**DRUŠTVO ZA INTEGRITET I VEK KONSTRUKCIJA**
**SOCIETY FOR STRUCTURAL INTEGRITY AND LIFE**

Eigth International Fracture Mechanics Summer School - IFMASS 8

**FROM FRACTURE MECHANICS TO STRUCTURAL INTEGRITY ASSESSMENT**

**REPORT**

## Introduction

First International Fracture Mechanics Summer School (IFMASS 1) "Introduction to fracture mechanics and fracture-safe design" had been organized in 1980 by Faculty of Technology and Metallurgy, Belgrade and GOŠA Institute, Smederevsska Palanka on the initiative of Prof. Michael Wnuk (University of Wisconsin, Milwaukee), and Prof. Stojan Sedmak (Faculty of Technology and Metallurgy, Belgrade). It happened that Prof. Wnuk was the guest of Prof. S. Sedmak at the Faculty of Technology and Metallurgy for his sabbatical in 1980, and by the end of the visit he proposed to organize IFMASS 1. The School attracted 63 participants, and 20 lectures, followed by one invited discussion had been presented. IFMASS 1 staff included 6 lecturers from abroad:

Prof. M. Wnuk (2 lectures), Dr. M. Ratwani - Northrop Co, U.S.A (5 lectures), Prof. A. Mazur – Academy of Minning and Metallurgy, Krakow (2 lectures), Doc. J. Orkish – Technical University, Krakow, Doc. A. Javorski, Technical Faculty, Warszaw, Dr. A. Neimitz, Technical University, Kielce, and

7 lecturers from Yugoslavia:

Prof. A. Radović, Military Technical Institute, Belgrade (2 lectures), Prof. Lj. Nedeljković, Faculty of Technology and Metallurgy, Belgrade, Dr. M. Berković, Aircracft Technical Institute, Belgrade, Prof. J. Pirš, Technical Faculty, Rijeka, Prof. S. Sedmak, Faculty of Technology and Metallurgy, Belgrade, Doc. J. Jarić, Faculty of Scences, Belgrade, prof. M. Radojković, Civil Engineering Faculty, Belgrade,

and invited discussion had been given by Đ. Dobi, Steelworks Ravne.

The industry strongly supported the organization of IFMASS 1 and the basic budget had been obtained by GOŠA Holding Co and its Institute. This was the time of penstock construction of Bajina Bašta pumping-up hydroelectrical power plant. The most stressed part of the penstock has been constructed of SUMITEN 80P steel (SM 80P weldable steel of 700 MPa nominal yield stress). The experience with welding of this class of steel was not sufficient, and the fracture resistance of SM 80P steel and its weldments was not properly defined. This situation explains the interest of industry for fracture mechanics, that is confirmed by number of participants to IFMASS 1. The monograph, entitled as IFMASS 1, has been published in Serbian. Thanks to

the support of this kind, fracture mechanics has been introduced in local industry broadly, as this can be concluded from the presentation given in a monograph about fracture mechanics development in the word, edited by G. Sih in 1981.

The demand from industry supported the organization of IFMASS 2 "Modern aspects of design and construction of pressure vessels and penstocks", 1982, IFMASS 3 "Fracture mechanics of weldments", 1984, IFMASS 4 "Prospective of fracture mechanics development and application", 1986, with continuously increased number of participants and extended number of lecturers, both from abroad and from Yugoslavia. The round table discussions and significant number of participants, presented by invited young experts from Yugoslavia, contributed to the extended introduction of fracture mechanics to its practical application for structural integrity assessment. Monographs, published in Serbian after each IFMASS, also contributed to extended application of fracture mechanics. The next School, IFMASS 5, "The application of fracture mechanics to residual life assessment of thermoelectrically power plant components" had been organized in 1989. This was the biggest IFMASS, with 142 participants, the monograph has been published in English, and only shortened version in Serbian.

So, five IFMASS"s had been organized in eighties of the past century. It is to mention that in time period 1982-1992, joint Yugoslav – U.S. research project "Fracture mechanics of weldments" had been realized, with contribution of National Institute of Standards and Technology (NIST) from U.S.A. and six research&development institutions from Yugoslavia.

Unhappy events, started by secession of Slovenia from Yugoslavia in the days of IFMASS 6 ("Service cracks in pressure vessels and storage tanks" organized in June 1991), reduced the activities in fracture mechanics, and consequently the IFMASS. The IFMASS 6 monograph had been published three years later, in 1994. Next three years passed before it was possible to organize next, IFMASS 7 "Experimental and numerical methods of fracture mechanics" in 1997. Again, the activities had been stopped due to NATO aggression on our country in 1998, and the monograph has been published in the year 2000.

The appearance of the IFMASS 7 monograph revealed the possibility to continue the activity in fracture mechanics, accounting for critical situation with the equipment in local industry, especially destroyed and damaged by NATO bombardment, and necessity to assess structural integrity of equipment. The experts from Serbia & Montenegro, previously engaged in IFMASS, decided to organized the Society for structural integrity and life (DIVK) in 2001. New established DIVK journal "Structural integrity and life" also attracted many experts to contribute in this area. After consolidation of DIVK, the renew of IFMASS had been required by the members. On the other hand, new situation in South-Eastern Europe offered the possibility the experts from regional countries to take part in IFMASS. After consideration, the experts from our country, Bulgaria and Greece, decided to organize jointly next IFMASS.

The IFMASS 8 had been supported by Ministry for Science, Technologies and Development and Ministry for Urban Planning and Construction of Gouverment of Serbia, GOŠA FOM, Institute for Material Testing, Company NBGH –ŽIKS HARD and Company Zwick – Roell.

Prof. Dr. Dragan Domazet, Minister of Science, Technolgies and Development, opened IFMASS 8.

## Procedure of IFMASS 8 preparing

After decision about the title, content and term of IFMASS 8 by the Scientific Advisory Board, provisional program had been defined and presented in call for participation.

**Society for Structural Integrity and Life (DIVK)**
**GOŠA Insitute**
**Faculty of Technology and Metallurgy**
in cooperation with
**Ministry of Science, Technologies and Development of Serbia**
**City Assembly of Belgrade**
**Military Technical Institute**
under the auspice of
**European Structural Integrity Society - ESIS**
organize
**Eigth International Fracture Mechanics Summer School IFMASS 8**

FROM FRACTURE MECHANICS TO STRUCTURAL INTEGRITY ASSESSMENT

Belgrade, 23rd to 27th June 2003
City Hall
Belgrade, Trg Nikole Pašića 2

Previous seven International Fracture Mechanics Summer Schools (IFMASS) had been organized from 1980, the last one took place in 1997. After that, there was no possibility to organize IFMASS, due to well known situation in former Yugoslavia. Meanwhile, in 2001 the Society for Structural Integrity and Life (DIVK) has been established in Belgrade. The DIVK members had been the organizers and participants in previous IFMASS. The success of previously organized IFMASS and its importance motivated DIVK to continue with IFMASS 8 in 2003. On the meetings, held during 14th European Conference on Fracture (ECF 14) in September 2002 in Cracow, with the participation of Prof. L. Toth (Hungary), the chairman of ESIS Comission TC13: Education and Training , Prof. E. Gdoutos (Greece), Prof. D. Angelova (Bulgaria) and Prof. S. Sedmak (Srbija) it has been decided to organize IFMASS 8 for South-Eastern European countries.

The title ²From Fracture Mechanics to Structural Integrity Assessment² enables to review the development and practical application of fracture mechanics. The participants can be acquainted with structural integrity problems in different stages (design and material selection, man-u-facturing and quality assurance, service, maintenance, repair) through the lectures, selected for the program.

Joint organization of IFMASS of South-Eastern Europe countries, under the auspece of European Structural Integrity Society (ESIS) could be considered as the first step in founding the regional Forum for Structural Integrity of South–Eastern European Countries. Recently, at the regional meeting, held in Belgrade, the cooperation in this region is strongly recommended by the gouverments and encouraged by European Union. The organizers of the Forum can account in future with the help of gouvermental institutions and of European Union.

**Scientific Advisory Board**

Prof. Dr. Stojan Sedmak Prof. Dr. Dorin Dehelean Prof. Dr. Laszlo Toth
Prof. Dr. Michael Wnuk Prof. Dr. Dragoslav Šumarac Prof. Dr. Stefan Vodeničarov
Prof. Dr. Donka Angelova Prof. Dr. Emmanuel Gdoutos Prof. Dr. Jovo Jarić

**Organizing Committee**

Mr Ljubica Milović, secretary Prof. Dr. Milosav Ognjanović Dr. Zijah Burzić
Prof. Dr. Stojan Sedmak Dr. Vencislav Grabulov Mr. Zoran Radaković
Prof. Dr. Aleksandar Sedmak Mr. Dejan Momčilović Prof. Dr Nenad Radović
Prof. Dr. Katarina Gerić Mr. Milorad Zrilić Dr. Miodrag Arsić
Prof.Dr.Dragoslav Kuzmanović Dr. Marko Rakin Aleksandar Bređan
Jano

**Registration fee:**
· 150 EUR
· 100 EUR for ESIS members, 50 EUR for students
**Accomodation**
The accomodation is awailable in the hotels in the vicinity of City Hall at prices 25 to 60 Euro.
For further information please visit our web site: **divk.org.yu** or contact:
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**Prof. Dr. Stojan Sedmak**

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**Program of IFMASS 8**

1. J. Jarić, A. Sedmak: "Physical and mathematical aspects of fracture mechanics"
2. E. Gdoutos: " Fracture mechanics under mixed -mode loading"
3. M. Wnuk: "Enhancement of fracture toughness due to energy screening effect in the early stages of non-elastic failure"
4. D. Krajčinović, D. Šumarac: "Basic principles of damage mechanics"
5. A. Radović, N. Radović: " A contribution of fracture mechanics to material design"
6. R. Nikolić, J. Veljković: 'Interfacial cracks '
7. D. Angelova: "Basic fatigue conceptions and new approaches to fatigue failure"
8. V. Grabulov: "Static and impact tests (tensile, drop weight, explosion bulge) and result analysis"
9. G. Lenkey: "Charpy impact testing and its application in fracture mechanics"
10. J.Landes: "Development of experimental testing of crack behavior"
11. S. Sedmak, Z. Burzić: "Fracture mechanics standard testing"
12. K. Gerić, I. Blačić: "Fractographic analysis"
13. V. Šijački-Žeravčić: "In-service failure of structures: examples"
14. P. Agatonović: "Fracture case studies – basic principles"
15. V.T.Troščenko: "Fracture toughness of metal under cyclic loading"
16. L. Toth: "The role of fracture mechanics parameters in reliability assessment of engineering structures operating under different loading conditions"
17. G. Pluvinage: "Fracture transferability problems and mesofracture"
18. S. Vodeničarov: "Fracture testing in nuclear power stations"
19. D. Dražić, B. Jegdić: "Corrosion and stress corrosion"
20. T. Maneski: "Stress analysis for structural integrity assessment"
21. Gui-Rong Liu: "Meshfree methods (in numerical analysis)"
22. N. Gubeljak: "SINTAP-Structural INTegrity Assessment Procedure"
23. M. Kojić, M. Živković: "Numerical programs for life assessment of thermoelectrical power plants"
24. Karl-Heinz Schwalbe:"Structural assessment under elastic-plastic conditions with particular reference to mechanically heterogeneous structures"
25. M. Ognjanović: "Reliability and safe service of structures"
26. V. Gliha: "Prediction of fracture and fatigue properties of welds by simulated HAZ"

## Lecturers, lectures, and timetable of IFMASS 8

Realized program is slightly different from announced one. Due to unexpected problems, Prof. M. Wnuk and Prof. E. Gdoutos cancelled, so their lectures (2 and 3 from the announced list) had been omitted. Having in mind the general IFMASS 8 title, a new lecture is included (Nr 25).

## Performed program and timetable of IFMASS 8 and Workshop

| Lecture | Lecturer | Affilation |
|---|---|---|
| **A. Theoretical background** | | |
| 1 | Physical and mathematical aspects of fracture mechanics | Prof. Jovo Jarić<br>Prof. Aleksandar Sedmak<br>Faculty of Sciences, Belgrade, S&MN<br>Mechanical Engineering Faculty, Belgrade |
| 2 | Basic principles of damage mechanics | Prof. Dušan Krajćinović,<br>Prof. Dragoslav Šumarac<br>Arizona State University,Tempe, Az, USA<br>Faculty of Civil Engineering, Belgrade, S&MN |
| 3 | A contribution of fracture mechanics to material design | Prof. Aleksandar Radović<br>Prof. Nenad Radović<br>Faculty of Technology and Metallurgy,<br>Belgrade, S&MN |

4
Interfacial cracks
Prof. Ružica Nikolić
dr Jelena Veljković
Mechanical Engineering Faculty, Kragujevac,
S&MN

5
Basic fatigue conceptions and new approaches to fatigue failure
Prof. Donka Angelova
University of Chemical Technology and
Metallurgy, Sofia, Bulgaria

**B. Experiments and testing**

6
Static and impact testing (tensile test, drop weight test, explosion bulge test) and result analysis
Dr. Vencislav Grabulov
Military Techical Institute, Belgrade, S&MN

7
Charpy impact testing and its application in fracture mechanics
Docent Gyöngyvér Lenkey
University of Miskolc, Miskolc, Hungary

8
Development of experimental testing of crack behaviour
Prof. John Landes
The University of Tennessee,Knoxville,Tn, USA

9
Fracture mechanics standard testing
Prof. Stojan Sedmak
Dr. Zijah Burzić
Faculty of Technology and Metallurgy, Belgrade
Military Techical Institute, Belgrade, S&MN

10
Fractographic analysis
Docent Katarina Gerić
Faculty of Technical Sciences, Novi Sad, S&MN

## C. Service problems

11
In-service failure of structures: examples
Prof. Vera Šijački-Žeravčić
Mechanical Engineering Faculty, Belgrade

12
Fracture case studies – basic principles
Dr. Petar Agatonović
Consulting and Analysis (CA), Germany

13
Fracture toughness of metal under cyclic loading
Acad. Prof. Valerij T. Troshchenko
Institute for Problems of Strength, Academy of Scences of Ukraine, Kiev, Ukraine

14
The role of fracture mechanics parameters in reliability assessment of engineering structures operati
Prof. Laszlo Toth
Bay Zoltan Foundation, Miskolc, Hungary

15
Fracture transferability problems and mesofracture
Prof. Guy Pluvinage
University of Metz, Metz, France

16
Fracture testing in nuclear power stations
Dr. Stefan Vodeničarov
Institute of Metal Science, Bulgarian Academy of Sciences, Sofia, Bulgaria

17
Corrosion and stress corrosion
Acad. Dragutin Dražić
Mr. Bore Jegdić
Serbian Academy of Sceience and Art, Belgrade
Military Techical Institute, Belgrade

## D. The assessment and extension of residual life

18
Stress analysis for structural integrity assessment
Prof. Taško Maneski
Mechanical Engineering Faculty, Belgrade

19
Meshfree methods (in numerical analysis)
Prof. Gui-Rong Liu
University of Singapore, Singapore

20
SINTAP (Structural INTegrity Assessment Procedure)
Docent Nenad Gubeljak
Mechanical Engineering Faculty, Maribor,
Slovenia

21
Numerical programs for life assessment of thermoelectrical power plants
Prof. Miloš Kojić
Prof. Miroslav Živković
Mechanical Engineering Faculty, Kragujevac,
S&MN

22
Structural assessment under elastic-plastic conditions with particular reference to mechanically heter
Prof. Karl-Heinz Schwalbe
GKSS Forschungscentrum, Geesthacht,
Germany

23
Reliability and safe service of structures
Prof. Milosav Ognjanović
Mechanical Engineering Faculty, Belgrade

24
Prediction of fracture and fatigue properties of welds by simulated HAZ
Docent Vladimir Gliha
Mechanical Engineering Faculty, Maribor,
Slovenia

25
The application of fracture mechanics to structral integrity assessment
Prof. Aleksandar Sedmak
Mechanical Engineering Faculty, Belgrade

Monday

Tuesday

Wendesday

Thursday

Friday

9.00
Opening
9.00
Lecture 22
7.45
MTI visit
8.30
Lecture 16
8.30
Lecture 21

9.30
Coffee
9.50
Lecture 13
8.30
Greeting word
9.20
Lecture 5
9.20
Lecture 15

9.45
Lecture 1
10.40
Coffee
8.45
Lecture 6
10.05
Coffee
10.10
Lecture 20

10.35
Lecture 8

11.00
Lecture 4
9.20
Lecture 9
10.20
Lecture 11
11.00
Lecture 23

11.30
Lecture 14
11.50
Lecture 12
9.50
Coffee break
11.10
Lecture 19
11.50
Lecture 25

10.15
Laboratories
12.00
Lecture 17
15.00
Workshop A
16.00
Coffee
16.00
Coffee

16.00
Coffee
17.00
Coffee

16.15
Lecture 7
16.15
Lecture 2

16.15
Lecture 24
17.15
Workshop B
17.05
Lecture 3
17.05
Lecture 18
20.00
Joint dinner
17.05
Lecture 10
20.00
Workshop dinner

**List of IFMASS 8 participants**

| | Name | Country and affiliation |
|---|---|---|
| 1 | Abdunasser Hamza Fadel | Libya |
| 2 | Adžiev Gorgi | Macedonia – Mechanical Engineering Faculty, Skopje |
| 3 | Aleksić Boško | Serbia & Montenegro (S&MN) - HIP Azotara, Pančevo |

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Libya

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Anđelković Zoran
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Anyiam Hyacinth
U.S.A.

9
Argob Omar Muhamed
Libya

10
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Bakić Gordana
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Doll Verner
Germany - ROELL AMSLER

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S&MN - Oil Refinery, Belgrade

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Germany - ZWICK/ROELL

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The Netherlands - Technobar

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Romania

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Potkonjak Željko
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## Workshop New Trends in Fracture Mechanics Application

The workshop had been organized as a satelite event after IFMASS 8, by Society for Structural Integrity and Life (DIVK), Belgrade Chamber of Economy, GOŠA Institute and Faculty of Technology and Metallurgy.

European Union (EU) and its institutions in many cases support the organization of workshops, devoted to specific topics. Taking into account further cooperation in South-East Europe, supported by EU, and proposed establishment of Forum for Structural Integrity in this region, workshops can be convenient form for the cooperation. The Forum will organize the activity toward and on the benefit of the industry, as it is the case with Society for Structural Integrity and Life (DIVK) in Serbia and Montenegro. IFMASS 8 was the place for meeting of experts in structural integrity and fracture mechanics, not only from South-East Europe, offering the possibility to start with organization of workshops. Up to thirty experts in fracture mechanics and structural integrity assessment from all countries of the region are invited to take part in the Workshop.

The interess of practical application of fracture mechanics is extended in last years to many new sectors. Two of them are selected for this Wrokshop and the world known experts in the field are invited to present state of the art and govern the discussion:

Section A: **Development of Ceramic Matrix Composites (CMC)**

Dr. Petar Agatonovic, Germany, will present the development of CMC for high temperature application, interesting for the advancement in space program.

Section B: **Mesoscopic approach of mechanical properties of materials**

Prof. Guy Pluvinage, University of Metz, Metz, France proposed European project under given title. It is assumed that after material science approach based on "micro to macro", future developments in material science in general, and of nano and multi materials in particular, need a new paradigm mainly based on mesoscopic approach, in order to solve the problem of transferability of mechanical properties.

## List of Wokrshop participants

1. Pashnjari Armand, Albania
2. Vukojevic Nedeljko, B&H
3. Posavljak Strain, B&H (Republika Srpska)
4. Prof. Angelova Donka, Bulgaria
5. Doc. Gočev Jovan, Macedonia
6. Petzek Edward, Romania
7. Gido Anca, Romania
8. Dr. Burzić Zijah, S&MN
9. Dr. Grabulov Vencislav, S&MN
10. Mr. Milović Ljubica, S&MN
11. Prof. Sedmak Stojan, S&MN
12. Prof. Katarina Gerić, S&MN
13. Prof. Nenad Radović, S&MN
14. Bedkowski Wlodimierz, Poland

1. Murat Buyuk, Turkey
2. Dr. Petar Agatonović, Germany
3. Prof. Guy Pluvinage, France
4. Prof. Gui-Rong Liu, Singapore
5. Dr. Rakin Marko, S&MN
6. Prof. Jovo Jarić, S&MN
7. Zrilić Milorad, S&MN
8. Jakovic Dragan, S&MN
9. Momčilović Dejan, S&MN
10. Burzic Meri, S&MN
11. Ignjatovic Dragan, S&MN
12. Ivo Blačić, S&MN
13. Prof. Milosav Ognjanović, S&MN

**Forum for Structural Integrity for South-Eastern European Countries**

The idea to establish the Forum for Structural Integrity for South-Eastern European Countries

is explained in the Memorandum, accepted by representatives of counties participated in IFMASS 8.

**Memorandum**

The participants from Balkan and South-East European countries in Eight International Fracture Mechanics Summer School (IFMASS 8), held from 23rd to 27th June 2003, and at the Workshop New Trends in Fracture Mechanics Application, held on 27th June in Belgrade, gathered on the meeting after these events, discussed the achievements in development of fracture mechanics and its application to structural integrity assessment in the region. It is concluded that the organization of IFMASS 8 has shown:

- clear interest of the experts from the region in further development and research in structural integrity assessment;
- wish of all participants to contribute to more close and extended cooperation between the experts in the region;
- the need to find convenient form for exchange of results in achievements in fracture mechanics and structural integrity assessment through better links between the countries in the region, as well as with European Structural Integrity Society (ESIS).

The aim of formal organization, e.g. in the form of Forum for Structural Integrity, can be to put together individuals, institutions and countries, interested in cooperative actions for further development of structural integrity, based on scientific achievements and solutions of failures in service and requirements for equipment life extension. In this way the benefit for all parties involved in such an organization can be reached in the most convenient way. In addition, formal organization can also help in proposing standards and codes of interest for the regional industry, e.g. regarding the safety and reliability of equipments, having in mind also the environment protection. This kind of regional cooperation is broadly accepted and involved in Europe.

In order to prepare the proposal for establishing best form of future regional organization the committee of five members is selected, as follows:

Representative of Serbia & Montenegro
Representative of Bulgaria
Representative of Macedonia
Representative of Albania
Representative of Bosnia & Herzegovina

The Committee shall prepare its proposal in next four months (up to November, 1st, 2003), in close contact with ESIS president Prof. Alberto Carpinteri and its office. The experts from the countries, not presented at the meeting, will be also invited to join this action (Croatia, Greece, Hungary).

International Fracture Mechanics Summer School (IFMASS) is considered as one of already established form of future cooperation. It is recommended to organize next School (IFMASS 9) in Bulgaria in 2004, together with Workshop as a satellite event.

The experts, taking part in this meeting, express their wish and readiness to help the committee in its activity and promote the proposal among the experts and institutions in their

countries.

**List of participants at the meeting for foounding of the Forum**

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