European Structural Integrity Society

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In this issue:

EDITORIAL BY THE ESIS PRESIDENT 1
WELCOME 2
ESIS ROOTS 3
ECF 18 4
COUNCIL MEETING 5
AWARDS 7
TECHNICAL COMMITTEES 8
CALENDAR OF TC MEETINGS 14
CALENDAR OF CONFERENCES 16
INVITED PAPERS:
"FRACTURE, FATIGUE AND STABILITY OF NANOCRYSTALLINE MATERIALS FOR STRUCTURAL APPLICATIONS"
by Ashok Saxena 17
"FRACTURE UNDER Combined Primary and Secondary Stresses "
by Marco Paggi 22

ESIS Officers

President
Prof. Leslie Banks-Sills
School of Mechanical Engineering,
Tel Aviv University
Ramat Aviv 69978, Israel
E-mail: banks@eng.tau.ac.il

Vice-President
Prof. Stefano Beretta
Dipartimento di Meccanica,
Politecnico di Milano
Via La Masa 1
20156 Milano, Italy
E-mail: stefano.beretta@polimi.it

Vice-President
Prof. Jaroslav Pokluda
Institute of Engineering Physics,
Brno University of Technology
Technicka 2,
616 69 Brno, Czech Republic
E-mail: pokluda@fme.vutbr.cz

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

EDITORIAL BY THE ESIS PRESIDENT

Five months have passed since ECF18 at Dresden. The Executive Committee (ExCo) is fired up by a commitment to continue to make ESIS a vibrant and exciting organization. Recently, the ExCo met in Brussels to move ESIS forward. The attendees included Jaroslav Pokluda and Stefano Beretta, the two vice-presidents, Giuseppe Ferro, the secretary/ treasurer, Wolfgang Brocks who is in charge of publications, Zhiliang Zhang, chairman of ECF20 in Trondheim, and Dietmar Klingbeil, chairman of ECF18, who attended as a guest. Unfortunately, Robert Goldstein, chairman of ECF19, was unable to attend. Professor Ferro has decided to step down as secretary, but will continue as treasurer. I personally, and I am sure everyone at ESIS, would like to thank him for a job well done.

As many of you know, we have had a contract with Elsevier since 2004. Under this contract, Elsevier provided ESIS with a 10,000 € honorarium each year and 5,000 € for each special issue that we published in one of the journals which we support, namely, Engineering Fracture Mechanics, International Journal of Fatigue and Engineering Failure Analysis. I would like to encourage you to publish in these journals. Unfortunately, the contract has come to an end. We are currently negotiating a new contract in which the terms are regrettably less favorable. But we wish to continue our relationship with Elsevier. The special issues are a result of Technical Committee (TC) meetings and ECFs. I would like to encourage all of you to look at our web site and join a TC which is close to your area of expertise. If you are interested in starting a new TC, please contact me and we will try to arrange it with the necessary approval.

As a result of our loss of revenue, we will not be able to support all of the scientists which we previously supported at ECF meetings. The ESIS Council decided at its last meeting in Dresden that ECF chairmen would raise money for this endeavor. I would like to remind you that Dietmar Klingbeil and his committee of ECF18 was successful in doing this. However, we are looking into other initiatives such as COST to help ESIS and the TCs financially. If there is anyone who is interested in working on these initiatives, they should contact me.

Joining ESIS has been made simpler through the web site. It is possible with a credit card to join either individually, as a national group or as a corporate member. Please renew your ESIS membership soon for 2011. You will then receive a membership card, as some of you did last

year. If you do not receive a card, please contact Professor Beretta. ESIS had about 450 members in 2010.

At the initiation of Stefano Beretta and Wolfgang Brooks a blog is being started which will discuss articles beginning with Engineering Fracture Mechanics, and if successful will be expanded to the International Journal of Fatigue and Engineering Failure Analysis. This should bring additional attention to articles of particular interest and result in a lively discussion of various aspects of fracture and fatigue problems. You will soon be able to enter the blog through our web site.

Professor Pokluda is currently working on our legal status. Moreover, we plan to strengthen our relations with ASTM and the Chinese Association for Mechanics.

Finally, I want to encourage you all to come to Kazan to present your research results at ECF19. Kazan is a vibrant city that is growing with a tremendous investment by the Russian government, and is a leading science center of the Russian Academy of Science.

Leslie Banks-Sills

WELCOME !

Dear colleagues,
A new face in this place. After ECF18, I took over the task of editing the Newsletter from Stefano Beretta, who will still be responsible for the ESIS web site.

We had a very successful conference, ECF18, in Dresden last year, and you will find a report on it in the present issue, together with the minutes of the Council Meeting held during the conference and the laudations of the 2010 Awardees.

The meeting revealed a problem that over the last years ESIS has lost members from some Western European countries like Finland, France, The Netherlands, and Sweden among others, who once contributed significantly to ESIS. Nations with less than ten members lose their vote in the Council, which is an unpleasant situation for a society aiming to represent European engineers and scientists. We shall have to look for the reasons why ESIS appears not to be attractive for these countries any more. In order to start this discussion, I asked Dominique François, who founded the European Group on Fracture some 35 years ago, for a contribution on the "ESIS roots".

The aim of ESIS is not only to develop and extend knowledge in all aspects of structural integrity but also to "disseminate this knowledge world-wide" by means of scientific publications and "to educate young engineers and scientists". We would like to promote this objective and intensify our connection to Elsevier through a blog on IMECHANICA for discussing some papers published in Engineering Fracture Mechanics. This activity will be launched shortly and the rules will be announced.

I started my work with an inquiry among the Technical Committees (TC) as some changes have taken place after the Council meeting. It also turned out that some information given on the ESIS web site was out-dated. As an outcome of this request, you will find an updated list of TCs. The information is still not complete, unfortunately, as some e-mail addresses appeared to be invalid and some addressees did not respond. Stefano Beretta indicated in NL #46, already, that there are inactive TCs. It is not only activity, which is important, however, but also communication of what is done. Hence, I urgently ask the TC chairpersons to report on all activities to Stefano Beretta and me at regular intervals, so that we can keep the information up-to-date for all ESIS members.

Finally, you will find two invited papers by Prof. Ashok Saxena, winner of the Wöhler medal, and Dr. Marco Paggi, winner of the Young Scientist Award, in the present issue.

Wolfgang Brocks

ESIS Website

www.structuralintegrity.eu

- **become a member of ESIS and take advantage of all the "Members Only" resources on this Web site**
- **register automatically as a Member and pay the fee by PayPal system**
-
- **obtain your username and password for accessing the private area for downloading EGF-ESIS books and Procedures**
-
- **exchange new ideas, advancements and documents with the other ESIS Members**

Advantages of being an ESIS member

- participation in TC activities and access to TC documents;
- full on-line access to ESIS procedures;
- full on-line access to former EGF-ESIS books;
- support for ESIS activity.

how to renew?
see page 29 or
www.structuralintegrity.eu

ESIS ROOTS

About the origins of the European Group on Fracture (EGF) and the European Society for Structural Integrity (ESIS)

EGF was founded now something like thirty-five years ago. Without any written documents of the time at hand it is not easy for me to remember exactly the gestation. I will attempt to recall how the idea was born, the aims we had in mind more or less consciously, the background around the foundation. It is quite possible that I deform the reality and put emphasis on the less important facts. But, I will try to be as objective as possible.

In the sixties, fracture mechanics was yet in its adolescence. In France we had only fresh knowledge about a scientific field, which had mostly developed in the US and in the United Kingdom. What was going on in the Soviet Union was little known. From a year spent at Stanford University I had come back persuaded that fracture mechanics was a most exiting challenge both from the scientific and from the economic points of view. I was struck by the very little knowledge that the French engineers, not to speak of the French universities, had about this field. I then organised a "summer school" on the subject. Following 1968, a series of summer schools were initiated by young scientists who wanted an equal and active sharing of knowledge. In 1969, the one at la Colle-sur-Loup, devoted to fracture, was very well attended. I had invited Alan Tetelman and Régis Pelloux to give courses. The participants thought it would be a good idea to keep in touch afterwards and it was decided to create an informal structure, the French group on fracture, meeting twice a year in different places.

On one occasion, we went to Sulzer in Switzerland. This was a first opportunity to discover as a group what was going on in a nearby country and the idea emerged to enlarge and to envisage a European group.

"Université de Technologie de Compiègne" (UTC) was a newly born university and was deliberately engaged in promising research. Thus, I started a new laboratory mostly devoted to structural integrity. I created a "diplôme d'études approfondies" (DEA) called "the ruin of structures"; many said I had in mind the ruin of the French academic system!

I soon decided that this European meeting we contemplated at Zurich was very much needed. This is why I invited a number of European colleagues for a two days small colloquium in Compiègne. I remember that the heating system of our newly built university was not up to our ambitions; the conference room was pretty cold. However, not so the participants. We had an extremely fruitful exchange of ideas, results and projects. It was decided this meeting needed to be followed by another one. This was how the European group on fracture started.

Later on, it was found that this completely informal gathering needed a more sound basis. This was ESIS.

It seems to me that through the circumstances around the birth of ESIS, it is possible to stress a few considerations, which were more or less present in our mind and which structured our action. There is no doubt that we had been much influenced by the hot discussions, which took place in May 1968. We believed that the "mandarinat" was to be destroyed. We were eager for sharing knowledge and we were sure it needed informal discussions among equal peers, allowing discussions of controversial issues, in a way which the web allows nowadays. At the time establishing rules was simply unconceivable.

Nationalistic notions were out-dated. The universal nature of universities was to be lived fully. Boundaries could be abolished. Nevertheless, Europe was not quite like the rest of the world. Those of us who had lived in America were well aware that Europeans had something particular in common. In getting acquainted, we immediately found a particular way of thinking, an interest for the same problems, a similar approach to politics, all this rooted in a common rather cruel past. It seemed then important to unite in a Cold War world, overcoming the East-West barriers. However, this sense of European unity was accompanied by the evidence that Europe possessed great diversities, which was a wealth not so much available in the US. I was struck by a statement of De Leiris, an important French expert in structural integrity, who insisted on the importance of expressing an idea

in different languages for fully grasping its sense. Europe had an asset in this respect.

Living in foreign countries demonstrated how fully enriching was such an experience. International exchanges of students and of professors were not so developed. We had a great desire to develop those exchanges. For this it was needed to expand our international relationships.

I also envisaged that, in the light of the summer school of La Colle-sur-Loup, EGF would organise European summer schools to provide students with the most advanced knowledge.

At the same time, we were within the "thirty glorious years", the years of expansion and of strong belief in technical progress. We wished for academic research to open to technology and to industry. Research in the US was an example. We realized that meetings of engineers and academics were essential.

And we were proud of the achievements of our European industries. Aeronautics, railways, petroleum industry, nuclear energy in particular looked promising. These were the areas where fracture mechanics was finding fruitful applications. For the benefit of these industries, we felt that as European experts we had to contribute to the progress of the technology out of America. Of course, this contribution to economic competition could be conflicting with our ideals of universalism. I do not remember of large debates among us about this contradiction.

Finally, to sum up, EGF at its foundation was devoted, in the field of structural integrity and in Europe, to the spreading of knowledge through meetings and summer schools, to the development of friendship of scientists and engineers and as a contribution to the European construction.

Dominique François,
Honorary professor of École Centrale de Paris

ECF 18

The European Structural Integrity Society (ESIS) 18th European Conference on Fracture (ECF18) took place in Dresden, Germany, from August 30 to September 3, 2010. The local organizing group was headed by the German Association for Materials and Testing (DVM). The official website is online under www.ecf.de so that specific information about the conference still may be retrieved from this site.

The executive chairman of the conference was Prof. Dr.-Ing. D. Klingbeil from the Federal Institute for Materials Research and Testing (BAM), Berlin, Germany. The co-chairmen were Prof. Dr.-Ing. M. Vormwald, TU Darmstadt, Germany and Prof. Dr.-Ing. habil. K.-G. Eulitz, TU Dresden, Germany. More than 460 participants from 44 nations worldwide were registered and a total of 370 oral contributions were presented in the scope of 85 sessions which were organized according to specific fields of research.

The scientific program was compiled by the ESIS National Scientific Committee and the Organizing Committee (DVM, BAM). Thirteen plenary lectures as well as several key-notes were presented by world leaders in fracture, damage and fatigue. The honorary lecture was given by Prof. A. Pineau, École de Mines de Paris, France, a worldwide acknowledged scientist and teacher.

A number of high-level contributions dealing with fracture, fatigue and damage of multi-scale modelling and outstanding experimental setups were presented. About 300 presentations were published in the Book of Abstracts and in the Proceedings on CD ROM. Selected papers were destined for publication in special issues of scientific journals like Engineering Fracture Mechanics or International Journal of Fatigue.

Accompanying Sessions

In the frame of ECF 18, a number of important meetings of international scientific authorities took place as, for example, the ESIS Council, the ESIS Executive Committee and some ESIS Technical Committees. Moreover, several ICF-WASI invited meetings, Sino-German Center meetings and an Elsevier Editorial Board meeting were held. It can be stated that many very important personalities in the field of fracture and fatigue were present. The conference was accompanied by an exhibition with 8 exhibitors.

The Welcome Party was associated with the registration of arriving participants. The Lord Mayor Reception at Dresden City Hall was aimed to meet the local political representatives. While listening to Dixieland jazz the guests of the Steam Ship Excursion passed the old city and the vineyards of Dresden on a historical paddle steamer and visited Pillnitz Castle. During the conference dinner in the Westin Bellevue Hotel with famous Canaletto-View the ESIS president and the executive chairman traditionally passed the ESIS awards.

Walking tours through the historical city of Dresden and a Museum Tour "Old Masters' Gallery" as well as a visit of the Semper Opera rounded off the social programme. Technical visits led interested people to the Institute of Lightweight Structures and Polymer Technology as well as the Otto-Mohr-Laboratory for Construction of the Technical University of Dresden. The Fraunhofer Institute for Ceramic Technologies and Systems could be visited as well as IMA Company where a full scale fatigue and fracture testing facility of the Airbus A380 could be gazed at.

According to reactions of many participants during the conference the ECF 18 was a success.

Dietmar Klingbeil
Executive Chairman of ECF 18

ESIS COUNCIL MEETING

Wednesday Sept. 01, 2010, Dresden, Germany

AGENDA

1. Introduction and Communications
2. Support of ESIS to ECF participants
3. Election of President and ESIS Officers for 2010 – 2014
4. Decision for ECF20
5. ESIS Newsletter
6. Fellow members
7. ESIS Membership
8. National Groups
9. Financial Report
10. Technical Committees
11. New ESIS awards (Muskelishvili, Navarro)
12. ECF19 (Kazan, Russia)

ATTENDEES

Twenty-two Countries were represented at Council, which was composed of 41 Members.

1. INTRODUCTION AND COMMUNICATIONS

This Council Meeting was held during the week of the 18th European Conference on Fracture (ECF18), in Dresden (Germany). The President of ESIS, Professor Emmanuel Gdoutos, chaired the meeting.
The President, according to the statute, called the nations and TC in order to establish the voting member:
Austria (Mayor), Bulgaria (Angelova), Croatia (Tomkviczh), Czech Republic (Dlouhy), Germany (Klingbeil), Greece (Gdoutos), Israel (Banks-Sills), Italy (Carpinteri), Poland (Karolczuk), Romania (Marsavina), Russia (Goldstein), Serbia (Sedmak), Spain (Toribio), Switzerland (Brunners), UK (Williams), Ukraine (Panasuk),
TC2 (Pokluda), TC3 (Spagnoli), TC4 (Williams), TC8 (Yuan), TC9 (Ferro), TC11 (Dietzel by proxy), TC24 (Zerbst),
Vice-Presidents Neimitz, Banks-Sills,
Secretary Ferro.
In total there were 27 votes.
The President proposed a change in the Statutes so that the President's term would be two years instead of four. There were 16 in favor (not sufficient for having 2/3 of the total votes equal to 18). The proposal was not approved.

2. Support of ESIS to conferences

The President proposed the following motion approved by majority during the ExCo: the organizer of ECF agrees to support at least 30 people who require this support and organizes a means for achieving this goal. The Council approved this motion unanimously.

3. ELECTION OF PRESIDENT AND ESIS OFFICERS FOR 2010-2014

Following tradition, the President nominated the candidates. The new President is normally one of the two current vice-presidents. After a discussion in the Council, Banks-Sills was the candidate of the President, while the two vice-presidents proposed by the President were Beretta and Goldstein. Carpinteri was the second. Klingbeil nominated Pokluda as ESIS President, and Brocks and Beretta as vice-presidents.
The Presidential candidates presented their programs. After a long and constructive discussion, the voting started.
The results were as follows:

Banks-Sills	14 votes
Pokluda	13 votes

Banks-Sills was elected ESIS President for 2010-2014.
Karihaloo proposed, as the voting results were very close, to nominate Pokluda as Vice-President.
After a break for private discussions, Banks-Sills proposed the nomination of Pokluda as vice-president. Brocks was requested to be in charge of publications, and to withdraw his candidacy as Vice-President. Ferro suggested choosing Pokluda as Vice-President by acclamation, but there was no unanimity.
The voting results were as follows:

Beretta	22 votes
Pokluda	18 votes
Goldstein	13 votes
Nil	1 vote

Beretta and Pokluda were elected ESIS Vice-President for 2010-2014.

The new ExCo: Stefano Beretta, Leslie Banks-Sills, Jaroslav Pokluda, Giuseppe Ferro, Wolfgang Brocks

4. DECISION FOR ECF20

The President asked the candidates to present their proposal in 15 minutes.
Prof. Zhang presented the proposal for Trondheim - Norway. The proposed period was 30th June-4th July 2014. The organizers would be

Profs. Zhang, Skallerud and Thaullow from NTNU of Trondheim and Dr. Ostby from SINTEF. The conference venue would be at the Norwegian University of Science and Technology of Trondheim. For accommodation there will be the possibility to rent inexpensive student housing for young scientists. The approximate registration fee would be about 5500 kr (about 650 euro) for participants, 4500 kr for ESIS members, 3000 kr for students and 1500 kr for accompanying persons.
Profs. Panasuk and Dmytrakh presented the proposal for Ukraine. The proposed period was 1st-5th September 2014. The organizing committee would be chaired by Prof. Panasyuk, with Profs. Dmytrakh, Bobalo and Lobanov as Vice-Chairmen. The conference venue would be at Lviv Polytechnic National University. For accommodation, the hotel Dnister should be reserved with the prices between 60 and 80 euro. The registration fee should be about 500 euro for early registration and 600 for late, 250 and 300 for students and 100-150 for accompanying persons.
After the presentations, the results were:

NORWAY	15 votes
UKRAINE	11 votes

The ECF20 will be hosted in Trondheim and Prof. Zhang became an ExCo member as ECF organizer.

5. ESIS Newsletter

Beretta presented the Newsletter. He had difficulties in obtaining information from TCs. For the next issue, the ExCo should find some alternative ways to increase the exchange of information between the ExCo and TCs.

6. FELLOW MEMBERS

The President proposed the names of Nikita Morozov, Stojan Sedmak, Giuseppe Ferro, Stefano Beretta and Dragoslav Sumarac as ESIS Fellow members. The Council approved unanimously.

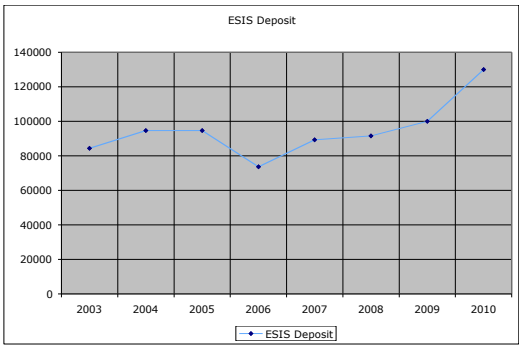
7. NATIONAL GROUPS

Banks-Sills informed the Council about the situation of the National Groups. As already stated earlier, only 16 nations had at least 10 ESIS members in the last three years (2008-10). The efforts of the next ExCo should to try to increase the involvement of some of the most important countries, such as Germany, France and UK, in ESIS activities.
Ferro reported the difficulties in obtaining the list of members from the National Representatives. The automatic Web procedure should solve the problem. Up until July, 425 members have been registered for 2010.

Country	*Members*
AUSTRIA	23
BRASIL	1
CANADA	1
CZECH REPUBLIC	23
CROATIA	1
FINLAND	1
GERMANY	1
ISRAEL	10
ITALY	81
NORWAY	1
JAPAN	1
POLAND	24
RUSSIA	43
SERBIA	65
SPAIN	115
SWEDEN	1
SWITZERLAND	5
UNITED KINGDOM	51
Total	*448*

8. FINANCIAL REPORT

Ferro informed the Council about the financial situation of the Society. From an economical point of view, the actual portfolio was close to 130,000 euros, with an increment with respect to 2009 by 30%. This increment was principally a result of the special issues published by ESIS in the last years. From the graph, the importance of the contract between ESIS and Elsevier is evident. ESIS contributed 14,500 euros to ECF18, in line with the contribution paid to ECF17 of about 15,000 euros.



9. Technical Committees

Beretta informed the Council about the situation of the TC activities in the last years. TC7 should be closed. The Council should nominate new Chairmen for TC1 and TC9. He proposed nominating Zerbst as chairman of TC1.
In 2002, monitoring of the TCs began. TC14, TC15, TC22 and TC23 were closed in 2004; TC17 and TC18 were closed in 2005. A new chairman was appointed to TC24; while TC19 is waiting for a new chairman. It will be closed if a new chairman is not found.
The TCs were examined again in 2006 (Alexandroupolis). The examination was focused on TC1, TC7, TC8, TC9, TC20 and TC6 in 2008. The problems were in finding new chairmen for TC1, TC8 and TC9, and in determining if TC7 still exists. Beretta suggested closing TC7 and TC20, and to nominate Zerbst as chairman of TC1. Carpinteri proposed Ferro as Chairman of TC9.

TC12 and TC13 will be discussed during the next Council.
The Council unanimously approved closing TC7 and TC20, and the new chairmen for TC1 (Zerbst) and TC9 (Ferro).

10. NEW ESIS AWARDS

Gdoutos informed the Council that there are two Medals and two Awards.
He proposed two new awards: the Navarro Award and the Muskhelisvili Award.
As the voting procedures for the new President and Officers lasted very long, he proposed postponing the decision during Banks-Sills Presidency.

11. ECF18 (Dresden, Germany)

Klingbeil informed the Council about the conference. Participation at the conference has been impressive, considering the problem confronted during the last two years.

12. ECF19 (KAZAN, RUSSIA)

Goldstein informed the Council that the Conference ECF19 will be organized in Kazan, instead of Perm.

The ESIS Secretary Prof Giuseppe Ferro
The ESIS President Prof Emmanuel Gdoutos

AWARDS

On the occasion of ECF 18 the following ESIS Awards were conferred:

- **Griffith Medal** to Prof. E. Gdoutos "for his seminal contributions in mixed-mode fracture and failure mechanisms of sandwich structures".

Emmanuel E. Gdoutos is Professor of Theoretical and Applied Mechanics and Director of the Laboratory of Applied Mechanics at the Democritus University of Thrace, Greece, and Adjunct Professor at Northwestern University of Illinois. He received his M.S. and Ph.D. from the National Technical University of Athens. His interests and experience include many areas of mechanics of materials with emphasis on experimental mechanics, fracture mechanics, composite materials and nanotechnology. He authored over 240 papers in refereed journals and conference proceedings, 15 books and edited 13 books. Nine of his books refer to fracture mechanics. Prof. Gdoutos is Corresponding Member of the Academy of Athens, member of the European Academy of Sciences and Arts, Academia Europaea, the European Academy of Sciences, Fellow of the Society of Experimental Mechanics, the American Academy of Mechanics, the American Society of Mechanical Engineers and the New York Academy of Sciences, and Honorary Member of the Italian Group of Fracture. He is editor-inchief of "Strain – An International Journal for Experimental Mechanics," President of the Greek Group of Fracture. He served as Chairman of the European Association for Experimental Mechanics. He is a member of the editorial board of eight international journals and guest editor of seven special issues of international journals. He has been awarded two Fulbright fellowships and an excellent teaching award from the University of Toledo. He chaired many conferences in theoretical and applied mechanics including the 16th European Conference of Fracture and the 13th International Conference on Experimental Mechanics.

- **Wöhler Medal** to Prof. A. Saxena "for his outstanding and seminal contributions on fatigue and fracture behaviour of structural materials, with special emphasis on creep crack growth, component life predictions, and nanostructured materials".

Ashok Saxena is the Dean of Engineering, Distinguished Professor and the Irma F. and Raymond C. Giffels' Endowed Chair in Engineering at the University of Arkansas. He joined the University of Arkansas in 2003 as the Dean of the College and was recently reappointed to the position by Chancellor Gearhart until June of 2015. Dr. Saxena previously held the position of Regents' Professor and Chair of the School of Materials Science and Engineering at the Georgia Institute of Technology in Atlanta and was a Fellow Scientist at the Westinghouse Research and Development Center in Pittsburgh. He is a Fellow of ASTM, a Fellow of ASM International and a Fellow of International Congress on Fracture and a winner of numerous other research awards including the 1992 George Irwin Medal from ASTM, the 1993 Outstanding Research Author Award from Georgia Tech., and the 2009 Fracture Mechanics Medal from ASTM.

- **Award of Merit** to Prof. J. Pokluda "for his outstanding contribution to micromechanics of fracture and good service to the European Structural Integrity Society".

Jaroslav Pokluda is Professor at the Institute of Physical Engineering and Head of the Dept. Materials Micromechanics and Applied Acoustics. He received his M.S. and Ph.D. at the University J. E. Purkyně in Brno. His scientific field is materials science and engineering with special focus on micromechanisms of fatigue and fracture, multiscale modelling deformation and

fracture, quantitative fractography, and failure analysis. He is author or co-author of 84 papers in refereed scientific journals, 152 contributions in conference proceedings including 11 keynotes, three textbooks and one monograph and editor of four books. Prof Pokluda has been co-chairman of seven international conferences (MSMF1-5, ECF17, ESOMAT 2009) and member of the editorial board of Metallic Materials, Strength of Materials, and Physicochemical Mechanics of Materials. He became Fellow of the Japanese Society of Promotion of Science in 2002 and the European Structural Integrity Society in 2009 and was awarded with the Commemorative Medal of the Institute of Materials Research, Slovak Academy of Sciences, in 2005 and the Silver medal of Brno University of Technology in 2008.

- **Honorary Membership** to Prof. R. Goldstein "for his outstanding contributions to fracture mechanics, its engineering applications, and distinguished service to the fracture mechanics community".

Robert Goldstein is Professor of Mechanics and Physics of Technological Processes at the K.E. Tsiolkovsky Russian State Technological University. He received his M.S. from Lomonosov's Moscow State University and his Ph.D. from the Academy of Sciences of USSR, where Barenblatt was one of his supervisors. His main fields of research are solid mechanics, fracture mechanics, mechanics of materials, strength and fracture in micro- and nanoelectronics, engineering applications of solid mechanics. He has been awarded both nationally and internationally, among others Honorary Fellow of the International Congress on Fracture in 1993, State Prize of the Russian Federation in Science and Techniques in 2000, Honoured scientist of the Russian federation in 2008. He is Deputy-Head of the Russian Scientific Council of the Academy of Sciences on Strength and Plasticity since 1985, became a member of the Executive Committees of ESIS in 1997 and ICF in 2001, Scientific Secretary of the Scientific Council on Mechanics of the Russian Academy of Sciences in 2004 and Vice-President of ICF in 2005. Professor Goldstein is a member of the editorial boards of the International Journal of Fracture, Fatigue and Fracture of Engineering Materials and Structures, Journal of the Russian Academy of Sciences "Mechanics of Solids", Journal of the Siberian Branch of the Russian Academy of Sciences "Physical Mesomechanics", Journal of the Ural Branch of the Russian Academy of Sciences "Computational mechanics of continuum media" and has been co-chairman of several international conferences on fracture mechanics.

- **Young Scientist Award** to Dr. Marco Paggi "for his outstanding contributions to fracture mechanics, and particularly in fatigue scaling, friction effects and nonlinear crack modelling".

Marco Paggi is Assistant Professor of Structural Mechanics at the 1st School of Engineering of the Politecnico di Torino and currently Alexander von Humboldt Research Fellow at the Gottfried Wilhelm Leibniz Universität of Hannover. He received his MEng and PhD at the Politecnico di Torino. He is a member of the scientific committee of the journal "Frattura ed Integrità Strutturale" of the Italian Group of Fracture and winner of the awards "Premio Optime - Riconoscimento al merito nello studio" by the Industrial Union of Turin in collaboration with the Turin University and the Politecnico di Torino in 2002, "Support to Young Researchers" by the Politecnico di Torino to the first 50 researchers younger than 40 with the best publication rate in 2008 and 2009, and "Prize for Young Authors IGF 2009" by the Italian Group of Fracture. Dr. Paggi is co-author of more than 30 articles in international journals. Since the Academic Year 2001-2002, he has extensively collaborated with Prof. A. Carpinteri and Prof. G. Zavarise on teaching activities in Structural Mechanics, Mechanics of Materials and Fracture Mechanics.

- **ESIS Fellowship** was awarded to Prof. Stojan Sedmak, Prof. Stefano Beretta, Dr. Dragoslav Sumarac, Prof. Nikita Morozov, and Prof. Giuseppe Andrea Ferro "for their outstanding contributions to the art, science, teaching or practice of fracture mechanics and their service to the Society".

TECHNICAL COMMITTEES

TC 1: Elastic-Plastic Fracture Mechanics
Prof. Uwe Zerbst
BAM
Unter den Eichen 87
D - 12205 Berlin, Germany
uwe.zerbst@bam.de

TC 2: Micromechanisms
Prof. Jaroslav Pokluda
Institute of Engineering Physics
Brno University of Technology
Faculty of Mech. Engng.
Technicka 2
616 69 Brno, Czech Republic
pokluda@fme.vutbr.cz

TC 3: Fatigue of Engineering Materials and Structures

Prof. Les P Pook
21 Woodside Road
Sevenoaks, Kent, TN13 3HF, UK
les.pook@tesco.net

Prof. Andrea Carpinteri
Dept Civil Engineering
University of Parma
Viale G.P. Usberti, 181/A
43100 Parma, Italy
andrea.carpinteri@unipr.it

Subcommittee on Multiaxial Fatigue

Prof. Ewald Macha
Opole University of Technology
Faculty of Mechanics
Department of Mechanics and Machine Design
ul. S. Mikołajczyka 5
45-271 Opole, Poland
e.macha@po.opole.pl

TC 4: Polymers and Polymer Composites

Prof. J G Williams
Imperial College
Dept of Mechanical Engg.
Exhibition Road,
London SW7 2BX, UK
g.williams@ic.ac.uk

Prof. Andrea Pavan
Dip. Chimica, Materiali e Ingegneria Chimica, Politecnico di Milano
Piazza Leonardo da Vinci 32
20133 Milan, Italy
andrea.pavan@polimi.it

TC 5: Fracture Dynamics

Hugh MacGillivray
Dept of Mechanical Engg
Imperial College
Exhibition Rd,
London SW7 2BX, UK
h.macgill@imperial.ac.uk

Gyongyver Lenkey
Bay Zoltan Institute
Miskolc, Hungary
lenkey@bzlogi.hu

Dr. Uwe Mayer
Materialpruefungsanstalt Universitaet Stuttgart
Pfaffenwaldring 32
70569 Stuttgart, Germany
Uwe.Mayer@mpa.uni-stuttgart.de

TC 6: Ceramics

Prof. Dr. J. Duzsa
Slovak Academy of Science,
Watsonova 47,
SK-04353 Košice, Slovakia

Dr. Tanja Lube
Institut für Struktur-und Funktions-keramik,
Peter-Tunner-Strasse 5,
A-8700 Leoben, Austria
tanja.lube@unileoben.ac.at

TC 8: Numerical Methods

Prof. Dr. Huang Yuan
Dept. of Mechanical Engineering
University of Wuppertal,
Germany
h.yuan@uni-wuppertal.de

TC 9: Concrete

Prof. Guiseppe Ferro
Dipartimento di Ingegneria Strutturale e Geotecnica
Politecnico di Torino
Corso Duca degli Abruzzi 24
10129 Torino, Italy
giuseppe.ferro@polito.it

TC 10: Environmental Assisted Cracking

Prof. Jesús Toribio
University of Salamanca
Department of Materials Engineering
E.P.S., Campus Viriato,
Avda Requejo 33
49022 Zamora, Spain
toribio@usal.es

Subcommittee on Hydrogen Degradation

Prof. Hryhoriy Nykyforchyn
Karpenko Physico-Mechanical Institute of the NAS of Ukraine
Str. Naukova, 5
79601 Lviv, Ukraine
nykyfor@ipm.lviv.ua

TC 11: High Temperature Mechanical Testing

Dr. Hellmuth Klingelhöffer
BAM Federal Institute for Materials Research and Testing
Division V.2 - Mechanical behaviour of materials
Unter den Eichen 87
12205 Berlin, Germany
Hellmuth.Klingelhoeffer@bam.de

Larry Candler
Exova
Advanced Manufacturing Park
Technology Centre
Brunel Way
Rotherham, S60 5WG, UK
larry.candler@exova.com

TC 12: Probabilistic Interpretation of Mechanical Property Data

Dr Robert Moskovic
Magnox Electric
Oldbury Technical Centre
Oldbury, Naite
Oldbury on Severn.
South Gloucestershire BS35 1RQ, UK
robert.moskovic@magnoxnorthsites.com

TC 13: Education and Training

Prof Hans Peter Rossmanith
Vienna University of Technology
Abteilung für Technische Mechanik
Wiedner Hauptstr. 8
1040 Wien, Austria
Hans.Peter.Rossmanith@tuwien.ac.at

Prof Laszlo Toth
Bay Zoltán Institute for Logistics and Production Systems
Miskolctapolca
Bay Zoltán tér 1.
H-3519, Hungary
tlaszlo@alpha.bzlogi.hu

TC 24: Integrity of Railway Structures

Prof. Stefano Beretta
Politecnico di Milano
Dipartimento di Meccanica
Via La Masa 1,
20156 Milano, Italy
E-mail: stefano.beretta@polimi.it

Prof. Roderick Smith
Imperial College, London
roderick.smith@imperial.ac.uk

TC 3: Fatigue of Engineering Materials and Structures

Activities during 2010-2011

(a) Professor Bruno Atzori (Padua), Professor Andrea Carpinteri (Parma), Professor Paolo Lazzarin (Padua), Professor Les P. Pook (London) and Professor Andrea Spagnoli (Parma): Guest Editors of a Special Issue on "Crack Paths" of the International Journal "Engineering Fracture Mechanics", Vol.77, No.11, pp. 1617-2212, 2010 (with papers selected from those presented at the International Conference on "Crack Paths - CP 2009", held in Vicenza, Italy, 23rd to 25th September, 2009).

(b) Professor Andrea Carpinteri (Parma), Professor Les P. Pook (London) and Professor Cetin Morris Sonsino (Darmstadt): Chairmen of the 9th International Conference on Multiaxial Fatigue and Fracture (ICMFF9), held in Parma, Italy, 7th to 9th June, 2010.

(c) Professor Ewald Macha (Chairman of the ESIS TC 3.1 Sub-Committee "Multiaxial Fatigue"): Chairman of the XV International Colloquium on Mechanical Fatigue of Metals (XV-ICMFM), held in Opole, Poland, 13th to 15th September, 2010.

(d) Professor Andrea Carpinteri (Parma), Professor Les P. Pook (London) and Professor Cetin Morris Sonsino (Darmstadt): Guest Editors of a Special Issue on "Multiaxial Fatigue Models" of the "International Journal of Fatigue", Vol.33, 2011 (with papers selected from those presented at the International Conference on Multiaxial Fatigue and Fracture - ICMFF9, held in Parma, Italy, 7th to 9th June, 2010).

(e) Professor Andrea Carpinteri (Parma), Professor Les P. Pook (London) and Professor Andrea Spagnoli (Parma): Guest Editors of a Special Issue on "Multiaxial Fracture" of the International Journal "Engineering Fracture Mechanics", Vol.78, 2011 (with papers selected from those presented at the International Conference on Multiaxial Fatigue and Fracture - ICMFF9, held in Parma, Italy, 7th to 9th June, 2010).

(f) Professor Ewald Macha and Professor Dariusz Rozumek (Opole): Guest Editors of a Special Issue "XV-ICMFM" of the "International Journal of Fatigue", Vol.33, 2011 (with papers selected from those presented at the XV International Colloquium on Mechanical Fatigue of Metals - XV-ICMFM, held in Opole, Poland, 13th to 15th September, 2010).

(g) Professor Ewald Macha (Chairman of the ESIS TC 3.1 Sub-Committee "Multiaxial Fatigue"): Chairman of the 13th Conference on Fracture Mechanics (XIII-CFM), to be held in Opole, Poland, 5th to 7th September, 2011.

(h) Professor Andrea Carpinteri (Parma) and Professor Les P. Pook (London): Chairmen of the 4th International Conference on Crack Paths (CP 2012), to be held in Italy, 19th to 21th September, 2012.

Professor Andrea Carpinteri
Professor Les P. Pook

Subcommittee 3.1 on Multiaxial Fatigue

6th Int. Conf. „Mechatronic Systems and Materials – MSM 2010" 5-8 July 2010, Opole, Poland

Between 5-8 July 2010 on the premises of Opole University of Technology (OUT), the 6th International Conference „Mechatronic Systems and Materials – MSM 2010" was held. This Conference was a continuation of a series of MSM conferences initiated in the year 2005 by Vilnius Gediminas Technical University in Vilnius, Chairman – Prof. Andrejus Marcinkevicius, which are presently organized in cooperation with two

Lithuanian universities: Vilnius Gediminas Technical University and Kaunas University of Technology, and two Polish universities: Białystok University of Technology and Opole University of Technology. Previous MSM conferences were held in Cracow, 2006, Chairman - Prof. Ewald Macha, Kaunas, 2007, Chairman - Prof. Algimantas Bubulis, Białystok, 2008 – Chairman - Prof. Zdzislaw Gosiewski, Vilnius, 2009, Chairman - Prof. Algirdas Vaclovas Valiulis.

Conference MSM-2010 received financial support from the Polish Ministry of Science and Higher Education, and its main organizer was Department of Mechanics and Machine Design, Faculty of Mechanical Engineering of Opole University of Technology together with Opole Branch of the Polish Society of Theoretical and Applied Mechanics (PTMTS). European Structural Integrity Society (ESIS) took honorary patronage over this event.

Conference in numbers: 124 participants, 67 papers written by 252 authors from 15 countries were presented. *International Scientific Committee* consisted of 42 professors.

Conference proceedings were divided into 3 plenary sessions, 16 thematic sessions and 3 poster sessions.

The aim of the Conference was to provide an opportunity to share information and facilitate collaboration in mechatronics and new materials, and dissemination of current research results in this multi-disciplinary field.

All papers presented at the Conference sessions were published in a book containing 134 abstracts entitled: *6th International Conference Mechatronic Systems and Materials MSM 2010 – Abstracts, Kluger K., Macha E., Pawliczek R. (Eds.), Opole University of Technology, Opole, 2010, pp. 237*. Currently, editorial works are in process, so that the papers presented at the Conference will be published in Polish and international journals with high ranking.

On the first evening the participants took part in a walking tour of Opole with a guide. A barbecue outdoor dinner on the other day created an excellent opportunity to taste regional cuisine and typical Silesian dishes. Local craftsmen, especially invited on this occasion, showed the best preserved traditions of folk art. Participants could get practical experience, encouraged by the artists to try their skills at porcelain painting with use of characteristic flowery regional designs or egg decoration through various techniques like wax or scratching.

At the end of MSM-2010 the participants went to one of the two all day long excursions of their choice. There was an opportunity to visit GUIDO Coal Mine in Zabrze or Museum Auschwitz-Birkenau in Oświęcim.

Prof. Ewald Macha,
Opole University of Technology

XV Int. Coll. on Mechanical Fatigue of Metals – XV-ICMFM
13-15 September 2010, Opole, Poland

XV International Colloquium on Mechanical Fatigue of Metals (XV-ICMFM) was held between 13-15 September 2010 on the premises of Opole University of Technology in Opole. XV-ICMFM is a continuation of a series of colloquium started in the year 1972 in Brno, Czech Republic. The mentor and the person who initiated this event after some break was Prof. Valery Troshchenko from Pisarenko Institute of Problems of Strength, National Academy of Sciences of Ukraine. The previous ICMFM took place in Warna (2009) and it was organized by Prof. Stefan Vodenicharov, and gathered approximately seventy participants, mainly from Central and Eastern Europe: Belarus, Bulgaria, Poland, Russia, Romania, Ukraine, but also from India and Portugal.

XV-ICMFM received financial support from the Polish Ministry of Science and Higher Eduacation and its main organizer was Department of Mechanics and Machine Design together with Opole Branch of the Polish Society of Theoretical and Applied Mechanics (PTMTS). European Structural Integrity Society (ESIS) took honorary patronage over this undertaking.

In the Colloquium participated 44 persons, 45 papers written by 108 authors from 14 countries were presented. Scientific Committee of XV-ICMFM consisted of 41 researchers.

Conference proceedings were divided into 2 plenary sessions, 4 thematic sessions and a poster session. The following papers were presented in the plenary sessions:

Troshchenko Valery T.: Cyclic inelasticity and high-cycle fatigue of metals with consideration of the stress gradient effect,

Brighenti Roberto, Carpinteri Andrea, Vantadori Sabrina: A multiaxial fatigue approach based on damage mechanics.

The aim of the Colloquium was to share information and facilitate collaboration regarding fatigue of materials and fatigue crack development and also dissemination of current research in this field. The themes centred on crack development, fatigue of materials and machine elements together with mathematical and functional description. The colloquium provided a platform for a multi-disciplinary approach towards design, construction and exploitation of machines and devices for durability prediction.

Within the scope of the Colloquium were the following themes:

- Physical and phenomenological approaches to the description of the fatigue damage;
- Environmental (corrosive medium, temperature, loading waveform, etc.) effects on fatigue crack propagation;
- Fatigue strength with allowance for the effect of manufacturing and service factors;
- Fatigue life of machine components;

- Variable amplitude loading;
- Mixed mode fatigue and fracture;
- Multiaxial fatigue;
- Fatigue modelling and simulation;
- Software for life prediction;
- Testing and applications.

All papers presented at the Colloquium and at the poster session were published in a book containing 48 abstracts entitled: XV International Colloquium on Mechanical Fatigue of Metals (XV-ICMFM) – Abstracts, Dariusz Rozumek, Ewald Macha (Eds.), Opole University of Technology, Opole, 2010, pp. 60. At present, editorial works are ongoing to ensure publication of the papers in national and international journals with best ranking and high impact.

Prof. Ewald Macha,
Opole University of Technology

TC 8: Numerical Methods

Protocol of TC8 meeting

TU Dresden, 30. August, 2010

Status of the round robin on the cohesive zone model (CZM): This action was initiated in the workshop 2009 in Wuppertal, Germany. But no significant progress was made due to problems in coordination and difficulties in experiments. The activities are running in difference institutes. The situation should be changed in the future. The following points were discussed:

a. Forming a research team for cohesive zone models. The team consists of scientists who have been working on cohesive zone models for both monotonic and cyclic cracking as well as experimental researchers on material failure and are interested in extend their activities on CZM for material failure modelling.
b. Starting a round robin for monotonic crack simulation in 2D/3D specimens under different loading conditions. The goal of the round robin should be exchanging actual research results, studying different models, locating the shortcomings of the CZM's, clarifying limits of CZM for applications and extending applications of the CZM for engineering applications. The details of the present action will be defined in next weeks.
c. Cooperative research on CZM for LCF crack growth. On this subject there exists less experience and more detailed research works are necessary. Here we intend to form a research group with ESIS including numerical and experimental works.

Prof. Dr.-Ing. Huang Yuan
Department of Mechanical Engineering
Uni. of Wuppertal, Germany

ESIS-TC8 Workshop on Numerical Methods for Materials Failure

Mines Paris Tech CNRS, France
April 14-15, 2011

The workshop on numerical methods for materials failure is an annual meeting for ESIS TC8: Numerical Methods and serves as a forum for in-depth discussions among colleagues in a small circle, who are interested in computational modeling and modern numerical methods. Major aims of the workshop are to strengthen the dialogue and improve mutual comprehension among different research groups to propse new research focuses in computational mechanics and to define future activities within TC8.

One special topic of the workshop will be formulation, implementation and application of the cohesive zone model for ductile fracture as well as for low cycle fatigue modeling. However, all other relevant new numerical methods and new material models shall be dealt with in this workshop. Applicability of different methods/ models to solve practical problems shall be demonstrated by means of case histories.

Specific Topics to be dealt with primarily:

- Cohesive zone models for crack simulation
- New numerical methods for material failure modeling
- Micro-mechanical models for fracture and fatigue
- New modeling strategies for fracture and fatigue

Prospective authors are invited to submit a one-page abstract of contributions for oral presentations before **Feb. 28, 2011**.

The workshop language will be English. Authors of accepted contributions will have the opportunity for oral presentations up to 20 min. There will be ample time for detailed discussions. Selected papers will be published in an international journal after peer review.

Please send your abstract as soon as possible to:

Univ.-Prof. Dr. H. Yuan
Department of Mechanical Engineering
Bergische Universität Wuppertal
D-42119 Wuppertal, Germany
Phone: +49-202-439-2124 / 2018
Fax: +49-202-439-2027
Email: h.yuan@uni-wuppertal.de

TC 10: Environmentally Assisted Cracking

and

Subcommittee on "Hydrogen Degradation"

TC10 was strongly involved in the Workshop "Integrity of Pipelines Transporting Hydro-carbons" which was organized in the frame of NATO "Science for Peace" in Biskra, Algeria, April 26-29 2010.

For the 18th European Conference on Fracture, and its SC on "Hydrogen Degradation" organised a Symposium on "Environmentally Enhanced Effects" comprising six sessions and a total of 28 presentations. A joint technical meeting of the TC and the SC was held in conjunction with this symposium.
The SC on "Hydrogen Degradation" participated in the First Greek-Ukrainian Conference on Fracture Mechanics of Materials and Structure which was organised in Xanthi, Greece, October 20-23, 2010, with a strong focus on hydrogen degradation from the Ukrainian side.
At the ESIS Council Meeting held during ECF18 the long-time chairteam of TC10, Dr. Wolfgang Dietzel from GKSS Research Centre in Germany and Dr. Giovanna Gabetta from ENI in Italy, stepped down and handed over the chairmanship to Professor Jesús Toribio from the University of Salamanca in Spain.

Future Activities

- Co-organising of the 12th Summer School on Fracture Mechanics, in Warsaw, September 2011
- Co-organising of the Second Greek-Ukrainian Conference on Fracture Mechanics of Materials and Structure, in Lviv, October 2011.

Jesús Toribio
H.M. Nykyforchyn

A blog for discussing fracture papers

The aim of ESIS is not only to develop and extend knowledge in all aspects of structural integrity, but also to disseminate this knowledge world-wide by means of scientific publications and to educate young engineers and scientists. Promoting and intensifying this aim is what we want to achieve through a new blog for discussing some of the papers which appear in Engineering Fracture Mechanics. The link

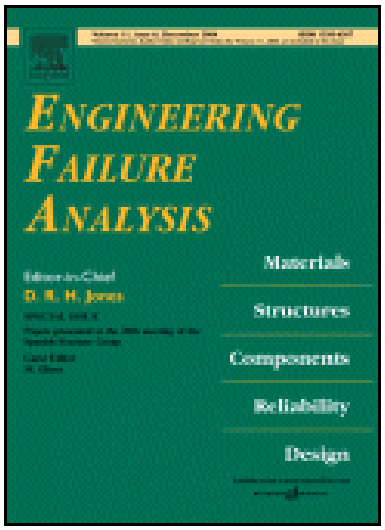
http://www.imechanica.org/node/9631

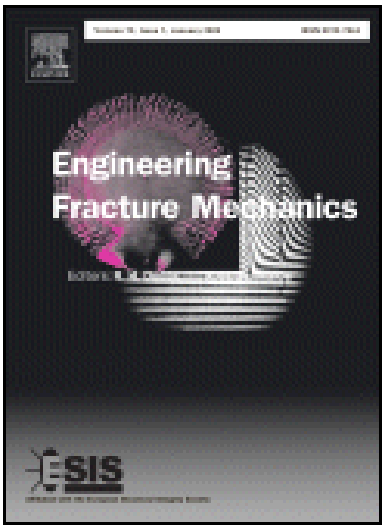
can easily be reached via the ESIS website **www.structuralintegrity.eu**.

The rules are

1. A group of leading scientists headed by Prof. W. Brocks will post onto this iMechanica node comments and remarks to some of the papers published in EFM;
2. The authors of the papers will receive a notification of the remarks by the ESIS Webmaster and will be invited to reply through a detailed document that will appear on the ESIS website;
3. The replies will also be posted onto iMechanica by ESIS (so that the authors do not have to worry about technical details). Hopefully, we will receive further comments and questions by other scientists and practitioners.

3 Elsevier journals are affiliated with ESIS





CALENDAR OF TC MEETINGS

TC 4	18th-20th May 2011 11th-15th Sept 2011 15th-16th Sept 2011	Regular Committee meeting 6th International ESIS TC4 conference Regular Committee meeting	Eurotel in Les Diableret	Dr. B. Blackman b.blackman@imperial.ac.uk
TC 8	14th-15th April 2011	Regular Committee meeting	École des Mines de Paris	Dr. Jacques Besson jacques.besson@ensmp.fr
TC 11	12th-13th May 2011	2nd Int- Workshop on Thermo-Mechanical Fatigue	BAM Berlin, Germany	Dr. Hellmuth Klingelhöffer Hellmuth.Klingelhoeffer@bam.de
TC 11	2nd-3rd November 2011	60th Committee Meeting in conjunction with QA Workshop Part 1	INCO Hereford, UK	Malcolm S Loveday malcolm.loveday@np.co.uk
TC 11	15th-16th May 2012	61th Commitee Meeting in conjunction with QA Workshop Part 2	Barnwood, Gloucester, UK	Malcolm S Loveday malcolm.loveday@np.co.uk
TC 24	3rd-4th March 2011	Workshop on "Effects of corrosion on the fatigue performance of British axles"	RSSB / ImechE London, UK	Prof. S. Beretta stefano.beretta@polimi.it

International Conference on Mechanical Behavior of Materials ICM11

5 - 9 June, 2011
Como Lake (Italy)

www.icm11.org/

6th International Conference on Fracture of Polymers, Composites and Adhesives

11-15 September 2011, Les Diablerets, Switzerland

Important dates and deadlines

5th November 2010	– submission of abstracts
14th January 2011	– author notification
25th February 2011	– author registration
3rd June 2011	– one page abstract submission
11th September 2011	– full paper submission

http://www.tc4pca.elsevier.com

11th International ASTM/ESIS Symposium on Fatigue & Fracture Mechanics
(38th ASTM Natl Sym FFM)
May - 2011 Anaheim, CA

Symposium Co-Chairs Steve Daniewicz, Charlotte Belsick, Emmanuel Gdoutos

To access the scope of the symposium click on:

http://www.astm.org/E08symp511.htm

19th European Conference on Fracture

August 26-31, 2012
Kazan, Russia

http://www.ecf19.ru/

13th International Conference on Fracture

May 26-31, 2013
Beijing, China

www.icf13.org/

14th International Conference on Fracture

ICF 14

May 7-12, 2017
Rhodes, Greece

Executive Chair:
Professor Emmanuel Gdoutos
egdoutos@civil.duth.ge

Technical Programme Co-Chair:
Prof. James Marrow,
james.marrow@manchester.ac.uk

International Steering Committee:
Professor D M R Taplin
coliemore@hotmail.com

CALENDAR OF CONFERENCES

February 14th-17th, 2011	Processing, Performance and Failure Analysis of Engineering Materials	Luxor, Egypt	http://www.icf-egypt2011.org e-mail: info@icf-egypt2011.org
March 7th-9th, 2011	1st IJFatigue & FFEMs Workshop on Characterisation of Crack Tip Stress Fields	Forni di Sopra, Italy	http://gruppofrattura.it
April 7th-9th, 2011	2nd Int. Conf. on Manufacturing Science and Engineering (**ICMSE**)	Guilin, Guangxi	http://www.icmse.net e-mail: icmse@188.com
April 27th - 30th, 2011	2nd Conf. on Inverse Problems in Mechanics of Structures and Materials (**IPM2011**)	Rzeszow/Sieniawa, Poland	http://ipm.prz.edu.pl/
May 16th -18th, 2011	4th Int. Conf. on Environmental Degradation of Engineering Materials (**EDEM**) & 5th Conf. on Materials Engineering and Technologies (**COMET**)	Gdańsk, Poland	http://www.edemet2011.pl e-mail: edemet2011@pg.gda.pl
May 26th-28th, 2011	3rd Int. Conf. on Computational Dynamics and Earthquake Engineering (**COMPDYN 2011**)	Corfu, Greece	www.compdyn2011.org
June 5th-9th, 2011	11th Int. Conf. on the Mechanical Behavior of Materials (**ICM11**)	Como, Italy	www.icm11.org
June 6th-8th, 2011	Int. Conf. on Computational Modeling of Fracture and Failure of Materials and Structures (**CFRAC 2011**)	Barcelona, Spain	http://congress.cimne.com/cfrac2011
June 7th-9th, 2011	7th Int. Conf. on Mechatronic Systems and Materials (**MSM-2011**)	Kaunas, Lithuania	www.ktu.lt/msm
June 9th-11th, 2011	Computational Analysis and Optimization	Jyväskylä, Finland	http://www.mit.jyu.fi/CAO2011
June 20th-22nd, 2011	Computational Methods for Coupled Problems in Science and Engineering	Kos Island, Greece	http://congress.cimne.upc.es/coupled2011
June 28th-July 1st, 2011	5th Int. Conf on Very High Cycle Fatigue (**VHCF-5**)	Berlin, Germany	http://www.vhcf5.de email: vhcf5@dvm-berlin.de
August 31st-September 2nd, 2011	2nd Int. Conf. on Material Modelling (**ICMM2**)	Paris, France	http://www.icmm2.eu email: icmm2@mat.ensmp.fr
September 5th-7th , 2011	13th Conf. on Fracture Mechanics (**XIII CFM**)	Opole, Poland	www.cesti.po.opole.pl/XIIICFM e-mail: d.rozumek@po.opole.pl
September 12th-14th, 2011	Design and Maintenance of Airfields (**DMAir 2011**)	Vienna, Austria	http://DMAir2011.conf.tuwien.ac.at
September 12th-14th, 2011	Trends & Challenges in Computational Mechanics (**TCCM 2011**)	Padua, Italy	http://tccm2011.unisalento.it/index.html
October 26th–28th, 2011	II Int. Conf. on Particle-based Methods. Fundamentals and Applications	Barcelona, Spain	www.eccomas.org
June 25th-27th, 2012	Int. Conf. on Damage Mechanics (**ICDM**)	Belgrade, Serbia	http://www.icdm.rs e-mail: info@icdm.rs

Newsletter #47-2011

FRACTURE, FATIGUE AND STABILITY OF NANOCRYSTALLINE MATERIALS FOR STRUCTURAL APPLICATIONS

Ashok Saxena
Dean and Distinguished Professor, College of Engineering
University of Arkansas, Fayetteville, AR 72701
asaxena@uark.edu

Introduction

The unique and desirable tensile, fatigue and fracture behavior of nanocrystalline materials (NCMs) is singularly attributed to the large number of grain boundaries relative to their coarse grain material (CGM) counterparts, which translates into a significant fraction of atoms (on the order of 50%) located in interfacial regions. Thus, the atomic structure and properties of the grain boundaries are of extreme importance in determining the macroscopic physical and mechanical properties of NCMs. However, one of the biggest challenges is to produce durable nanostructures that will not lose their properties during service.

Hardness, strength, fracture toughness, creep and fatigue experiments have been conducted to assess the properties of nanostructured Cu and their durability under temperature and stress in our laboratory. In parallel studies conducted by collaborating groups, molecular dynamics calculations were carried out to investigate how segregated dopant atoms affect the energetics of grain boundaries and their implications on grain growth in nanocrystalline metals.

Nanocrystalline materials (NCMs) are defined as polycrystalline solids with an average grain size, *d*, of less than 100 nm. It is well established in the literature that nanocrystalline materials have unique and often superior properties compared to those with coarse grained microstructures [1-3]. The unique and desirable behavior of NC materials is singularly attributed to the high density of grain boundaries (GBs), which translates into a significant fraction of atoms (up to 50%) located at or near interfacial regions [2-4]. These materials have the potential to revolutionize the performance of next generation products in biomedical, aerospace, electronics, automotive and renewable power industries, thereby considerably improving the quality of human lives. Unfortunately, previous experimental results have also reported [5-8] that metallic materials in nanocrystalline form including Fe, Cu, Al, Ag, Pd, and Pb undergo microstructural coarsening at ambient temperature. Consequently, grain growth destroys the nanocrystalline structure of the material and as the grain diameter approaches the microscale, the superior properties of the material are lost.

Mechanical Properties of Nanocrystalline Materials

Previous molecular dynamics simulation results have shown that dopant atoms which have a natural affinity for grain boundary regions (such as Sb in Cu) can stabilize the grain structure in metallic NC materials [9-12]. The thermal instability of nanocrystalline materials is inherent due to the large excess enthalpy associated with the high density of grain boundaries composed of atoms that are not fully coordinated. The introduction of dopant atoms at the grain boundaries can stabilize the grain structures by reducing the interface excess enthalpy.

NCMs used in our studies are produced via an equal-channel angular extrusion (ECAE) technique that results in nanocrystalline materials with average grain sizes of approximately 45 nm and a distribution of sizes that range between 15 to 70 nm for Cu and between 10 and 52 nm for Ni [13]. Our experimental results have definitively shown that the strength, the high cycle fatigue behavior and the fatigue crack growth properties of NC metals are enhanced several fold in comparison to their conventional grain size counterparts [16-18]. The accompanying reduction in fracture toughness and low cycle fatigue was not significant. A summary of these results for commercially pure Cu is shown in Fig.1. We found that the microstructures in nanocrystalline materials are unstable even when subjected to temperatures that are well below their conventional recrystallization temperatures and/or when they are subjected to sustained or cyclic loading. Figure 2 shows examples of creep curves for nanocrystalline copper and nickel subjected to temperatures well below their known ecrystallization temperatures (100°C and 250°C for Cu and Ni, respectively) at stress levels of 0.87 times yield strength. Previous thermal exposure experiments at these same temperatures confirmed that there was no significant grain growth without the presence of stress. Measurable creep strains were also observed in these materials at these temperatures under sustained loading. Creep curves exhibited both primary and steady-state stages similar to that observed for coarse-grained metals at temperatures higher than 35 percent of the melting point in degrees Kelvin.

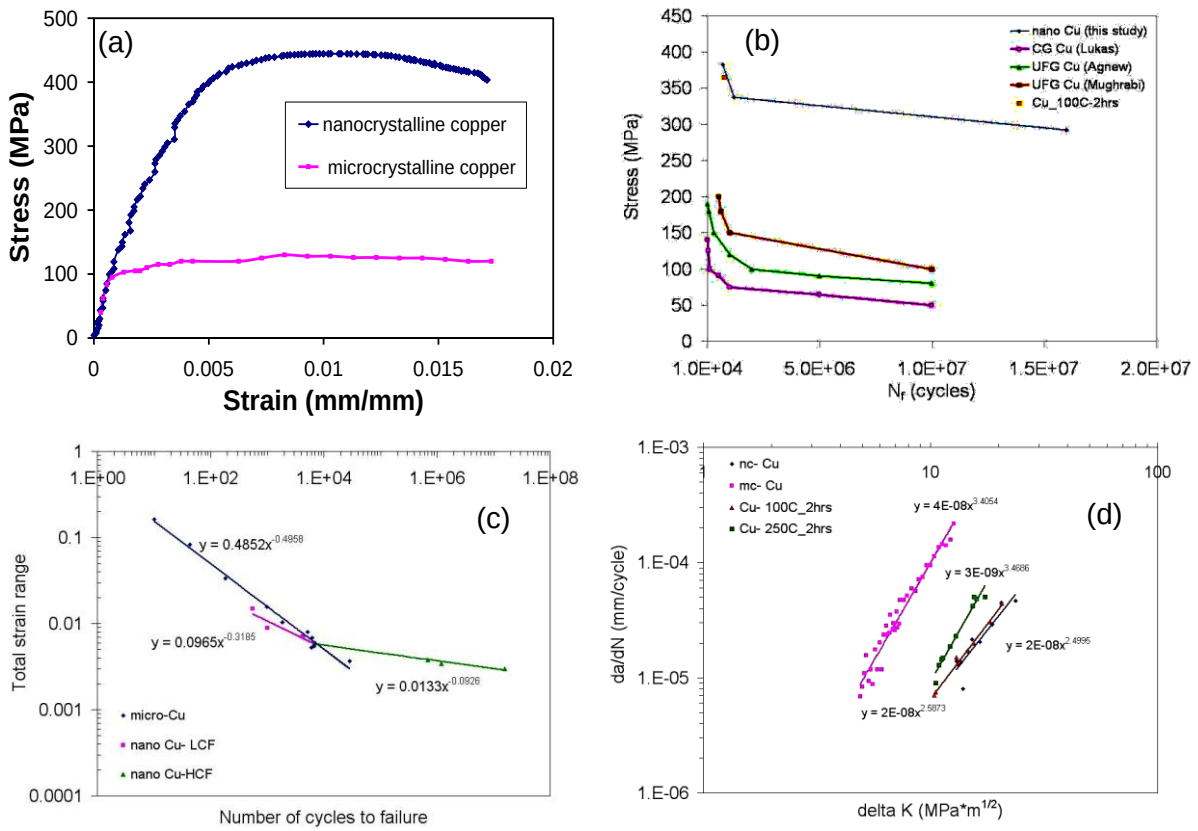


Figure 1. (a) Stress-strain diagram; (b) High cycle fatigue; (c) Low cycle fatigue; and (d) Fatigue crack growth behavior of nanocrystalline Cu. The affect of grain growth on material properties is evident in (a), (b) and (d) [16-18].

Several characteristics in the creep behavior of these materials are indicative of dominant diffusive mechanisms that seem to become operative in the presence of stress. The primary creep component of the deformation has the classical time dependence with the power of 1/3. For NC Cu and Ni, the secondary creep rate dependence on stress is governed by a power-law with exponents (Fig. 3(a)) approximately twice those of their microcrystalline counterparts and there exists a threshold stress below which the steady-state creep rate (SSCR) is very low. This threshold stress value is 200 MPa in case of copper and about 500 MPa for nickel. Since creep deformation is constrained by the surrounding grains, the high stress exponent in nano-

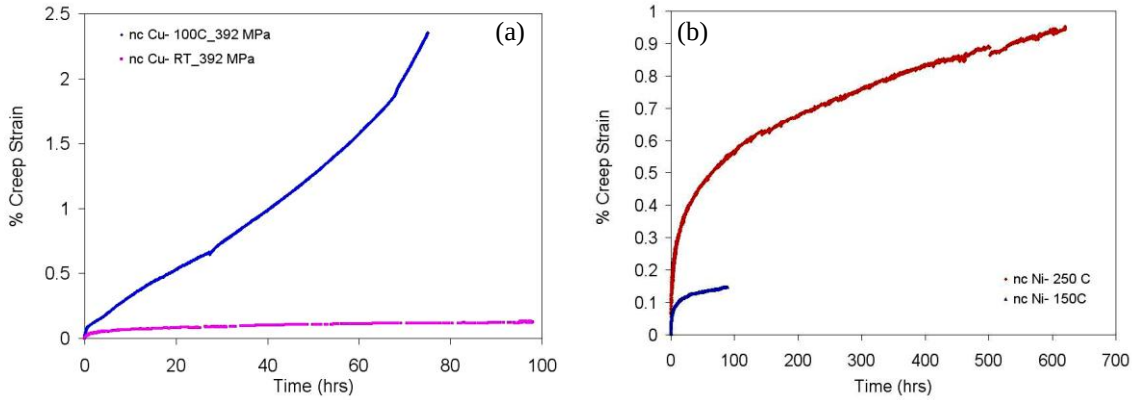


Figure 2. Creep curves for nanocrystalline (a) copper as a function of temperature at a stress level of 392 MPa and (b) nickel as a function of temperature at a stress level of about 713 MPa [13,18].

crystalline metals is understandable due to geometrical compatibility conditions. High values of n and the existence of a critical threshold stress implies the presence of additional mechanisms, for instance grain rotation and coalescence, to accommodate the necessary changes in grain shapes and sizes. It also suggests that GBs of nano-grained copper or nickel are not perfect sources and sinks for atoms (or vacancies). GB diffusion could be limited by grain rotation / coalescence and emission / absorption of atoms or vacancies. In other words, the grains first rotate to minimize mismatch with neighboring grains and coalesce, and only then does GB diffusion occur [13]. The initial rotation and coalescence of neighboring grains could be the source of primary creep which was prominent in all reported creep tests.

When the SSCR is correlated to the difference between applied stress and the threshold stress, stress in the boundary plane, which maximizes diffusion flux through the GBs and also minimizes energy dissipation during deformation. Other authors [20-22] have made similar observations of GB diffusion creep in nanocrystalline materials. Yamakov et al. [23] have demonstrated Coble-creep as the main creep mechanism in nanocrystalline Pd accompanied by geometrically necessary GB sliding to accommodate the elongation of grains. This GB sliding to accommodate Coble creep is known as Lifshitz sliding.

Effects of Dopants on the Stability of Nanocrystalline Materials

Doping nanocrystalline materials with impurity atoms should enhance creep performance along with preventing grain growth. The addition of impurities should also inhibit grain rotation/coalescence by inducing 'solute-drag' at

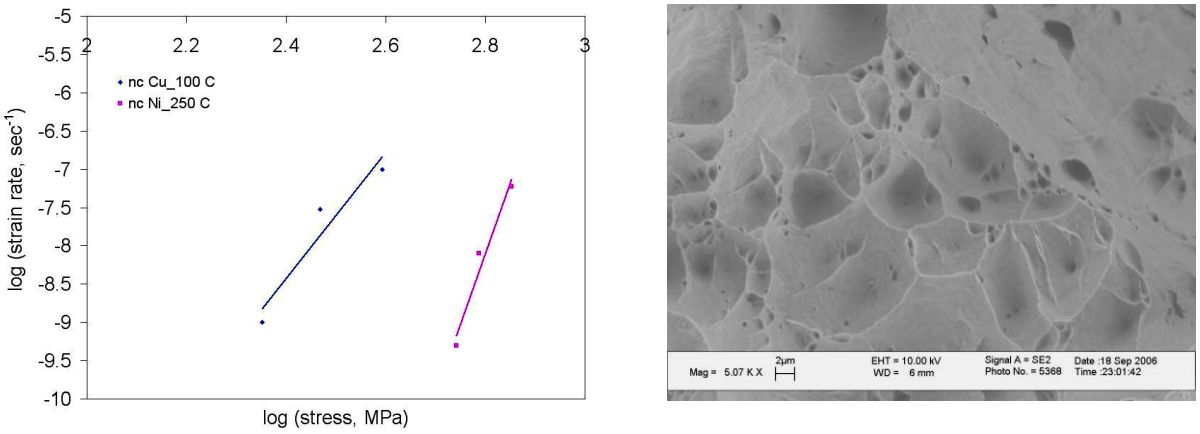


Figure 3: (a) Steady state creep rate as a function of applied stress for nano-grained pure copper and nickel. (b) Creep rupture surfaces for nanocrystalline copper at 373 ^{o}K and 392 MPa [13,18].

the exponent reduces to around 3 for both materials, indicative of diffusive processes. We determined that the activation energy for creep deformation is indeed comparable to the activation energies of self-diffusion along grain boundaries for Cu and Ni, respectively. In the presence of such grain boundary activity, one would expect grain growth to ensue during creep deformation. Figure 3(b) shows the fracture surface of a specimen that ruptured under creep conditions clearly showing dimples large enough to encompass several grains thus implying grain growth/grain coalescence.

Furthermore, the experimental evidence provided here agrees very well with molecular dynamics simulations on creep of nanocrystalline metals. Haslam et al. [19] in their simulation of creep in nanocrystalline Pd have reported alignment of GBs in a direction 45o to the loading axis. This orientation results in maximum resolved shear grain boundaries thereby reducing creep deformation at NC grain boundaries. Deng et al. [24] studied the stress dependence of SSCR at a temperature near 0.5TM, where TM is the melting point in degrees Kelvin, for a nanocrystalline (~28 nm grain size) Ni-P alloy and compared it with a coarse-grained (~257 nm grain size) alloy. They concluded that the creep rate of nano-grained samples was mainly controlled by grain (and/ or phase) boundary diffusion, while the creep rate of the coarse-grained samples was controlled by a combined mechanism that also involves dislocation creep. It has also been shown by our group via MD simulations [10] that the presence of impurities at nanocrystalline GBs improves the sliding resistance which would be effective in enhancing the creep resistance of the material.

More specifically, Millett, Selvam and Saxena [9] have utilized molecular dynamics (MD)

simulations to investigate how segregated dopant atoms affect the energetics of grain boundaries and their implications on grain growth in nanocrystalline metals. Previous results are shown in Fig. 4. These preliminary studies consisted of a monolayer of atoms (two-dimensional domain) constructed in a bicrystal configuration. Dopant atoms were created near the interface at randomly selected sites. In the preliminary studies, the Lennard-Jones (LJ) potential was chosen for the atomic energies because its parameters can be easily varied to approximate many materials. The pair-wise nature of this potential is not as accurate for metallic bonding as many-body functionals, such as the embedded atom method (EAM); however, the EAM has only been fitted for a limited number of metallic elements and its parameters cannot be varied systematically. Two parameters: σ (linear function of atomic radius) and ε (the cohesive energy of the bonded pair) define the form of the LJ pair potential. Millet et al. systematically varied the atomic radius mis-match, Δr ($\sigma_{dopant}/\sigma_{Cu}$), cohesive energy ($\varepsilon_{dop}$), and concentration ($X_{dop}$) of the dopant atoms and measured the change in grain boundary energy, γ. MD simulations indicated that εdop had little effect on γ; whereas, Δr effectively lowered γ when the dopant atom was located at the interface. As shown in Fig. 4, upon increasing the dopant concentration, the grain boundary energy could be driven to zero.

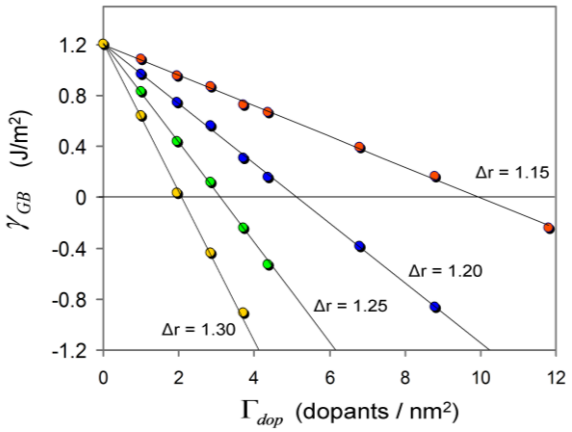


Figure 4. Grain boundary energy as a function of dopant concentration for various atomic radii mismatch ratios, Δr [9].

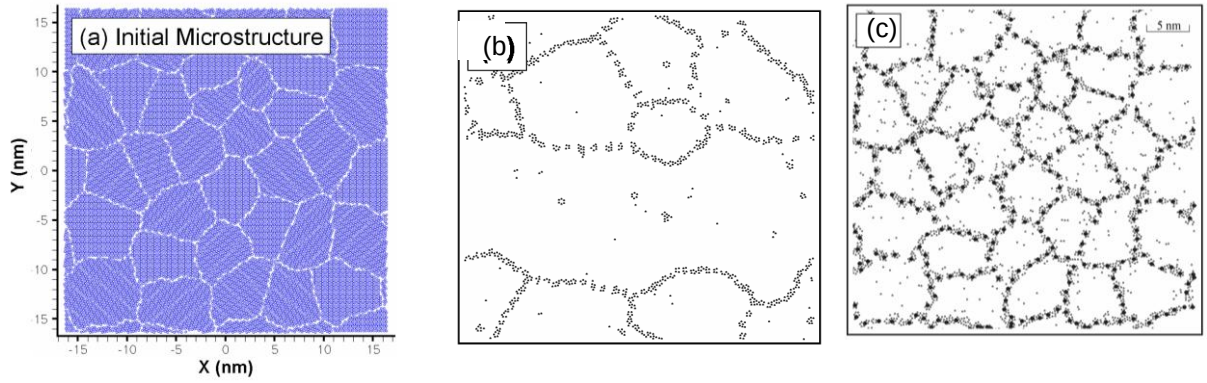


Figure 5. (a) Initial structure of the pure nanocrystalline Cu specimen; (b) MD simulation of grain structure after 300 ps at 800K; (c) MD simulation of grain structure of doped NC sample after 600 ps at 800K. Grain growth is suppressed by the addition of a critical concentration of dopants [11]. The scale in (b) and (c) is identical to that presented in (a).

This principle was extended to a NC microstructure to determine if grain growth could be suppressed [11,12]. Dopant atoms with varying Δr and X_{dop} were randomly placed in the grain boundary regions of a Voronoi-constructed nanocrytalline microstructure, shown in Fig. 5(a). These specimens were then subjected to isothermal annealing at 800K using the isothermal-isobaric NPT ensemble [25]. Extensive grain growth of the pure Cu specimen by means of grain rotation and grain boundary migration was observed; the final topology (at 300 ps) is shown in Fig. 5(b). With the addition of dopants at the grain boundaries, grain growth was suppressed to varying degrees (depending on the dopant concentration). The excess enthalpy, ΔH, of the alloy samples was measured prior to annealing, and it was found that for each Δr, a critical X_{dop} existed such that $\Delta H = 0$ corresponding to a completely thermodynamically stable state. For these samples, no grain growth occurred as shown by Fig. 5(c). These results offer support for the notion that the grain boundary energy can be reduced to zero and that dopant segregation can successfully stabilize the microstructure of nanocrystalline materials at high temperatures as also envisioned by Weissmüller [26].

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INTERFACE TAILORING AS AN ACTIVE APPROACH TO MATERIALS DESIGN

Marco Paggi

Leibniz Universität Hannover, Institut für Kontinuumsmechanik
Appelstraße 11, 30167 Hannover, Germany.
On leave from Politecnico di Torino, Torino, Italy
paggi@ikm.uni-hannover.de, marco.paggi@polito.it

Summary. Interface mechanical problems are of paramount importance in engineering and materials science. Traditionally, due to the complexity of modelling their mechanical behaviour, interfaces are often treated as defects and their features are not explored. In this paper, a different approach is illustrated, where the interfaces play an active role in the design of innovative materials and tools. Numerical examples regarding cutting tools made of hierarchical polycrystalline cells are proposed, showing that tailoring of interfaces at the different scales is the way to achieve superior mechanical responses that cannot be reached using standard polycrystalline materials.

Introduction

A significant advancement in the field of strength of materials has been achieved with the advent of composites. Combining different materials together allows us to realize structures with enhanced mechanical properties. Fiber reinforced materials are just one of these successful examples. The matrix contributes to the toughness and the density of the material, whereas fibers significantly increase the strength. Notable applications regard metal matrix composites used for aerospace applications, as well as fiber reinforced concrete for civil engineering purposes [1]. Similar strategies are accomplished with laminates and sandwich structures, where superior mechanical properties are achieved through the suitable combination of the individual material constituents [2].

In this context, the mechanical behaviour and the overall performance of composites are usually not limited by bulk properties, but by the interface characteristics. Debonding between matrix and reinforcement develops from early stage of deformation under monotonic and cyclic loading [3]. This damage affects the tensile strength, the fatigue strength, the fracture toughness, as well as the main mechanical properties.

Therefore, to understand the effect of the interface properties upon the mechanical response, several theoretical, numerical and experimental studies have been put forward in the last decades. Although research progresses are evident, especially from the computational point of view, a lot of work has still to be done to understand the mechanics of interfaces and have an impact on industrial applications. In general, interfaces are commonly considered as defects, i.e., weak points of the material microstructure that limit the achievement of the maximum theoretical strength. This way of thinking, in conjunction with the difficulty of defining appropriate physical and mathematical models for interfaces, leads to a passive design approach. The attention is therefore focused on preserving the structural integrity by remaining in the elastic regime, covering all the modelling uncertainties with severe safety coefficients.

A different approach, leading to an active design, could however be pursued. Once suitable models are developed for characterizing the mechanics of interfaces, then structural analysis should pay attention to the failure modes, optimizing the material microstructure through a suitable tailoring of the interface properties.

This way of thinking is clearly inspired by biological structures, where interfaces play an active role in the realization of an optimized structured by using individual constituents of relatively poor mechanical properties [4]. For instance, bone tissue undergoes microcracking as a result of repeated daily loading cycles. Fracture toughness capabilities are related to the osteonal structure. A ductile osteon-matrix interface promotes crack initiation, but, at the same time, it reduces the velocity of crack propagation in compact bone by blunting the crack tip and trapping it within the lamellar structure [4]. Therefore, design of biological

structures suggests not to avoid microcracks and defects, but rather include them as an important parameter for the optimization of the material microstructure. Recent research on this field has focused on the characterization of biological interfaces, which is considered nowadays as a topic of extreme importance. The investigation of the constituent materials organization and distribution is also a compelling need. Preliminary results show that the realization of hierarchical microstructures is the way how biological materials achieve superior material properties. Robust and reliable adhesion systems of geckos are obtained through a hierarchical assembly of fibrils [5]. Similarly, toughness and defect tolerance of biological hard tissues are the result of hierarchical microstructures ranging over several length scales, from nano to macro [6].

The outcome of this research may contribute to a future development of new nanocomposite materials, mimicking the structures of biological materials. A pioneering effort in this direction is given by cellular polycrystalline materials recently designed by Fang et al. [7]. Extruded single fibers were packed together and put through a further extrusion process. The result is a honeycomb microstructure as sketched in Fig. 1, in which the cores are of polycrystalline diamond (PCD) and the cell walls are of WC/Co. Toughness and hardness of these new materials are considerably higher than those of standard homogeneous PCD, as also analytically predicted in [8]. This seems to be primarily attributed to the cell boundary material, which deters crack propagation and absorbs fracture energies, while the high hardness of the cell material provides wear resistance.

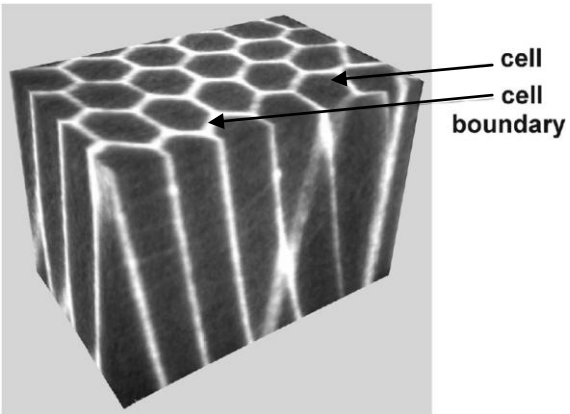

Fig. 1: scheme of a functionally designed cellular microstructure (adapted from [9]).

In this context, to understand the role of the process variables on the mechanical response, it is urgent to move from real experiments to virtual (numerical) simulations. In this paper, an example of active design is proposed, where it is shown that the interfaces in hierarchical cellular materials are determinant for the realization of desired material responses.

Fracture mechanics of hierarchical cellular materials

Let us consider a bimaterial component where an external layer composed of polycrystalline cells is bonded to a substrate (see Fig. 1). This is for instance the case of the bit of a cutting tool, where the external layer is usually made of polycrystalline diamond (PCD) and the substrate is hardmetal. This composite structure is then joined to a steel support (for more details, please refer to [10,11]). When subjected to repeated loadings, as during cutting operations, different failure modes (micro-, meso- and macro-chipping) may occur, depending on the initiation point of a crack on the vertical side in tension. Different failure mechanisms (brittle crack propagation, fatigue crack growth) may also occur. In general, chipping leads to a premature failure of the bit ad therefore to a reduced lifetime of the tool. In case of a standard PCD layer, where the size of the polycrystals is much smaller than the size of the layer, the material can be considered as homogeneous from the modelling point of view.

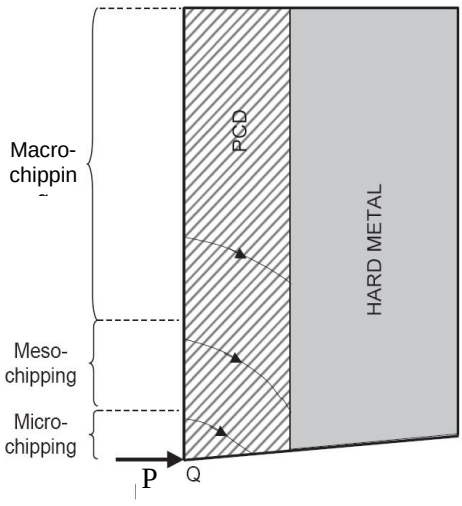

Fig. 2: sketch of a PCD bit used in cutting tools [10]. The critical impact load is denoted by P_c and different possible failure modes ranging from micro- to macro-chipping are sketched.

As a consequence, crack propagation takes place under prevailing Mode I conditions and

the crack path is curvilinear, as shown in Fig. 2. If heterogeneous cellular PCDs are used instead of a homogeneous layer, then a different crack path can be obtained. More specifically, considering the mechanical stress field due to a horizontal force acting at the tool tip, a magnification of the crack path for macro-chipping is shown in Fig. 3.

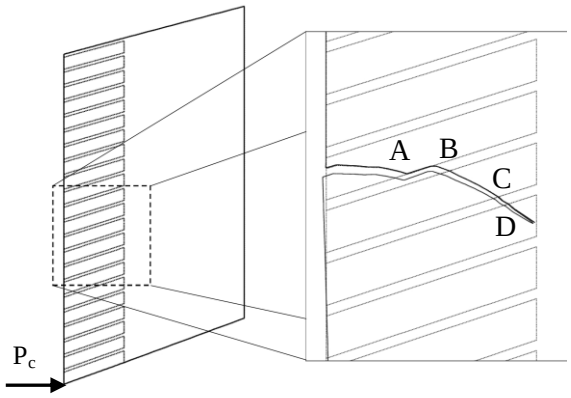

Fig. 3: fracture of a cutter with a cellular microstructure: scheme of the compact bit (left) and magnification of the crack path in the region inside the rectangular dashed box (right).

This result is obtained by performing a finite element analysis of the bimaterial structure using linear elastic fracture mechanics. The simulations are carried out exploiting the interface fracture mechanics features of FRANC2D [12]. More specifically, the fracture parameters of the bimaterial interfaces are assumed equal to the average value of those of the neighboring materials. The rod diameter is equal to 200 μm and the thickness of the binder between the cells is 50 μm (see [9] for more details about the geometry of the material microstructure).
The critical load for crack propagation, P_c, which corresponds to the condition of $K_I = K_{IC}$ at the crack tip, is shown in Fig. 4 vs. the crack length a. The load P^* represents the average load typically experienced during experimental tests and amax is the final crack length, when the crack meets the hardmetal substrate. At the beginning of the simulation, the crack propagates into a PCD road, and therefore there is no difference with respect to a standard homogeneous material, at least in 2D simulations. Interestingly, when the crack tip meets the bi-material interface, delamination of the rod cell takes place (path A-B). Since the interface fracture energy is higher than that of the PCD, the external applied load required for crack propagation has to be significantly increased with respect to the homogeneous case. Subsequently, crack deviates again into the rod (path B-C). A second peak is finally observed when the crack propagates through the binder between the cells (path C-D).

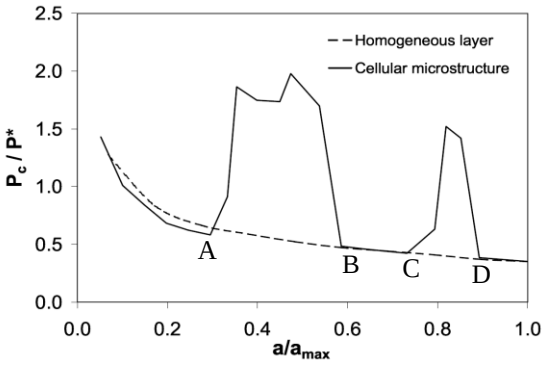

Fig. 4: dimensionless critical load for brittle crack propagation vs. dimensionless crack length. The response of a cellular micro-structure is compared with that of a homogeneous PCD layer.

These results are important for two reasons. First, a crack would arrest its propagation at the first interface if the dimensionless applied load is lower than 2.0. This situation is substantially different from the case of a homogeneous layer, where the critical dimensionless load is a monotonic decreasing function of the crack length. Therefore, when the applied dimensionless load exceeds 1.5, then the crack cannot be arrested. Therefore, the use of a cellular microstructure acts as a crack-arrester, controlling the evolution of chipping failure modes.
On the other hand, interfaces tougher than the rods is not always a desirable situation. In case of micro-chipping, weak interfaces may promote crack propagation along the rod boundaries. This would be suitable to activate a self-resharpening process of the tool tip, which progressively loses its cutting efficiency due to wear. Therefore, the optimal material microstructure would correspond to cellular rods embedded into a tougher matrix, with interface properties depending on the vertical coordinate on the cutting edge.
In case of subcritical crack propagation, which may occur in case of repeated forces of magnitude lower than P_c, the Paris' law can be applied to determine the crack growth rate. Then, this quantity can be further integrated in order to compute the corresponding loading cycles N [13]. For the present case, using the Paris' law parameters reported in [10], the

fatigue life of a cellular microstructure is predicted to be approximately four times longer than that of a homogeneous material (see Fig. 5).

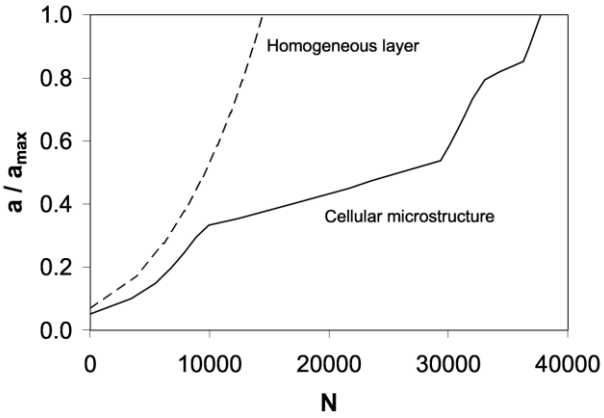

Fig. 5: dimensionless crack length vs. loading cycles. The response of a cellular microstructure is compared with that of a homogeneous PCD layer.

It is also possible to quantify the effect of structural hierarchy by simulating the mechanical behaviour of a cellular micro-structure using the finite element method and nonlinear fracture mechanics. To this purpose, let us consider the material microstructure depicted in Fig. 6.

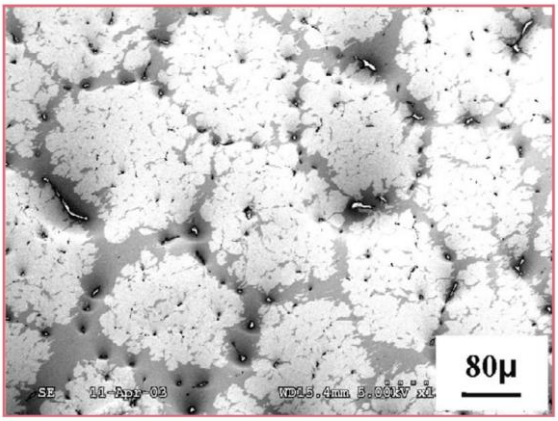

Fig. 6: cross-section of cellular rods with bright cells and dark grey cell boundaries (adapted from [9]).

Each exagonal rod (mesostructure) is composed of a standard polycrystalline material (microstructure). At the microscopic scale (level I), polycrystalline grains are separated by interfaces. Such polycrystals compose the material mesostructure (level II), which is represented by the hexagonal rods. Such rods are also separated from each others by interfaces, much thicker and with different composition with respect to the interfaces of level I. As proposed in [14,15] interface fracture can be modelled by simplifying the real material microstructure and considering zero-thickness interface elements between the grains. Then, a suitable cohesive zone model (CZM) which takes into account the properties of finite thickness interfaces has to be used. In the present study, we consider the nonlocal CZM recently proposed by Paggi and Wriggers [14,15].

A sketch of the interfaces of a standard polycrystalline material is shown in Fig. 7. Ideal exagonal shapes are considered for the polycrystals. The constitutive model of each interface is described by a Mixed Mode stress-separation relation, given by the nonlocal CZM [14,15].

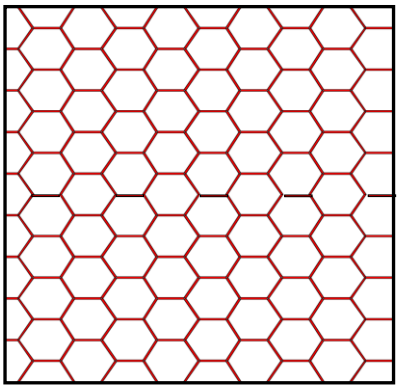

Fig. 7: 2D model of a polycrystal (CZM interface elements are shown in red with a suitably amplified thickness, for visual representation).

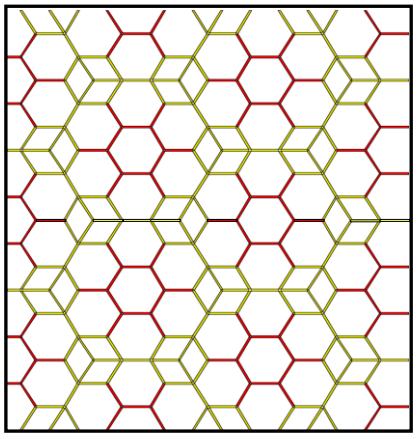

Fig. 8: 2D model of a hierarchical polycrystal (CZM interface elements are shown in yellow and red, at the different scales).

To model the present materials processing, we remark that each rod is realized first through sintering of polycrystalline materials as those shown in Fig. 7. Then, the individual roads are joined together using high pressure and

temperature conditions, such that the interfaces of level II develop. This configuration is sketched in Fig. 8, where yellow interfaces define the boundaries of the rod cells. A direct comparison between Figs. 7 and 8 clearly shows that the two microstructures are not physically similar, if different constitutive laws are used for the interfaces at the two levels.

As an example, let us consider interfaces at the second level tougher than those of the first level. In particular, we select $G_{IC}^{II}/G_{IC}^{I}=5$. Keeping constant the CZM parameters of the interfaces of level I, different CZM shapes are considered for the interfaces of level II, as shown in Fig. 9 in case of pure Mode I deformation. Here, $\sigma_{\max}^{I}$ denotes the peak cohesive stress of the interfaces of level I, and g_{Nc}^{I} is the critical relative opening displacement corresponding to vanishing cohesive stresses for the interfaces of level I. Considering virtual tensile tests, imposing a monotonic horizontal displacement to the nodes on the vertical right side of the material microstructure, the homogenized response of the representative volume element of the hierarchical material is determined.

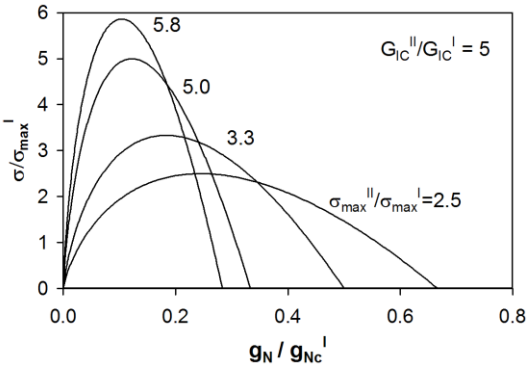

Fig. 9: shapes of the CZMs of the interfaces at the level II (mesostructure).

The peak stresses for the various simulations are plotted in Fig. 10 vs. $\sigma_{\max}^{II}/\sigma_{\max}^{I}$. These peak stresses are made dimensionless using the Mode I fracture energy of level I and the grain size diameter of the polycrystals composing the rods, d^{I}. In this diagram, the response of a standard polycrystalline material without structural hierarchy, as that shown in Fig. 7, is represented by the grey dot in correspondence of $\sigma_{\max}^{II}/\sigma_{\max}^{I}=1$. The results clearly show that the tensile strength of the material can be significantly increased by using a hierarchical microstructure. The interfaces of the level II act as crack-arresters for the microcracks into level I. The main effect of material hierarchy is therefore to increase the ability of a heterogeneous material to tolerate defects.

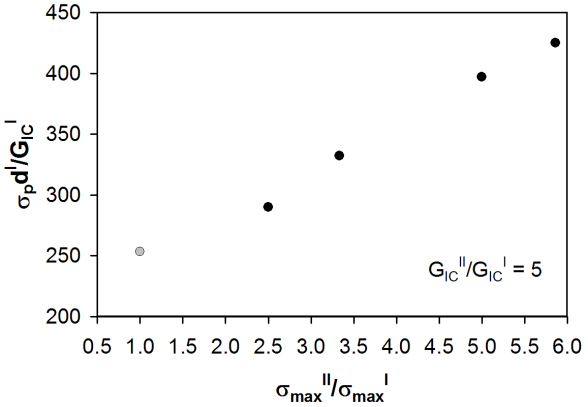

Fig. 10: dimensionless tensile strength vs. CZM peak stress ratio between levels II and I.

Conclusions

In this paper it has been shown that functionally designed microstructures can offer enhanced mechanical properties as compared to traditional heterogeneous materials. Tailoring the interfaces properties allows us to enforce crack propagation along desired paths. In this way, self-resharpening effects can be achieved. Structural hierarchy is also particularly important. In this study it has been demonstrated that the interaction of interfaces with different properties at the different hierarchical levels may explain the experimental results in [7].

Further work has to be done in this direction, especially for the 3D simulation of crack propagation in polycrystalline materials. Finite element analyses should also consider coupled thermo-elastic problems, an issue particularly important in cutting technology due to the high temperature conditions. The present study has been limited to a two-level hierarchical composite material. More hierarchical level should be investigated in the future research. However, due to very different length scales involved in the problem, ranging from the size of the sample to the size of the smallest heterogeneity, modelling the mechanical behaviour is a challenging task and multiscale computational methods should be invoked [16]. One possibility is to define representative volume elements (RVE) that provide a homogenized constitutive relationship to be used at the upper level. However, although such an approach is very appealing and has been pursued by several authors [17], some aspects require special attention. For instance, the definition of a RVE is not obvious, especially in case of localized phenomena, like

crack nucleation and propagation. Moreover, the condition of scales separation has to be checked with care, otherwise the risk is to exclude coupling effects between length scales that may influence the mechanical response of the material.

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