Reappraisal of Design and Assessment Methods
Location : London, UK
Organizer : The Institute of Metals, London, UK
Inquiries : Ms. M.E. Blower (SIWC)
Conference Department, Institute of Metals
1 Carlton House Terrace
London SW1Y 5DB, UK
Tel. 01-839 4071
Telex 8814813, Telefax 01-839 2289

March 20-22, 1990
Engineering Integrity Through Testing – EIS '90
Location : Birmingham, UK
Organizer : Eng. Integrity Society et al.
Deadlines : Feb 15, 1989 - Abstracts (200 words)
July 31, 1989 - Final manuscripts
Inquiries : Dr. H. G. Morgan, UKAEA
Northern Res. Laboratories - Springfields
Salwick, Preston PR4 0RR, UK
Tel. 0772-728262 extn. 31670

April 1-6, 1990
Fourth International Conference on Creep and Fracture of Engineering Materials and Structures
Location : Swansea, UK
Organizer : University College, Swansea, UK
Deadlines : May 1, 1989 - Abstacts (200 words)
Nov. 1, 1989 - Full manuscripts
Inquiries : Prof. B. Wilshire
Department of Materials Engineering
University College
Singleton Park
Swansea, SA2 8PP, UK
Tel. (0792) 295243, Telex 48358

April 3, 1990
14. Sitzung der SVMT-Fachgruppe Bruchmechanik und Ermüdung. Themes: Numerical Methods in Fracture Mechanics; Composite Materials and Metals
Location : Alusuisse S.A., Neuhausen am Rheinfall
Organizer : SVMT
Language : German and French, others ask Dr. Prodan
Deadlines : March 1, 1990 - announcements of contributions and registration
Inquiries : Dr. M. Prodan
Gebr. Sulzer AG, Abt. 1502
8401 Winterthur, Switzerland

April 18-20, 1990
Int. Conference on Mechanics of Jointed and Faulted Rocks
Location : TU Vienna, Vienna, Austria
Organizer : Institute of Mechanics, TU Vienna, Austria
Deadlines : July 30, 1989 - Abstracts (300 words)
Jan. 31, 1990 - Full papers
Inquiries : Doz.Dr. H.P. Rossmanith
Institute of Mechanics
Technical University Vienna
Wiedner Hauptstraße 8-10/325
A-1040 Vienna, Austria
Tel. (0222) 58801-5514,5519
Tlx (61) 3222467 = TUW

AGENDA cont'd

April 23-27, 1990
Fifth International Conference on
NUMERICAL METHODS in FRACTURE MECHANICS
Location : Freiburg, FRG
Organizer : IWM Freiburg, FRG
Sponsor : EGF
Deadlines : Sep. 1, 1989 - Abstracts (500 words)
Jan. 31, 1990 - Full papers
Inquiries : W. Schmitt
Fraunhofer Inst. für Werkstoffmechanik
Wöhlerstraße 11
D-7800 Freiburg, FRG
Tel. (0761)5142-104,Fax (0761)5142-147

April 1990 (one day in week April 22-27)
1st Symp. on Advances in Fatigue Life Predictive Techniques
Location : San Francisco CA, USA
Sponsor : ASTM Committee E-9
Deadlines : June 15, 1989 - Abstracts (300-500 w.)
Feb. 15, 1989 - Final Manuscripts
Inquiries : Dr. M.R. Mitchel, Symposium Chairman
Rockwell International Science Center
1049 Camino dos Rios
Thousand Oaks, CA 91360, Tel. 805/373-4450

June 15-20, 1990
2nd Int. Conference on Aluminum Alloys (ICAA2)
Location : Beijing, China
Organizer : Beijing Univ. of Aeronautics&Astronautics
Deadlines : June 30,1989 - Abstracts (250 words)
Dec. 31, 1989 - Full papers
Inquiries : Prof. C.Q. Chen – Co-chairman ICAA2
Dept. of Materials Science & Engineering
Beijing Univ. of Aeronautics&Astronautics
Beijing 100083, Peoples Republic of China

June 25-27, 1990
Int. Conference on Surface Engineering: Current Trends and Future Prospects
Location : Toronto, Canada
Organizer : Univ. of Toronto, Canada
Deadlines : Abstracts (300w) - July 14, 1989
Full papers - Feb. 2, 1990
Inquiries : Prof. Shaker A. Meguid
Univ. of Toronto, Dept. Mech. Engineering
5 King's College Road
Toronto, Ontario M5S 1A4, Canada
Tel. (416) 978-5741, Telex 06218915 ut eng tor
Fax (416) 978-7753

June 26-28, 1990
1st International Conference on Computer Aided Assessment and Control of Localized Damage
Location : University of Southampton
Organizer : Wessex Inst.of Technology, Southampton UK
Sponsors : ISCME, EGF
Deadlines : Abstracts (300 w.) - Oct. 9, 1989
Full papers - March 1, 1990
Inquiries : Julia Futers, Conference Secretary
Computaional Mechanics Institute
Ashurst Lodge, Ashurst
Southampton, s04 2AA, UK
Tel. (042129) 3223, Fax (042129) 2853
Telex 47388 Attn. COMPMECH

June 26-28, 1990
22nd National Symposium on Fracture Mechanics
Location : Atlanta, Georgia, USA
Sponsor : ASTM, Committee E-24
Deadlines : Sep. 15, 1989 - Abstracts (300-500 w.)
May 1, 1990 - Final manuscripts
Inquiries : Prof. Hugo A. Ernst, Symposium Chairman
G.W. Woodruff School of Technology
Atlanta GA 30332
Tel. 404/894-3074

July 15-20, 1990
Fourth International Conference on Fatigue and Fatigue Thresholds (Fatigue 90)
Location : Honolulu, Hawaii
Organizer : Soc. of Material Science, Japan
Deadlines : June 15, 1989 - Abstracts (500 words)
Dec. 15, 1989 - Full papers
Inquiries : Secretary of Fatigue 90
The Society of Material Science, Japan
1-101, Yoshida Izumidono-cho, Sakyo-ku
Kyoto 606, Japan
Tel. Kyoto (075) 761-5321
Fax (075) 761-5325

October 1-5, 1990
Eigth European Conference on Fracture (ECF8)
Location : Torino, Italy
Organizer : Italian Group on Fracture, EGF
Deadlines : Sep 15, 1989 - Abstracts (300 words)
Dec 15, 1989 - Acceptance notice
March 15, 1989 - Final manuscripts
Inquiries : IGF c/o prof. D. Firrao
Politectico di Torino
Dip.di Scienza dei Materiali e Ingegneria Chimica
C.so Duca degli Abruzzi 24
10129 Torino, Italy
Tel. (39)11-556.7777/6763, Telex 220646 POLITO
Fax (39)11-556.6799/7990

December 6-8, 1990
Sixth Int. Conf. on Biomedical Engineering
Location : Singapore
Organizer : Nat. University of Singapore
Deadlines : will follow this preliminary announcement
Inquiries : Secretary 6th Biomed Conference 1990
Dept. of Orthopaedic Surgery
National University Hospital
Lower Kent Ridge Road
Singapore 0511

July 29-August 2, 1991
Sixth International Conference on Mechanical Behaviour of Materials – ICM-6
Location : Kyoto, Japan
Organizer : Society of Materials Science, Japan
Deadlines : June 1, 1990 - Abstracts (500 words)
Jan. 1, 1991 - Full papers
Inquiries : Prof. T. Inoue, Secretary General ICM-6
The Society of Materials Science, Japan
Yoshida-Izumidono-cho, Sakyo-ku 606
Kyoto, Japan
Fax 075-761-5325

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P.O. Box 5025
2600 GA DELFT, The Netherlands

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