

# Newsletter

Official Newsletter of the European Group on Fracture

Nr. 4, Autumn 1987

## Standardization of Fracture Mechanics Testing *the CEC investigates the needs of it*

Contents  
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The Bureau Communautaire de Reference (BCR), a part of the Directorate-General XII - Science and Technology of the CEC, have asked prof. R.G. Baker (UK) to carry out a study for them with the objective of defining the metrological needs related to Standardization in Fracture Mechanics testing, and recommending ways in which the BCR could help to fulfil them.

The scope of the study – which started June this year – is confined, at this stage, to fracture instability in the elastic, elastic-plastic and plastic regimes in metals of all sections from wire to thick plates, and is directed principally at plain, rather than joined materials.

In the meantime prof. Baker has visited a large number of companies and institutes throughout the European Community to draw up an inventory of tests being used and under development in the various countries and their similarities and/or differences with those in other European countries, USA and Japan. In addition, he sounded the visited persons on their experience with existing standards and their views with regard to future trends, e.g. regarding:

- Data and/or opinions concerning the source of experimental uncertainty associated with the application of tests being applied or under development.

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### *Happy Birthday*

*This is the fourth issue of the EGF Newsletter and because we plan to distribute four issues per year, we now can celebrate its first anniversary and such an occasion asks for a retrospective view.*

You may remember that its birth did not proceed that smoothly as one generally wishes. Its parents kept delaying its birth because they felt that they did not have enough money to support it. Finally, however, they decided to do what most parents of human babies do, viz let it come and hope for the future.

Its first sounds were very joyful, crying out that its birth marked a new and important milestone in the life of his family. At the same time it realized that, although it was able to speak from the moment of its birth, it was still unable to stand and walk on its own feet and that it needed help to move along the road marked by that milestone. When this help did not come fast enough in its opinion, it started to complain and its sounds became somewhat grumpy. The road was so long, its pavement not so good and there was not enough manpower for its maintenance and for constructing new tracks. It even complained about the quality of the large number of birthday cards received.

In the meantime, it starts to realize that growing up is a difficult process with many ups and downs, and that the ups should also be remembered. One of these is the fact that many relatives have contributed to its growing up. It therefore decided not to spoil its birthday by repeating all its worries about the future, but to approach things more optimistically. For instance, the rumour that a rich uncle is thinking about giving a scholarship for its further education. It was also very pleased by a letter received from a relative, explaining that fracture – being its right to exist – is not always a negative aspect of life, but that you can also make use of it in a positive sense – like for the opening of beer cans and sardine cans – and that he is looking for more people to join him in his positive attitude towards fracture.

*Let us hope that it will serve more than beer and sardines at its birthday party, and that its present good temper will also last in 1988.*

*the editor*

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### Standardization in FM Testing - cont'd from page 1

- Uncertainties arising from differences in interpretation of test criteria and raw data between different centres and from differences between – or lack of precision in – derived relationships, and their effect on the overall uncertainty of the derived engineering data.
- The role fracture mechanics tests can and should play at the present time in engineering design and practice, and under what circumstances they can be safely and realistically used to assess defect significance in critical structures.
- Future trends, particularly in standardization, and how desirable trends can best be accelerated. Specifically, what targets should be adopted to improve precision and confidence in methods of predicting the behaviour of large structures from the results of small-scale tests.

Prof. Baker expects to finish his final report in December this year. At a meeting of the EGF Task Group on Elastic Plastic Fracture Mechanics at the Risø Laboratories (Roskilde, Denmark), October 29 and 30, he presented a lecture on his experience so far. For his conclusions we will have to wait until he has finished his report for the BCR. We will inform the readers of this Newsletter as soon as this becomes available, in particular about its possible impact for the European Group on Fracture.

## New Round Robin for the Fatigue Task Group

Contact person: K.J. Miller

Surfaces of engineering materials, particularly metals, are of prime concern to engineers be they designers, stress-analysts, maintenance, manufacturing or commissioning engineers. The reason is simple; most failures start from surfaces e.g. fatigue, fretting, wear, spalling etc., and it is a surface that is subjected to externally imposed shock loading be it thermal or mechanical or both.

The importance of surfaces was recognised by EGF via their special technical publication "THE BEHAVIOUR OF SHORT FATIGUE CRACKS" Editors K.J. Miller and E.R. de los Rios, published by Mechanical Engineering Publishers Limited (see previous Newsletters) and now the time is judged to be right to initiate a new European round robin test programme specifically to look at the effect of various surface treatments on improving the resistance to fracture of engineering materials.

It is suggested that only 2 or 3 materials be selected and various competitive surface treatments be investigated to see what improvements can be achieved in the integrity of the surface layers and to what cost.

It is intended to hold a two-hour meeting on this topic at ECF7 in Budapest, Hungary during the conference week of September 19-24, 1988, details of which are provided in this Newsletter. Before that date, however, suggestions on this proposal should be forwarded to

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### PRODUCTION

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# Measurements of Stretched Zone Width (SZW)

## A Round Robin Program of the European Group on Fracture

Contact Person: Dipl.-Ing. A. Halim

In the last two years, a great number of different European Institutes joined this round robin program working on Measurements of Stretched Zone Width.

Participants were the following:

In April 1987, this round robin program has been finished, the results will be published under the same title mentioned above in the next edition of the Journal of Engineering Fracture Mechanics.

*I really appreciate this occasion to thank all participants of this Working Party of the Task Group on Micromechanisms of Fracture for the good co-operation which has led to important results.*

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## Task Group on Polymers and Composites

Chairmen : J.G.Williams & H.H.Kausch

A further meeting of this group was held in Les Diablerets, Switzerland from 13-15 October 1987. The major item of business, which took 1 1/2 days, was a review of the results achieved in the second round-robin aimed at establishing a standard method for determining  $K_{Ic}$  and  $G_{Ic}$  for plastics. These tests had been run to a draft protocol and were performed by sixteen groups on ten materials. Overall the results were most encouraging with quite a small range of values for each material. In general the  $K_{Ic}$  values were more consistent than those for  $G_{Ic}$ , as would be expected since the latter involve displacement measurements.  $G_{Ic}$  determinations are particularly important for polymers, since it is this value which is used for comparative purposes in composites. Some major problems in defining notching technique and the use of clip gauges appear to have been resolved. A revised protocol will now be produced and another round of tests performed on two materials to confirm its validity and to improve the  $G_{Ic}$  method. A full report will be presented in Budapest.

Half a day was spent on reviewing the results on measuring  $G_{Ic}$  and  $G_{IIc}$  on two carbon fibre composites. Eleven groups took part and the results were again encouraging. It was clearly established that load based methods for calculating  $G_{Ic}$  as opposed to energy or compliance methods, tended to give high values. It is planned to continue the testing programme with a revised procedure. The final half day was concerned with trying to agree a document on nomenclature and to make plans for future activities. It seems likely that the next major activity will be to investigate the possibility of a J test for polymers and some preparatory work is in hand.

The next meeting will be in Les Diablerets on 10-11 May 1988 when a full report on the second  $K_{Ic}$  round-robin will be reviewed and progress in the other tests will be reported. Twenty-five people attended the meeting which was generally felt to be most successful. *The chairmen wish to thank all the participants for their enthusiastic support in this Task Group.*

# ANNOUNCEMENT

NATO ASI – Residential Advanced Course

## ADVANCES IN FATIGUE SCIENCE AND TECHNOLOGY

Hotel D. JOÃO II, Alvor Beach, Algarve, Portugal

5th to 15th April 1988

*Sponsored by*

NATO Scientific Affairs Division

### Topics and presentation

State of the art lectures will be presented in the following topics:

- *Short cracks*
- *Threshold behaviour*
- *Thermal fatigue*
- *Notch effects in fatigue*
- *Multiaxial fatigue*
- *Fatigue of welded joints*
- *Variable amplitude loading*
- *Crack growth modelling*
- *Engineering applications*

Poster sessions, invited papers and demonstrations are also planned

### Organizing Committee

- Profs. C. Moura Branco and  
L. Guerra Rosa, Course Directors
- Prof. K.J. Miller
- Prof. R.P. Wei
- Prof. D. François
- Dr. S. Maddox
- Dr. W. Schutz

### Participants

Maximum number: 85

### Registration

400 US\$ including refreshments and entire set of course notes

### Hotel Accommodation

Average price for full board accommodation covering the eleven days of course will range from 550 to 740 US\$

### Travel Grants

A limited number of travel grants (maximum 800 US\$) will be awarded to participants from non-profit institutions

### Prospective applicants can write to :

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# Task Group Elastic-Plastic Fracture Mechanics

## *Account of the 15th Plenary Meeting*

### *Risø Nat. Laboratories, Roskilde (Denmark)*

*Chairmen G. Angelino and D. Firrao*

Over 50 participants from 10 different countries attended the 15th plenary meeting of the EGF Task Group on EPFM at the Risø National Laboratories, Roskilde, Denmark, on the 29 and 30 October 1987.

The meeting was opened by G. Angelino on behalf of the Task Group chairmen after which the participants were also welcomed by the head of the Metallurgy Department of the Risø Laboratories, prof. N. Hansen, who also gave a short survey of the past and present activities at the Risø Laboratories.

#### *Technical Program*

Twenty five lectures were presented during four working sessions on Thursday, October 29th and two on Friday morning, October 30st. The main topics covered were fracture behaviour in the ductile/brittle transition, K/J/CTOD test methods and dynamic fracture. The time available also allowed thorough discussions after each lecture.

#### *Working Parties*

- As explained earlier (see Newsletter 3), the *Working Party on Numerical FM* could not proceed, as its chairman, L.H. Larsson of JRC Ispra, was no longer able to spend enough time on its organization because of his other EGF commitments, which had to be given first priority. D. Firrao announced that this problem seems to be solved, since W. Schmitt (IWM Freiburg, FRG) has agreed to take over the organization of the Working Party.
- N. Knee reported about the *Working Party on R-Curves and Tearing Instability*. The information package on the last round robin to be executed (see Newsletters 2 and 3) has not yet been finished, but will be distributed soon. I. Milne has contacted various people in Europe to form a group that drafts a guideline document for performing fracture safety assessments of cracked components. He feels that some more countries (e.g. France) should be represented in this group before starting its activities.



- K.-H. Schwalbe reported that the round robin on the proposed EGF FM test procedure, organized by the *Working Party on Fracture Mechanics Testing Standards*, is somewhat delayed as the characterization of the (three) materials took more time than scheduled. As a consequence, the deadline for the participants to submit their results will have to be shifted from December 1987 to about March 1988.
- J.G. Blauel reported that the *Working Party on High Temperature Crack Growth* is preparing the final report on the round robin program organized by this group.
- The progress with the formation of a *Working Party on Crack Arrest* (possibly within a newly formed Task Group on Fracture Dynamics) is reported in a separate article below.

#### *Next Meeting*

D. Firrao announced that the next meeting will most probably be held in Paris, France. Provisional date is May 14th, 1988. Further announcement follows as soon as definite arrangements have been made. Note that the Spring meeting will be the only one in 1988, as it was agreed not to meet in the period that the European Conference on Fracture is organized (ECF7, Budapest, September 19-24, 1988).

The meeting was closed at the end of Friday morning by D. Firrao on behalf of the Chairmen, thanking all participants for contributing to another successful meeting. In particular he thanked S. Andersen of the Risø Laboratories for the hospitality and for taking care of all arrangements.

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## **EGF Task Group DYNAMIC FRACTURE with Working Party CRACK ARREST METHODOLOGY**

One day prior to the 13th MPA Seminar on Reliability and Availability in Designing Techniques with main theme Nuclear Technique at MPA Stuttgart, FRG on 8 and 9 October, 1987 a meeting took place at MPA between several European specialists in the field of crack arrest problematics.

This meeting was organized by Dr. E. Roos of MPA in order to explore the formation feasibility of a Working Party on Crack Arrest Methodology, operating within the framework of the European Group on Fracture (cf. EGF Newsletter 3); it was attended by some 20 persons.

A few months before Dr. Z. Bilek of the Institute of Physical Metallurgy, Czechoslovakian Academy of Sciences, Ziskova 22, 61662, Brno, CSSR had taken the initiative to form an EGF Task Group Fracture Dynamics, covering dynamic mechanical material properties, fracture initiation by impact and crack propagation/arrest (cf. EGF Newsletter 2). The MPA meeting thus appeared a suitable opportunity to merge these two initiatives and all present agreed in the formation of a Task Group Fracture Dynamics, starting at present with a Working Party on Crack Arrest Methodology.

Dr. Roos proved available as Contact Person for this Working Party, while later on Prof. Dr. J.F. Kalthoff of Experimental Mechanics, Ruhr University, Bochum, FRG. stated to be willing to act as co-chairman of Dr. Bilek for the EGF Task Group Fracture Dynamics, which met the shared chairmanship of Task Groups as previously proven efficient in other Task Groups, like on Elastic-Plastic Fracture and Fracture of Polymers and Composites.

As start of the activities of the new Working Party it was agreed to seek more information about the results of the international second round robin on crack arrest organized by MRL - in which some of the meeting attendants had participated and which was performed as a follow-up of the first one organized by Battelle (Hahn) - thus making an effort to obtain a covering report on this second crack arrest round robin. Further it will be tried to write down what is felt still to be white spots in our understanding of arrest and what are the difficulties met at the presently proposed test techniques and at the interpretation of results of experiments on arrest. Possible suggestions for an improved testing technique are solicited.

***Persons interested in (participation to) this Task Group or one of its Working Parties are encouraged to contact one of the 3 persons mentioned with their address in the above.***





# ASFM6

## Assessment of Cracked Components by Fracture Mechanics

The 6th Advanced Seminar on Fracture Mechanics (ASFM6) took place at the CEC's Joint Research Centre, Ispra, Italy on 28th September - 2 October 1987. It was attended by 38 participants from 10 countries. The EGF had nominated for ASFM6 an Advisory Board composed of

A. Bakker, Delft University of Technology, Delft (NL)  
M.G. Dawes, The Welding Institute, Cambridge (GB)  
A. Pellissier-Tanon, Framatome, Paris (F)  
E. Sommer, Institut für Werkstoffmechanik, Freiburg (D)

who collaborated with the scientific coordinator, L.H. Larsson, for the definition of the programme. The central part of ASFM 6 consisted of lectures and workshops on four assessment methods : the R6 method, CTOD methods, pressure vessel codes and the ESA fracture control procedure. These had been selected as being close to the status of design codes, and as representing various fields of application. Before and after the central part the programme contained lectures of an introductory or overview nature on various problems areas connected with crack assessment. The programme and the names of the authors of the lecture notes are listed below (in the case of multiple authors the lectures were delivered by W. Schmitt and S.J. Garwood).

L.H. Larsson	<i>Basic principles of fracture mechanics and an overview of ASFM6</i>
W. Schmitt and H. Kordisch	<i>Determination of stresses, strains and crack characterizing parameters</i>
A.U. de Koning	<i>Prediction of fatigue crack growth</i>
F. Mudry	<i>Rationalization of size effects in fracture toughness tests using local criteria for fracture</i>
W. Schmitt and W. Böhme	<i>Impact loading and crack arrest</i>
E. Roos	<i>Component tests and the R-curve approach for through-cracks</i>
S. Crutzen	<i>NDT techniques - Performances and reliability</i>
M.G. Dawes	<i>Application of fracture mechanics to welded structures</i>
S.J. Garwood, A.A. Willoughby	
R.H. Leggatt and T. Jutla	<i>Crack tip opening displacement (CTOD) methods for fracture mechanics assessments: proposals for revisions to PD 6493</i>
J.R. Gordon, S.J. Garwood	<i>Worked examples of CTOD analysis using the proposed revisions to PD 6493</i>
I. Milne	<i>The R6 method (incl. Workshop )</i>
A. Pellissier-Tanon	<i>Pressure vessel codes (incl. Workshop )</i>
G. Reibaldi	<i>The ESA fracture control procedure (incl. Workshop)</i>
D. Bergez	<i>Probabilistic failure analysis and application to the optimization of ISI on off-shore structures</i>
C. Bathias	<i>Fracture assessment of composite structures</i>

The revised and updated lecture notes will be published as an EGF Publication in 1988. The material presented in the workshops will be organized as problems and their solutions will be given at the end of the book.

# Plastic Fracture

A.G. Atkins

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In materials forming, limitations are set on many operations by the onset of surface or interior cracking. To achieve maximum deformation and process yield, and avoid excessive scrap, crack nucleation must be avoided in forging, stamping, rolling, pressing, extrusion and so on. On the other hand, in processes which concern the separation of parts, crack nucleation, initiation and propagation is desirable. Thus cracking is an inherent part of can-opening, blanking, cropping, guillotining, piercing, nibbling, slitting and machining. Problems in penetration of armour, plugging of plates and so on are all related to this general theme. In all these processes cracks nucleate within regions of deformation fields that are highly deformed - either simply by extensive overall flow (as in forging, say) or by localised flow produced by sharp tooling.

The initiation of cracks after extensive plastic flow is the field of study commonly called the mechanics of ductile fracture. Many investigations have taken place over the years both by those interested in microstructure and by those interested in bulk stress and strain values for engineering design. There is a host of empirical criteria for crack initiation, most of which turn out to be versions of

a critical value of  $\int (\sigma_H / \bar{\sigma}) d\bar{\epsilon}$  - where  $\sigma_H$  is hydrostatic stress,  $\bar{\sigma}$  effective stress and  $\bar{\epsilon}$  effective plastic strain - which is the simplest form of McClintock-type relations for void growth and coalescence, being the mechanism of initiation in commercial materials containing inclusions or hard second phases. The critical value of the path-dependent integral is connected with the spacing-to-size ratio of the voids in the model. The magnitude of the critical value itself is usually obtained from some simple test and then presumed to be applicable to more complicated problems. The advent of finite-element /finite difference computer codes (properly formulated for large strains and rotations) now enables complicated elastoplastic, thermomechanically-coupled flow calculations to be made for awkward tool geometries and there is great interest in correct criteria to predict the onset of fracture under multiaxial stressing.

There seems to have been far less work done on the subsequent propagation of cracks in extensive flow fields. But there are many problems of technological interest to which one would like answers. What, for example, are the forces required to open a beer can? What are the mechanics of guillotining ductile metal plates? Why does a characteristic number of equispaced cracks occur when the end of a ductile metal tube is flared out? If a ship tears a hole in its plating on an underwater obstruction, or through a collision, what forces are involved? What are the scaling laws for this sort of thing between model and prototype structures? These are all problems in combined flow and fracture. They concern both the initiation of cracks in extensive plastic flow fields and the propagation of cracks preceded by, and usually accompanied by, extensive plastic flow remote from the crack faces. They are problems that cannot be solved - or are too formidable to solve - by the usual form of post-yield elastoplastic fracture propagation mechanics which most often concerns plastic flow fields in which the strains are only just greater than yield point levels.

Over the past few years, the author and co-workers have shown that rigid-plastic fracture mechanics provides acceptable answers to many problems in combined extensive flow and fracture. The work rate equation for extensive plastic flow, where elasticity may be neglected, is

$$Xdu = d\Gamma = d(WV) \quad (1)$$

where  $X$  is load,  $u$  load-displacement,  $\Gamma$  is plastic work,  $W$  is plastic work / volume and  $V$  the volume of body being plastically deformed. Equation (1) is what is used in McClintock-type crack initiation calculations in non-uniform flow fields, and is basis of upper bound calculations in metalforming, for example, where  $\Gamma$  is the work associated with a kinematically admissible deformation field. It seems

reasonable for combined flow and fracture problems to write:

$$Xdu = d\Gamma + RdA \quad (2)$$

where  $R$  is the specific work of fracture in the presence of extensive flow (the fracture toughness) for the particular mode of fracture and  $A$  is crack area. This is the equation which has been successful in solving problems such as beer can opening, tube splitting, scaling of crashworthy structures and so on. For completeness we note the relationship between Equation (2) and the corresponding equations for elastic fracture, viz.:

$$Xdu = d\Lambda + RdA \quad (3)$$

where  $\Lambda$  is elastic strain energy, and for elastoplastic fracture viz.:

$$Xdu = d\Lambda + d\Gamma + RdA \quad (4)$$

Of course the "variables separable" form of Equation (4) may be doubted by some people (those who believe in  $J_R$  one supposes) and of course it is correct to wonder, whether  $R$  in Equations (2) - (4) is the same material parameter. It is tempting to believe so, if the process zones are the same, and in principle, it could be tested on cracked bodies of the same material, so proportioned that their sizes fall into the different deformation transition ranges (i.e. elastic, elastoplastic and plastic cracking - *J. of Mat. Sci.*, **21**, 1986, p. 1093), noting that in the partitioning of total work from unloaded work areas, proper account should be taken of residual elastic strain energy (*Int. J. Fracture*, **30**, 1986, p. 203).

I do not wish to get embroiled here in arguments about the correct formulation of elastoplastic fracture problems. The fact is that if reproducible, geometry-independent, values of  $R$  are obtained from a variety of combined extensive flow and fracture experiments, it is reasonable to go on to employ Equation (4) predictively to solve problems. Cotterell was the first to show how values of  $R$  in the presence of extensive flow could be determined and the appropriate tests for fracture in modes I, II and III are quite straightforward (for a review, see "Elastic & Plastic Fracture", Ellis Horwood/John Wiley, Chichester, UK, 1985). Typical plane stress values of  $R$  for ductile sheet materials are in the hundreds of kilojoules per square metre for many engineering alloys and polymers.

By way of example, consider the opening of sardine cans. For an incremental rotation  $d\theta$  of the opener key when the applied moment is  $M$ , the external work done is  $Md\theta$ . The internal remote plastic work done is  $d\Gamma = (\text{work/volume}) d(\text{plastic volume}) = (\sigma_y B/4\rho)wB\rho d\theta$  where  $\sigma_y$  is mean flow stress,  $B$  is thickness, and  $w$  the width, respectively of the lid of the can, and  $\rho$  is the mean radius of curvature in the rolled-up lid, the mean plastic strain in which is  $B/4\rho$ . The crack consists of fracture of a soldered strip of width  $w'$  along each edge (in older designs) or the tearing of the lid itself along the edges. The fracture terms are then either  $RdA = 2Rw' \rho d\theta$  or  $2RB\rho d\theta$  respectively. Equation (2) then gives  $M = \sigma_y B^2 w/4 + 2Rw'\rho$  for the soldered can lid and  $M = \sigma_y B^2 w/4 + 2RB\rho$  for the lid tearing case. These equations show how  $M$  varies with  $w$ ,  $w'$  and  $B$  and suggest how linear plots may be obtained from experiments, the slopes of which depend on  $\sigma_y$  and the ordinate intercept with  $R$ . Of course, there is really elastic springback on unloading (flicking the key on a partially-opened can shows this) but this simple approach gives the essence of the behaviour.

The conditions governing the transition from flow alone to flow plus fracture are important in studies of this sort. For example, on the edges of metal plates or sheets cut with shears, there is a well-marked boundary between the initial phase of indentation plastic flow beneath the blade and the subsequent formation of a running crack beneath the blade (*Phil. Mag.*, **43A**, 1981, p. 627). What determines this depth? Might measurement of the depth give information on the toughness of the cut material? What effect has blade sharpness, blade clearance, lubrication and so on? A fascinating aspect of these

transitions is that it is energetically favourable for flow and fracture to occur, rather than merely further plastic flow alone, even though there are now two energy sinks. This comes about because of the interplay between  $W$  and  $V$  in Equations (1) and (2) before and after crack propagation. Consider a tube with the end being flared out by being pushed on to a profiled mandrel (Int. J. Mech. Sci., **29** (1987), p. 115). Initially there is only plastic flow in which  $Xdu = d\Gamma = WdV + VdW$  since at continued expansion new material is being flared out from the undeformed parts of the tube (giving  $dV$ ) and the leading edge of the flare experiences increasing strain (giving  $dW$ ). At some critical expansion cracks form at the leading edge and thereafter there is no further plastic flow alongside the cracks. Under these conditions  $dW = 0$ , but  $dV$  still obtains as the tube is pushed further on the mandrel. So  $Xdu = WdV + nRdA$  for the formation of  $n$  cracks. At the transition, therefore,  $WdV + VdW = WdV + nRdA$  or  $n = (V/R) (dW/dA)$ . It may be shown that  $n \approx (8\pi/\sqrt{3}) (\sigma_y/R) r_0 \epsilon_{\theta}$  where  $r_0$  is the tube mean radius and  $\epsilon_{\theta} = \ln(a/r_0)$  is the hoop strain at radius  $a$  in the flared end at which the cracks form. This formula predicts well the number of cracks observed in the static and dynamic experiments of Reddy & Reid (Int. J. Mech. Sci., **28** (1986), p. 111) on ductile metal tubes expanded over mandrels. A further example concerns the scaling laws between model and prototype structures which experience extensive flow and fracture, which is of interest to those studying crashworthiness. Recent work (to be presented at the International Symposium on Structural Failure, MIT, 1988) gives a proper foundation for empirical energy scaling laws of the form  $\lambda^x$  ( $2 < x < 3$ ) where it is shown that  $x$  depends on two combined factors (i) the ratio of the plastic work done / volume to the toughness and (ii) the ratio, in the reference structure, of the volume of material plastically deformed to the crack area.

Needless to say full elastoplastic solutions to these problems would be formidable but the rigid-plastic simplification permits answers to be obtained fairly easily. Of course, if a unified theory of fracture exists - and one presumes so - analyses going into the plastic range starting from the elastic end should coincide with the analyses described here which start from the fully plastic end. I am not aware of people in the European Group on Fracture working in this field of large deformation flow and crack propagation (which is why most of the references are my own). I should be glad to learn of others working in the area. If there is sufficient interest, perhaps a working party or task group should be set up.

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## Fracture Mechanics Summer School in Yugoslavia

*Prof. S. Sedmak*

*Faculty of Technology and Metallurgy, Karnegijeva 4, 11000 Beograd, Yugoslavia*

The Fracture Mechanics Summer School was established in 1980, strongly supported by prof. Michael Wnuk from University of Wisconsin - Milwaukee, USA, with the aim to introduce fracture mechanics in practical application in Yugoslavia.

The school has been held biennially in the last week of June, jointly organized by the Faculty of Technology and Metallurgy from Belgrade and "GOSA" Industries from Smederevska Palanka.

The first school was organized in 1980 in Smederevska Palanka under the title "*Introduction to Fracture Mechanics and Fracture - Safe Design*". Twenty one lectures were given by eight lecturers from Yugoslavia, four from Poland and two from the USA. There were 63 participants from Yugoslav industry, universities and research institutes.

The second and third schools were held in touristic centers, Velika Plana and Arandjelovac in the vicinity of Belgrade, under the titles "*Pressure Vessels, Penstocks and Pipelines, Modern Design and Construction Aspects*" and "*Fracture Mechanics of Weldments*", respectively. Lecturer staffs consisted of 14 lecturers in the second school (7 from Yugoslavia, 3 from USA, 2 from England, 1 from

## Imperial College of Science and Technology

Mechanical Engineering Department, Exhibition Road, London SW7 2BX, UK.

A short course on

# *Fracture Mechanics of Engineering Plastics, Adhesives and Composites*

**5-7 January 1988**

*The course is designed to give a detailed introduction to both the theory and practice of Fracture Mechanics of Non-Metallic Materials, to show its industrial relevance and to discuss the present "state of the art".*

<b>Who should attend?</b>	Engineers, material scientists, physicists and chemists working on mechanical characterisation, and metallurgists engaged in research, development or technical service where the fracture and failure of engineering plastics, adhesives or fibre composites are of interest.
<b>Course Staff</b>	Dr. Tony Kinloch and Professor Gordon Williams of Imperial College, with specialist guest speakers.
<b>Fee</b>	The fee for the three-day course is £ 325, including lectures, demonstrations, copies of two books, additional course notes and coffee, lunch and tea each day.
<b>Further Information</b>	Please contact Dr. A.J. Kinloch or Prof. J.G. Williams (extns. 6179 or 6173), Tel 01-589 5111; Telex 261 503; Fax 01-584 7596

France and 1 from West Germany) and of 16 lecturers in the third school (7 from Yugoslavia, 5 from USA, 1 from SSSR, 1 from England, 1 from France). The number of participants was 79 in the second school and 67 in the third school.

The fourth school, entitled "*The Prospect of Development and Application of Fracture Mechanics*", was held in Dubrovnik, at the Adriatic seaside, from 23rd to 27th June 1986. There were 14 lectures, 8 from USA, 3 from Yugoslavia, 1 from England, 1 from Poland and 1 from West Germany. The number of participants increased to 96.

A very important feature of the fracture mechanics school is the open and very broad discussion. The school came into being platform for presentation of achievements of young researchers in Yugoslavia, that exposed 8 written contributions in the third school and 10 in the fourth school.

The lecture books in Serbo-Croatian, containing the lectures and discussions from the first three schools, are already published. The titles of these books are the same as the titles of the schools. The fourth book "*The Prospect of the Development and Application of Fracture Mechanics*" is in print now and will be available in October 1987. These books represent the main references in fracture mechanics, published in Yugoslavia.

The school organizers, Faculty of Technology and Metallurgy from Belgrade University and "Gosa" Industries Research Institute, consider the possibilities to improve the school organization and effects. That means the school would be open for participants from abroad. The most likely term for the next, fifth school is 1989. The decision about these matters will be announced soon.

# 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.

**January 5-7, 1988**

Short Course on FRACTURE MECHANICS OF ENGINEERING PLASTICS, ADHESIVES AND COMPOSITES

*Location* : Imperial College, London, UK  
*Organizer* : Imperial College, London, UK  
*Inquiries* : Dr. A.J. Kinloch/prof. J.G. Williams  
 Imperial College of Science and Technology  
 Mechanical Engineering Department  
 Exhibition Road  
 London SW7 2BX, UK  
 Tel. 01-589 5111, ext. 6179 or 6173  
 Telex 261503, Fax 01-584 7596

**February 7-12, 1988**

7-th Int. Conference and Exhibition on OFFSHORE MECHANICS AND ARCTIC ENGINEERING (OMAE)

*Location* : Adam's Mark Hotel, Houston, Texas, USA  
*Organizer* : ASME, OMAE Division  
*Deadlines* : April 20, 1987 - Abstracts  
 May 1, 1987 - Tentative acceptance notice  
 July 31, 1987 - Manuscripts  
*Inquiries* : Dr. R. Denys  
 Rijksuniversiteit Gent  
 Sint Pietersnieuwstraat 41  
 9000 Gent, Belgium  
 Tel. (32)91-232821-ext. 2462/2404  
 Telex 11344 ibsbil, facsimile (32)91-237326

**February 7-12, 1988**

First (1988) Int. Symp. on OMAE Materials Techn.  
 First (1988) Int. OMAE Pipeline Symposium  
 First (1988) Int. OMAE Symposium on Computers  
*all three symposia at OMAE '88 Houston*  
*Location* : Adam's Mark Hotel, Houston, Texas, USA  
*Organizer* : ASME OMAE Division  
*Inquiries* : Prof. Jin S. Chung  
 Colorado School of Mines  
 1500 Illinois Street  
 Golden, Colorado 80401, USA  
 phone (303)273 3673, telex 910 934 0190 csm

**March 17-18, 1988**

20. Sitzung des DVM-Arbeitskreises Bruchvorgänge "Corrosion and Fracture"

*Location* : DECHEMA, Frankfurt/Main  
*Organizer* : DVM and DECHEMA  
*Language* : German  
*Deadline* : Nov. 13, 1987  
*Inquiries* : Dr. Christina Berger  
 Kraftwerk Union AG  
 Dept. TWMF  
 P.O. Box 10 11 53  
 D-4330 Mülheim-Ruhr  
 FRG

**April 5-15, 1988**

NATO ASI Residential Advanced Course on ADVANCES IN FRACTURE SCIENCE AND TECHNOLOGY

*Location* : Hotel Joao, Alvor Beach, Algarve, Portugal  
*Organizer* : CEMUL/IST, Lisbon, Portugal  
*Sponsor* : NATO Scientific Affairs Division  
*Inquiries* : Prof. Carlos Moura Branco  
 NATA ASI Fatigue/CEMUL IST  
 1096 Lisboa, Portugal  
 Tel (1) 80 35 80/80 50 63  
 Telex 63 423 istul p

**April 12-14, 1988**

International Conference on Environment-Assisted Fatigue

*Location* : Sheffield, UK  
*Organizer* : Univ. of Sheffield, UK  
*Sponsor* : EGF  
*Deadlines* : Dec. 1, 1987 - Abstracts (500 words)  
*Inquiries* : Dr. P.M. Scott  
 Materials Development Division  
 Building 393, Harwell Laboratory  
 Oxfordshire OX11 0RA, UK

**Week of 24 April, 1988**

Symposium on Fatigue and Fracture Testing of Materials

*Location* : Las Vegas (Nevada), USA  
*Sponsor* : ASTM Committees E-9 and E-24  
*Deadlines* : Jul 1, 1987 - Abstracts (300-500 words)  
 Mar 1, 1988 - Full manuscript  
*Inquiries* : H.I. McHenry (symposium co-chairman)  
 National Bureau of Standards  
 Boulder, Colorado 80303  
 USA, Tel. 303/497-3268

**April 25, 1988**

Symposium on Surface Crack Growth: Models, Experiments and Structures

*Location* : Las Vegas (Nevada), USA  
*Sponsor* : ASTM Committee E-24  
*Deadlines* : Jul 1, 1987 - Abstracts (extended)  
 Mar 1, 1988 - Full manuscripts  
*Inquiries* : W.G. Reuter (symposium co-chairman)  
 Idaho National Engineering Lab.  
 P.O. Box 1625  
 Idaho Falls, ID 83401  
 USA  
 Tel. 208/526-1708

**April 25-26, 1988**

9th Symposium on Composite Materials

*Location* : Las Vegas (Nevada), USA  
*Sponsor* : ASTM Committee D-30  
*Deadlines* : Jun 1, 1987 - Abstract (500-1000 words)  
 Jan 31, 1988 - Full manuscripts  
*Inquiries* : S.P. Garbo (Symposium chairman)  
 United Technology, Sikorsky Aircraft Division  
 6900 North Main Street  
 Stratford (Connecticut) 06601-1381  
 USA  
 Tel. 203/386-4576

# AGENDA cont'd

**June 13-15, 1988**

**International Conference on Life Assessment and Life Extension of Thermal Plants**

*Location* : The Hague, the Netherlands

*Organizer* : NIL, the Netherlands

*Sponsor* : KEMA, VGB, EPRI, CRIEPI

*Deadlines* : to be announced later

*Inquiries* : NIL

Laan van Meerdervoort 2b

2517 AJ The Hague

The Netherlands

Tel. (31)70-600937

**June 15-17, 1988**

**Third International Spring Meeting on FATIGUE CRACK GROWTH UNDER VARIABLE AMPLITUDE LOADING**

*Location* : Paris, France

*Organizer* : Fatigue Commission of the French Metallurgical Society

*Sponsors* : ASTM et al.

*Inquiries* : Dr. J. Petit

EN SMA

86034 POITIERS Cedex

France

**June 28-30, 1988**

**21st National Symposium on Fracture**

*Location* : Annapolis MD, USA

*Sponsor* : ASTM Committee E24

*Deadlines* : August 1, 1987 - Abstracts (300-500 words)

Nov. 1, 1987 - Acceptance notice

April 1, 1988 - Final manuscripts

*Inquiries* : Dr. J.P. Gudas

David Tayler Naval Ship R&D Center

Metals and Welding Division, Code 281

Annapolis, MD 21402-5067

USA, Tel. (1)301/267-2841

**July 4-6, 1988**

**International Conference on Fracture and Damage of Concrete and Rock and Special Seminar on Large Concrete Dam Structures**

*Location* : Vienna, Austria

*Organizer* : TU Vienna, Institute of Mechanics

*Deadlines* : Nov. 30, 1987 - Abstracts (300 words)

March 31, 1988 - Full Papers

*Inquiries* : Doz.Dr. H.P. Rossmanith

Institute of Mechanics

Technical University Vienna

Karlsplatz 13

1040 Vienna, Austria

Tel. (43) 222-58801-3121, Telex 3 222 467 tw

**September 6-8, 1988**

**VIII. Symposium on Deformation and Fracture**

*Location* : Magdeburg, G.D.R.

*Organizer* : Univ. of Technology "Otto von Guericke"

*Language* : German, English, Russian

*Inquiries* : Prof. H. Blumenauer

Tech. Universität "Otto von Guericke"

PSF 124

3010 MAGDEBURG, DDR

**September 11-15, 1988**

**Sixth International Conference on Pressure Vessel Technology, ICPVT-6**

*Location* : Beijing, China

*Organizer* : Chinese Pressure Vessel Inst.

*Sponsor* : Int. Council for Pressure Vessel Technology

*Deadlines* : Feb 2, 1987 - Abstracts

Sep 5, 1987 - Full papers

*Inquiries* : Mr. C.B. Corbett

Manager Process Ind. Division

Inst. of Mechanical Engineers

1 Birdcage Walk, Westminster

London SW1H 9JJ, UK

**September 19-24, 1988**

**Seventh European Conference on Fracture, ECF7**

*Location* : Budapest, Hungary

*Organizer* : Scientific Society of Mechanical Engineers (GTE), Hungary

*Sponsor* : European Group on Fracture (EGF)

*Deadlines* : Sep. 30, 1987 - Abstracts (500 words)

Dec. 31, 1987 - Acceptance notice

March 31, 1988 - Full papers

*Inquiries* : Dr. E. Czoboly

Technical University Budapest

Inst. for Mechanical Technology and

Materials Science

P.O. Box 451

1372 Budapest, Hungary

**September 19-22, 1988**

**Second International Symposium on Brittle Matrix Composites**

*Location* : near Warsaw, Poland

*Deadlines* : Dec. 31, 1988 - Abstracts (500 words)

Apr. 31, 1988 - Final draft of papers

*Inquiries* : Prof. Dr. A.M. Brandt

Polish Academy of Sciences

Inst. of Fundamental Technological Research

Swietokrzyska 21

00 049 Warsaw, Poland

or

Dr. I.H. Marshall

Paisley College of Technology

Dept. of Mechanical and Production Engineering

Highstreet

Paisley PA1 2BE, Scotland

**September 26-30, 1988**

**20th Europhysics Conference on Macromolecular Physics**

**3rd Lausanne Polymer Meeting**

**Physical Mechanisms in Polymer Failure**

*Location* : Lausanne, Switzerland

*Organizer* : European Physical Society

Section of Macromolecular Physics *et al.*

*Deadlines* : Dec 31, 1987 - preregistration

*Inquiries* : Prof. H.H. Kausch

Laboratoire de Polymères

32, chemin de Bellerive

1007 Lausanne, Switzerland

Tel. (021) 472847

Telex 26676 (until 31.12.1987)

450676 (from 1.1.1988)

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## AGENDA cont'd

November 22-25, 1988

WELDTECH 88

**Location :** Ramada Inn, West London, UK  
**Organizer :** The Welding Institute, Cambridge, UK  
**Deadlines :** Dec 18, 1987 - Abstracts (500 words)  
June 17, 1988 - Final manuscripts  
**Inquiries :** Mr. Tony Gray  
The Welding Institute, Abington Hall  
Abington, Cambridge CB1 6AL, UK  
Tel. 0223 891162 Telex 81183 weldex g  
Telefax 0223 892588

March 20-24, 1989

Seventh International Conference on Fracture, ICF7

**Location :** University of Houston, Texas, USA  
**Organizer :** University of Houston  
**Sponsor :** The Int. Congress on Fracture  
**Deadlines :** May 1, 1988 - Full papers  
Oct 1, 1988 - Registration  
**Inquiries :** Dr. Kamel Salama  
Mechanical Engineering Dept.  
Un. of Houston, University Park  
Houston, Texas 77004, USA  
Tel. (713)749-4455 Telex 556475

**K. H. Schwalbe (Ed.)**

## The Crack Tip Opening Displacement in Elastic-Plastic Fracture Mechanics

Proceedings of the Workshop on the CTOD Methodology GKSS-Forschungszentrum Geesthacht GmbH, Geesthacht, Germany, April 23-25, 1985  
1986. XV, 360 pages. Hard cover DM 118,-. ISBN 3-540-16602-5

The present book represents the Proceedings of the Workshop on the CTOD Methodology, held on 23rd-25th April 1985 at the GKSS-Forschungszentrum in Geesthacht, West Germany.

The seventeen contributions cover several aspects of the crack tip opening displacement (CTOD) concept:

- Calculation of CTOD,
- Experimental techniques for determining CTOD,
- Relationship between CTOD and J-integral,
- CTOD as a correlation parameter for stable crack growth,
- Characterisation of welds with CTOD,
- Application of CTOD to structural assessment.

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