Structural Integrity and Life Society "Prof. Dr. Stojan Sedmak"

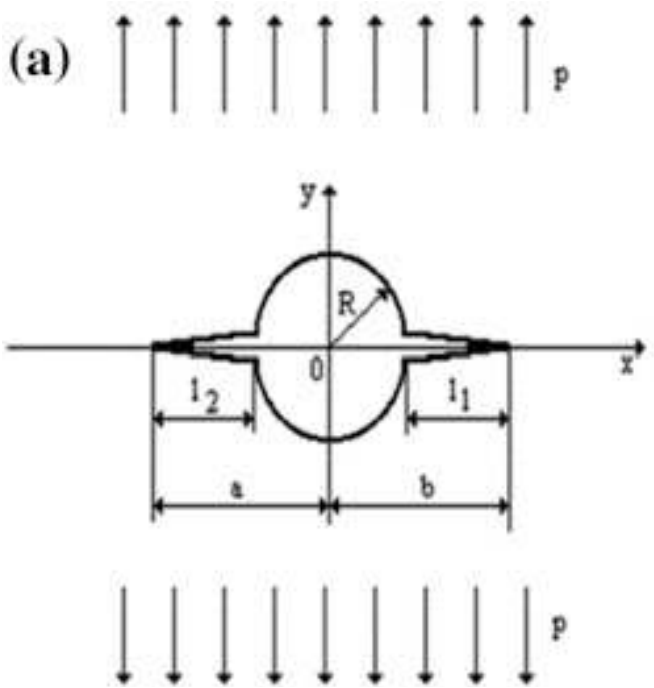
DIVK (Society for Structural Integrity and Life) (inovacionicentar.rs)

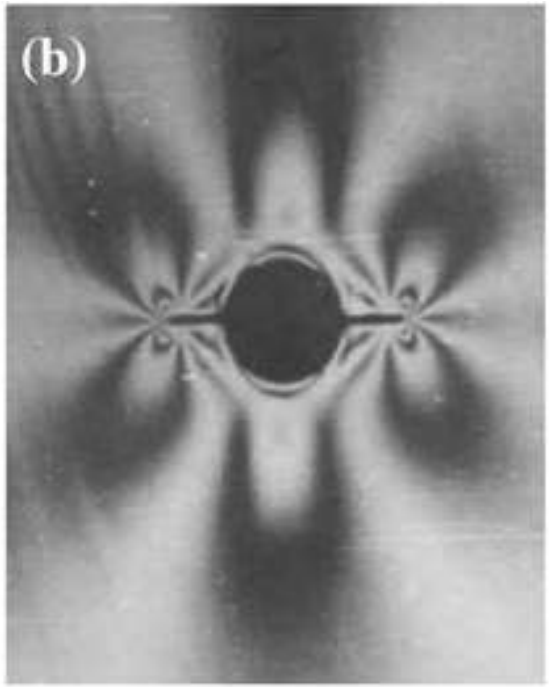
*The story of DIVK is in fact story of a great man who has introduced fracture mechanics in exYu and even SEE. It all started almost 60 years ago when **Stojan Sedmak** worked on his magister thesis, and was just about to finish his research on photoelasticity measurement of stress concentration factor, when his advisor, Prof. Nikola Hajdin, later to become the president of SANU, asked him if he could add a chapter on Bowie's problem which he just had read about. It was in 1968, the Chapter 5 was added and this is how it all begun.*

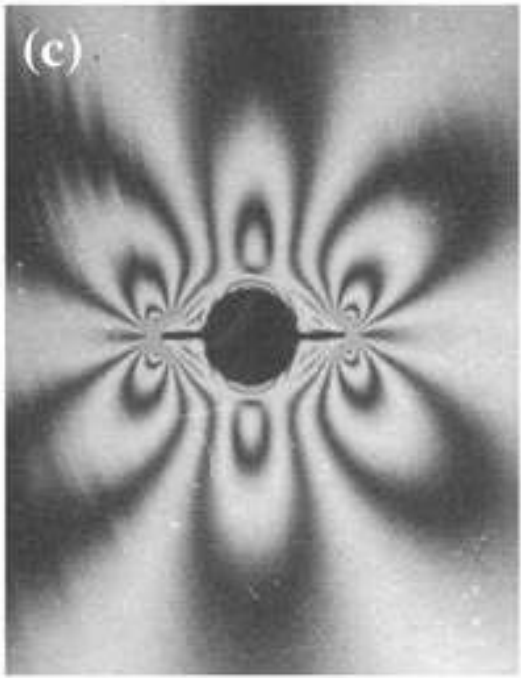
*Few years later Stojan met **Aleksandar Radovic** and started working on doctoral thesis using newly developed experimental techniques for testing brittle metallic alloys to obtain fracture toughness values. After 1977, when he defended his thesis, and attended few international conferences, where he met few world class experts, among them Prof. Michael Wnuk (USA, originally from **Poland**!), Stojan arranged for Wnuk's visit to Belgrade, which was crucial for one of 3 milestones, IFMASS. The other two were construction of RHE BB and USA – exYu project.*

Prof. Stojan Sedmak (1929-2014)

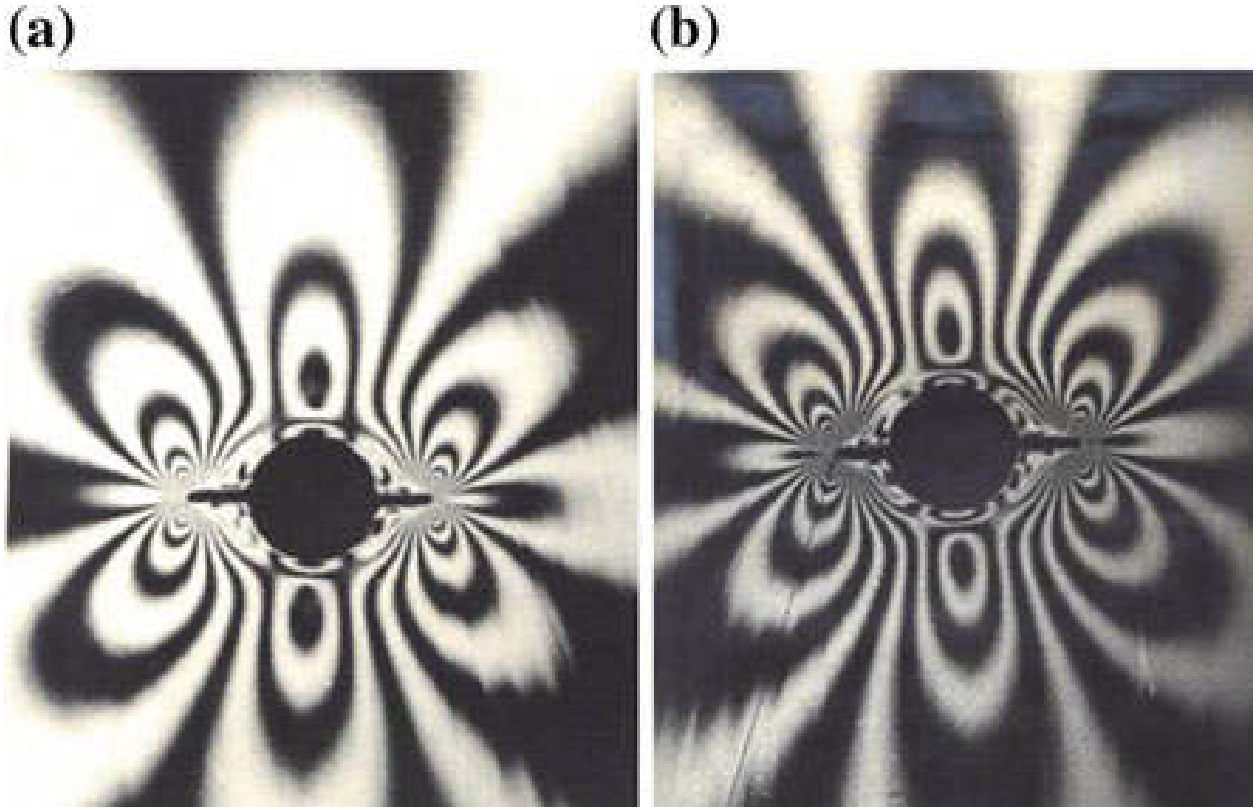
Magister thesis: Photo-elasticity was a standard method to solve stress concentration problems, but it was not so often applied to solve fracture mechanics problems back in Sixties. On the contrary, it was quite difficult to apply this method to solve the Bowie's problem, requiring long and tedious work, for more than a year. Actually, the first results (Fig. b, c) indicated SCF=3, which was not correct for the notches emanating from the circular opening. By repeating experiments to get more readable photos, Fig. 2, Stojan was capable to get more realistic results. Also, one should notice extrapolation technique, to get more precise number of isochromes, as shown in the next slide.





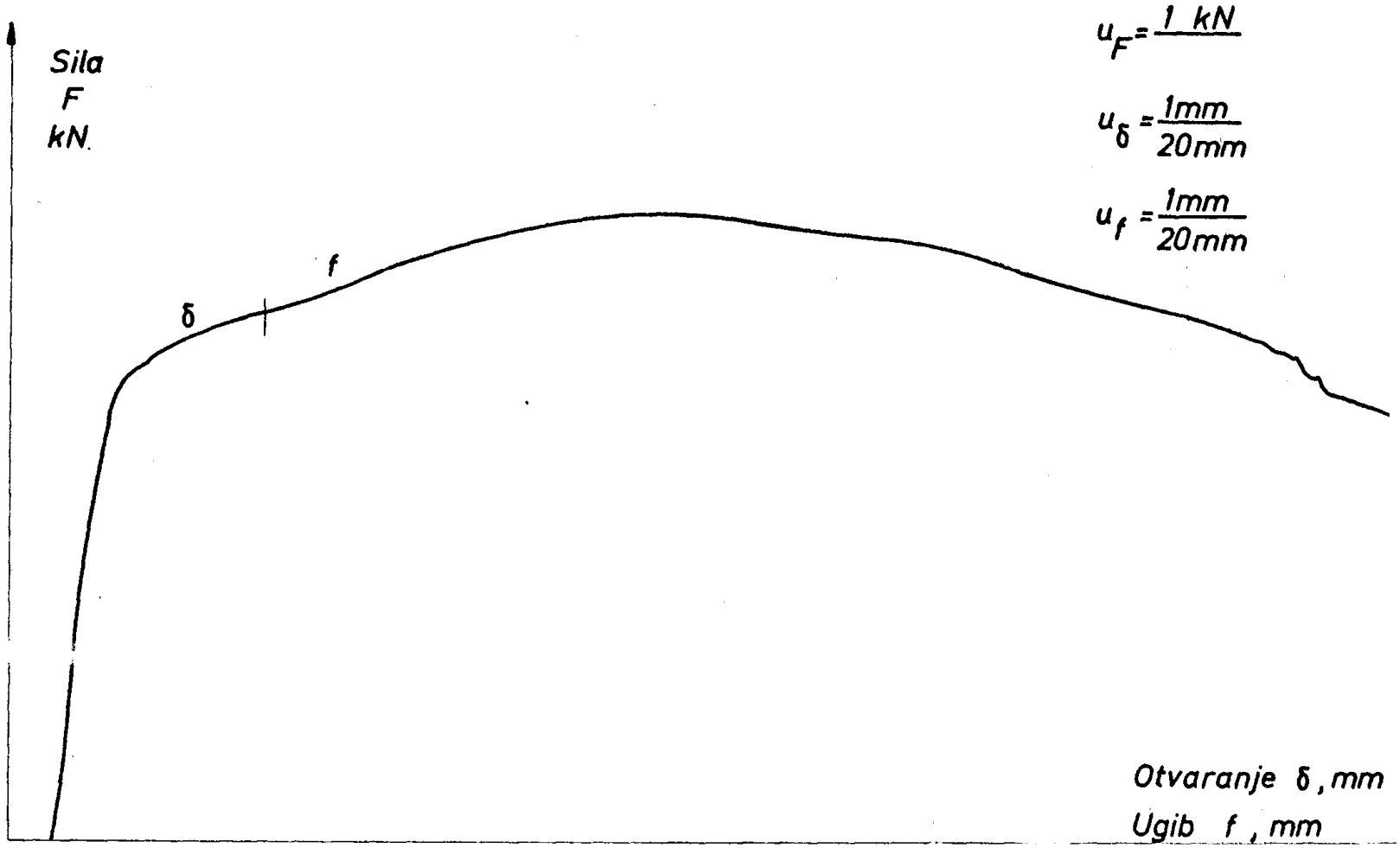


a) Isohromes (No = 10); SCF=3.22; b) Isochromes (No = 13 and 14.7 after extrapolation) SCF=3.45 and 3.9 after extrapolation,



Anyhow, he was still not satisfied with the results, so he made another model to be tested under the same conditions, but with technical improvements (different expositions to get sharper images, better magnifying glass). This has led to the final result for the stress concentration factor of **5.24.** Based on the experience gathered during this experimental work, Stojan Sedmak finally concluded that photo-elasticity is not suitable method to deal with crack problems.

First diagramme F-CMOD, recorded in 1973, Military-Technical Institute



Short history of DIVK

1965-1977 Stojan Sedmak Mag. thesis, D.Sc, Experimental FM

1975-1982 Int. conferences, **RHPP Bajina Basta**

1980-2008 **IFMASS 1-10**

1980-…. Theoretical (Jovo Jaric)
and Numerical FM (Mladen Berkovic)

1982-1990 **USA-exYu project Weldment Fracture Mechanics**

1992 ECF9 in Varna – mission impossible, but successful

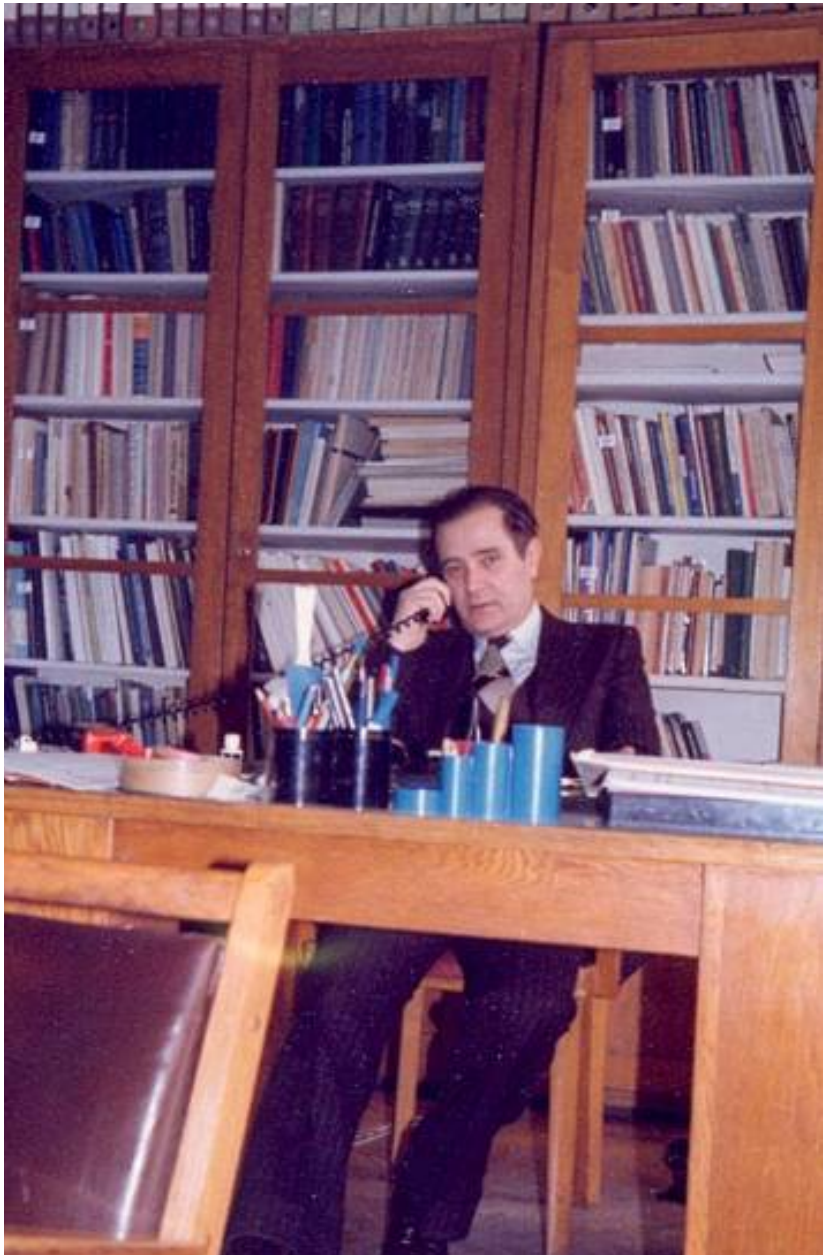
1990-2000 Chaos in exYu and Serbia

2001 DIVK established

2001 **Journal Structural Integrity and Life,** indexed in Scopus, emerging Clarivate WoS

2014 Vice-president from Serbia

2018 **ECF22** in Belgrade 560 participants



1st Int. Fracture Mechanics Summer School

- Wnuk (2) :

Mohana Ratvanija (5)

Mladen Berković

Adam Mazur (2)

Andrej Javorskog

Januš Orkiš

Andrej Neimic

- Stojan Sedmak

Aleksandar Radović (2)

Ljubomir Nedeljković

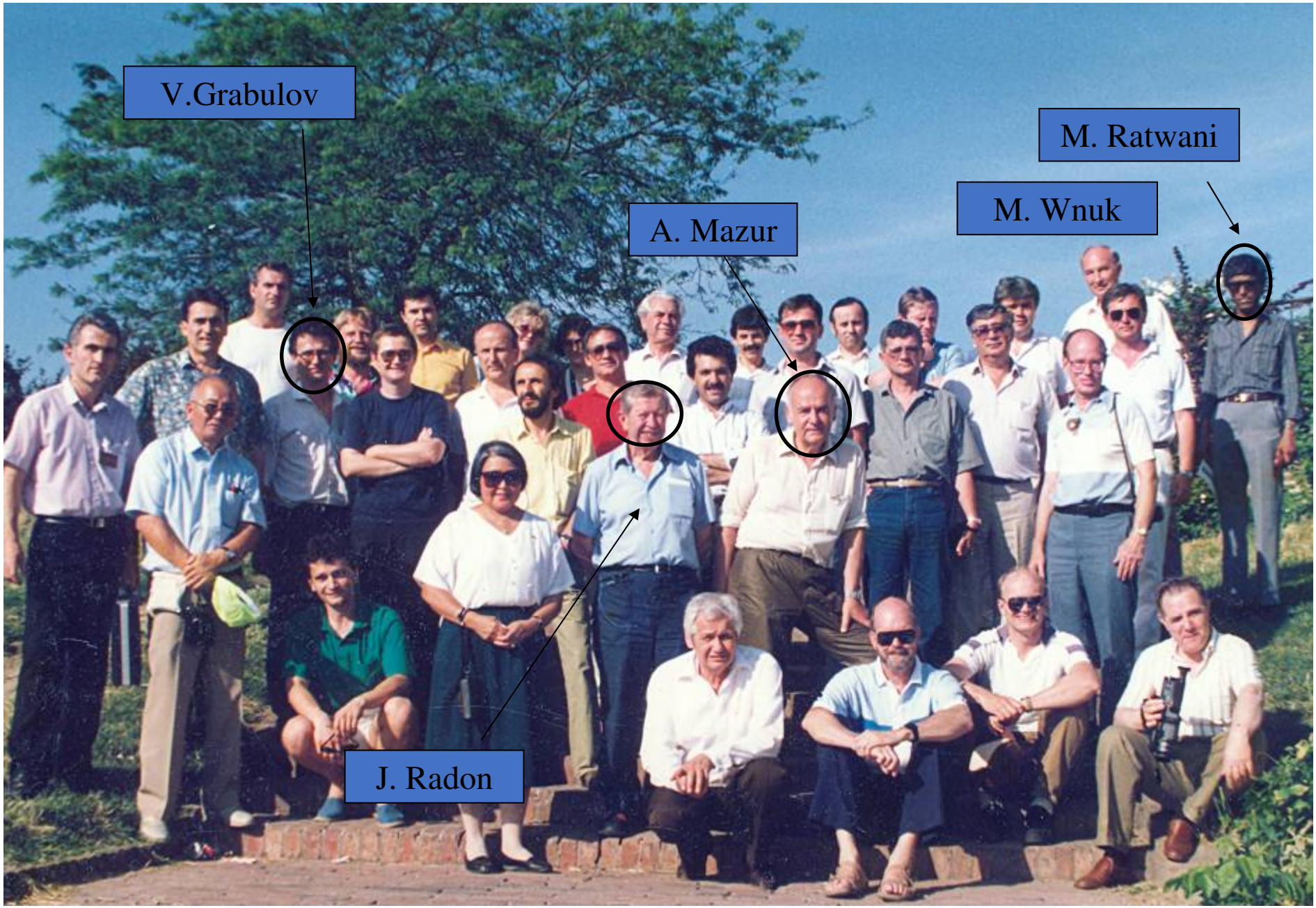
Jovo Jarić

Jože Pirš

Milan Radojković

Đorđe Dobi

Mladen Berković, 1936-1999, one of 5 FM “legends” in Serbia (SS, AR, TT, BZ).
His lectures at IFMASS 1-6 established Computational (Fracture) Mechanics in exYu.


V.Grabulov
M. Ratwani
M. Wnuk
A. Mazur
J. Radon

It is to underline the importance to gather experts from Yugoslavia in IFMASS, where substantial help came from **GOŠA company**. Since 1974 the company engaged a group of experts for possible problems of the pipeline at **Hydroelectric Plant "Bajina Bašta",** made of high strength steel, that required crack problem analysis and introduction of fracture mechanics. The initiative of **Michael Wnuk** to establish Fracture Mechanics Summer School supported by **S. Sedmak,** A. Radović and Lj. Nedeljković, was accepted by **Tihoslav Tošić,** director of GOŠA company, with financial support. So, in 1980 the first School was organised with 8 domestic and 6 foreign lecturers presenting 21 lectures in the scope of "Introduction to fracture mechanics and fracture-safe design," with 62 participants.

Before founding of DIVK, among seven summer schools, IFMASS 5 and IFMASS 7 have special importance with 142 and 138 participants.

Michael Wnuk,
Lecturing at the
1st IFMASS

INTERNATIONAL FRACTURE MECHANICS SUMMER SCHOOL

IFMASS 1 S. Palanka, 1980, Introduction to fracture mechanics and fracture safe design, Ed. S. Sedmak, 1981

IFMASS 2 Velika Plana, 1982, Modern aspects of design and manufacturing of pressure vessels and penstocks, Ed. S. Sedmak, 1982, (in Serbian)

IFMASS 3 S. Palanka, 1984, Fracture mechanics of weldments, Ed. S. Sedmak, 1984,

IFMASS 4 Dubrovnik, 1986, Prospective of fracture mechanics development and application, Ed. S. Sedmak, 1986, (in Serbian)

IFMASS 5 Dubrovnik 1989, The application of fracture mechanics to life estimation of power plant components, Ed. S. Sedmak, published by EMAS Ltd., 1990.

IFMASS 6 Vrdnik, 1991, Service cracks in pressure vessels and storage tanks, Eds. S. Sedmak and A. Sedmak, Belgrade, 1994, (in Serbian)

IFMASS 7 Belgrade, 1997, Fracture mechanics experimental and numerical methods in structural integrity assessment, Eds. S. Sedmak and A. Sedmak, 2000, (in Serbian)

IFMASS 8 “From fracture mechanics to structural integrity assessment,” with a workshop “New trends in fracture mechanics application,” 23–28 June 2003, Belgrade, with 108 participants, 27 from abroad. IFMASS 8 included 25 lectures (12 foreign, 13 domestic. The monograph “From Fracture Mechanics to Structural Integrity” is published in English. Download is available from DIVK and ESIS website and it has attracted several thousand visitors world-wide.

IFMASS 9. The attempt to organize IFMASS 9 in 2004 in Romania failed because of imposed visas for Serbian citizens. Despite this, IFMASS was held for the ninth time on it’s 25th anniversary, entitled “The challenges of materials and welded joints: integrity and life assessment,” in Golden Sands, Bulgaria, 19–23 September 2005, in cooperation with Prof. Donka Angelova, Prof. Stefan Vodenitcharov,, with support of Dr. Martin Beloev, president of the Bulgarian Welding Society. A total of 18 lectures were presented, from Serbia (10), Bulgaria (2), Romania (2), Ukraine (1), USA (1), Germany (1) and Macedonia (1) for 49 participants.

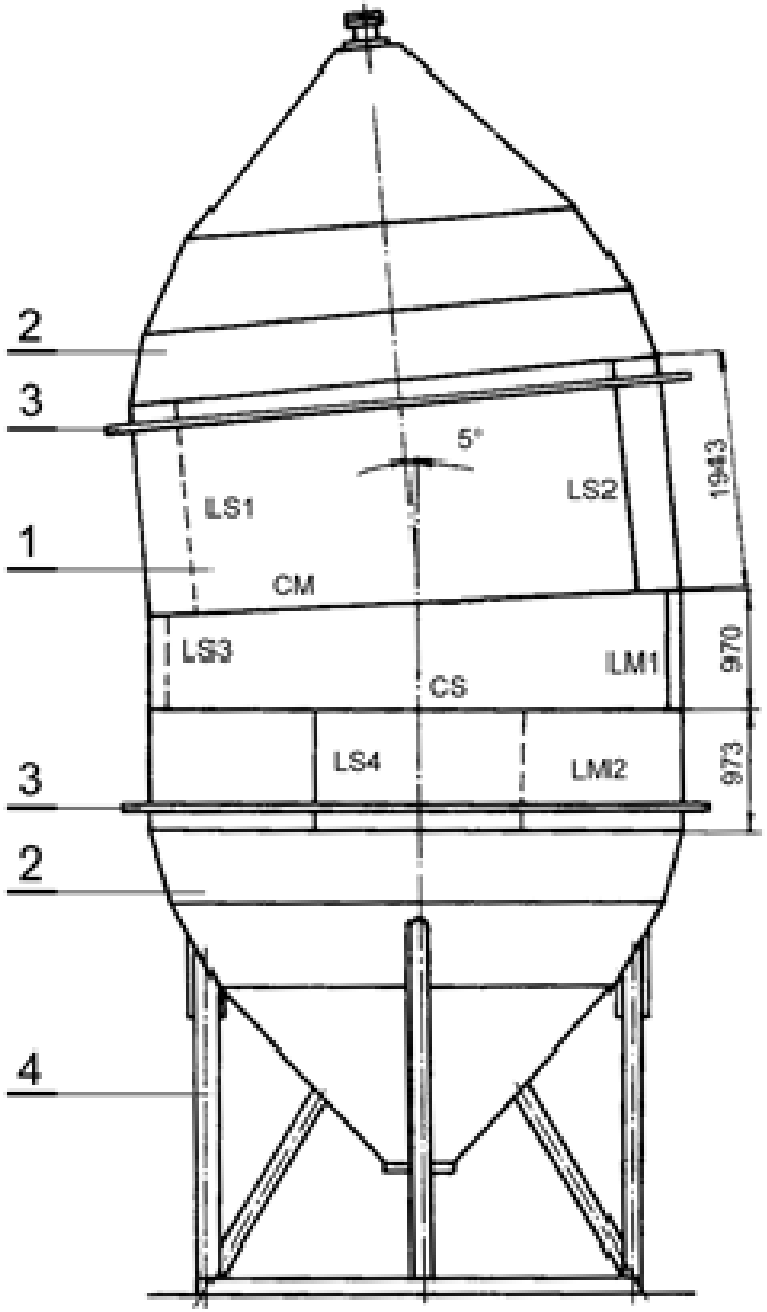
IFMASS 10 “Fundamentals of fracture mechanics and structural integrity assessment methods”, Zlatibor Serbia 2008, Ed. S. Sedmak, published by MF, TMF, DIVK and Institute for Material Testing (IMS), Belgrade, 2009.

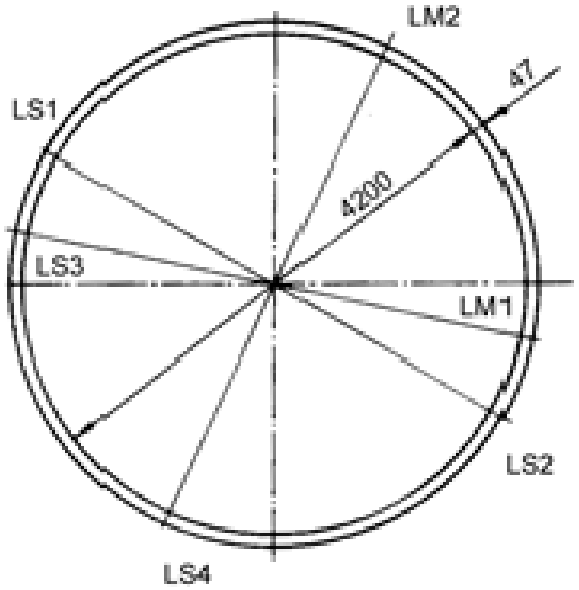
Monographs from IFMASS 9 and 10 are also available at ESIS website.

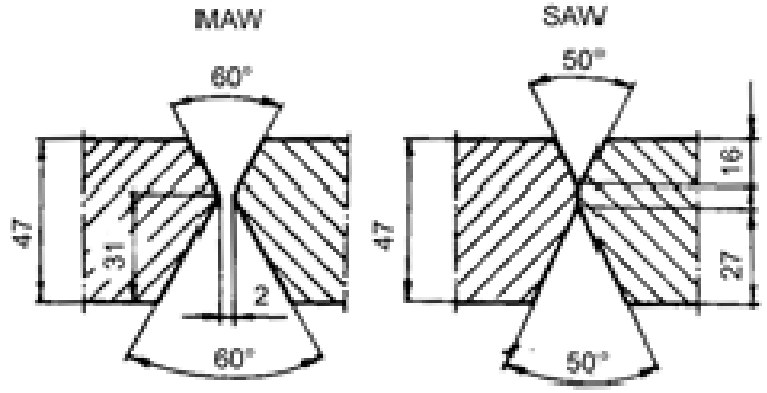
Creators of IFMASS

Stojan Sedmak and Michael Wnuk in 2009 on the occasion of Stojan's 80th Birthday

RHPP Bajina Basta – penstock prototype







Full testing of circular and transversal weldments made by MAW, SAW and MAG welding process

- Mechanical properties of welded joints

(Rm, A, Z, hardness, bend test…..)

-Instrumented Charpy test (crack initiation and propagation absorbed energy)

-Transition temperature

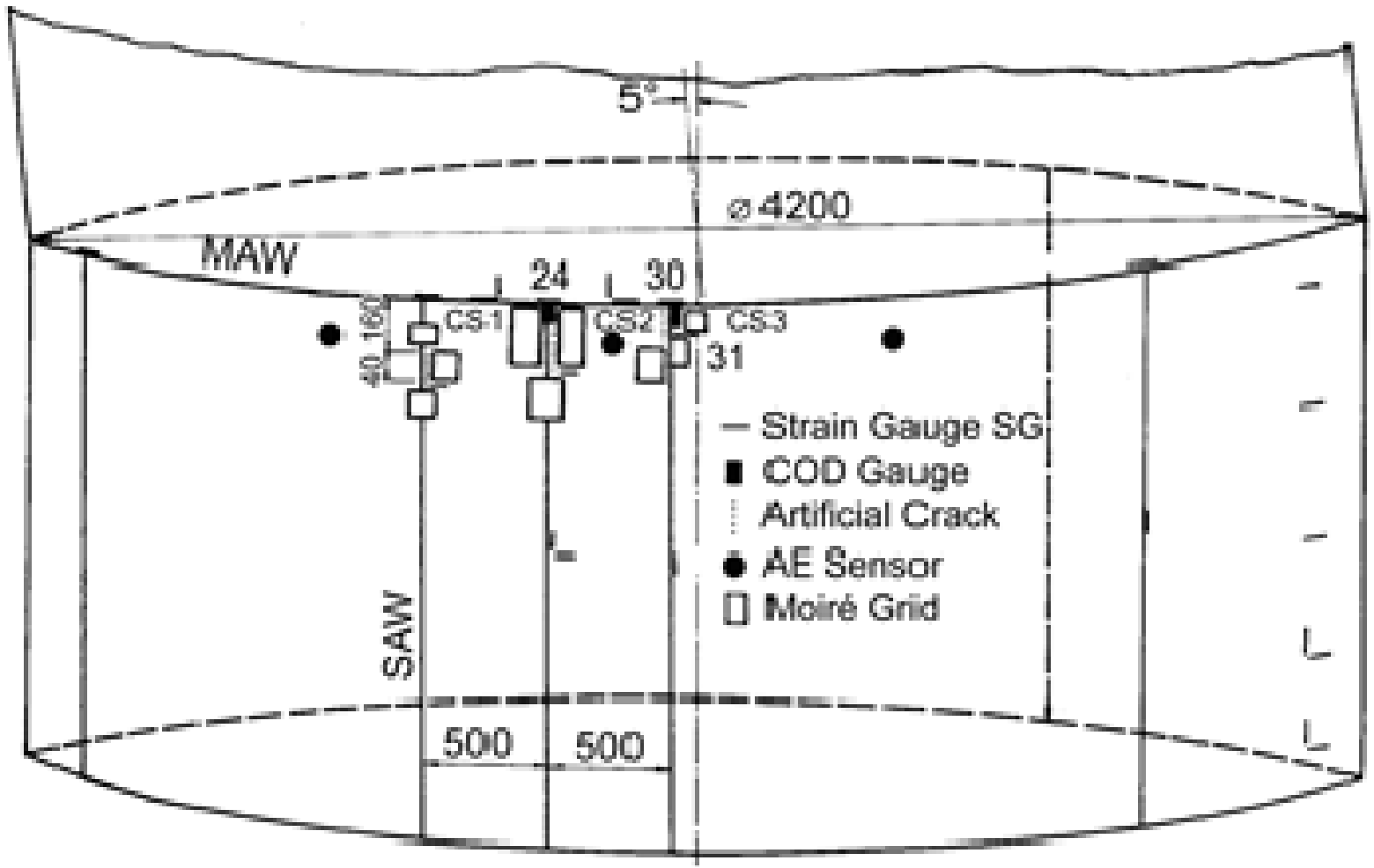
-Drop weight test (Nil ductility temperature)

-Fracture mechanics parameters

(K_{Ic}, COD, J integral, crack in BM, WM, HAZ)

- Strain gages, acoustic emission test, Moire grids

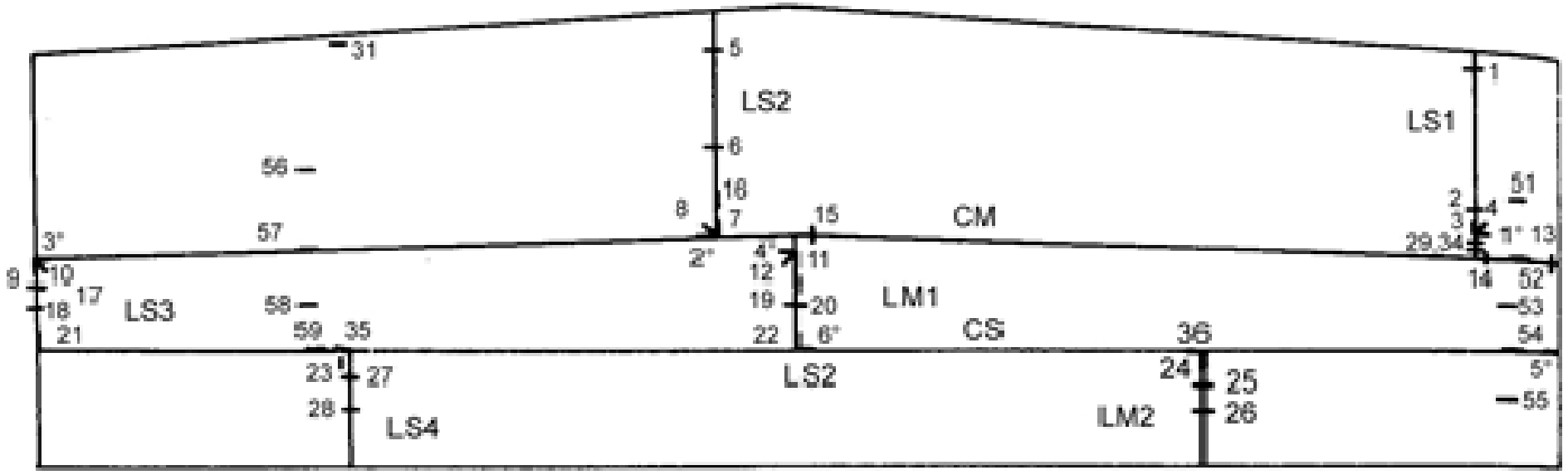
measurements



1 - 36 Strain Gauges 5 mm

51 - 59 Strain Gauges 50 mm

1° - 6° Large-strain Strain Gauges 5 mm

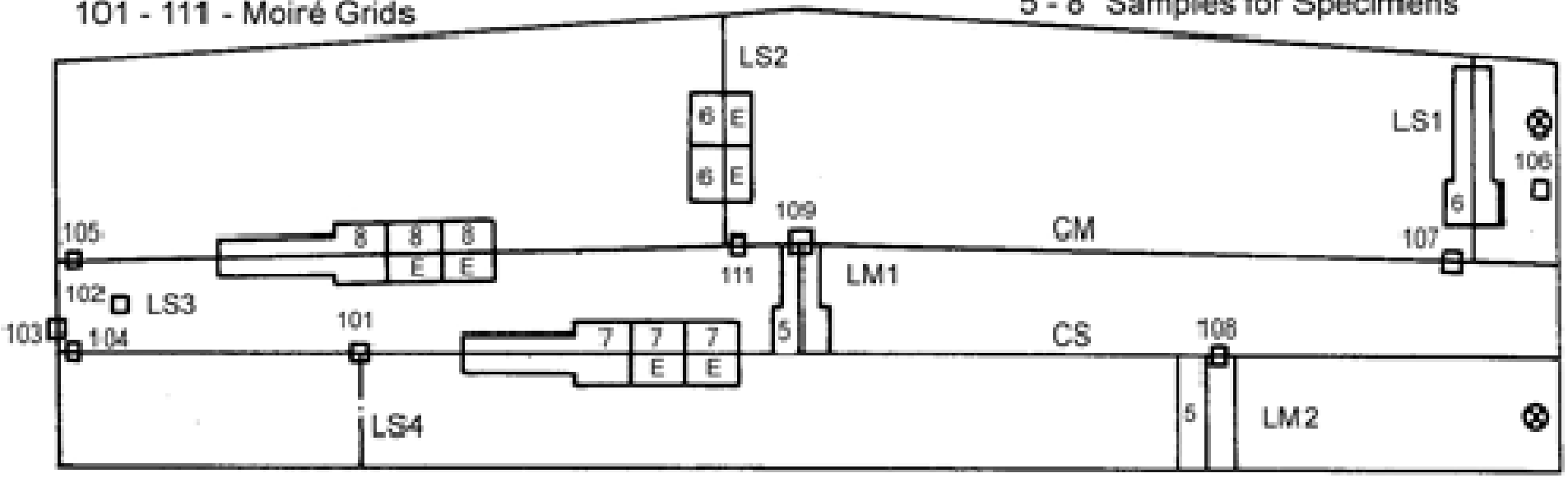


⊗ — Acoustic Emission Sensors

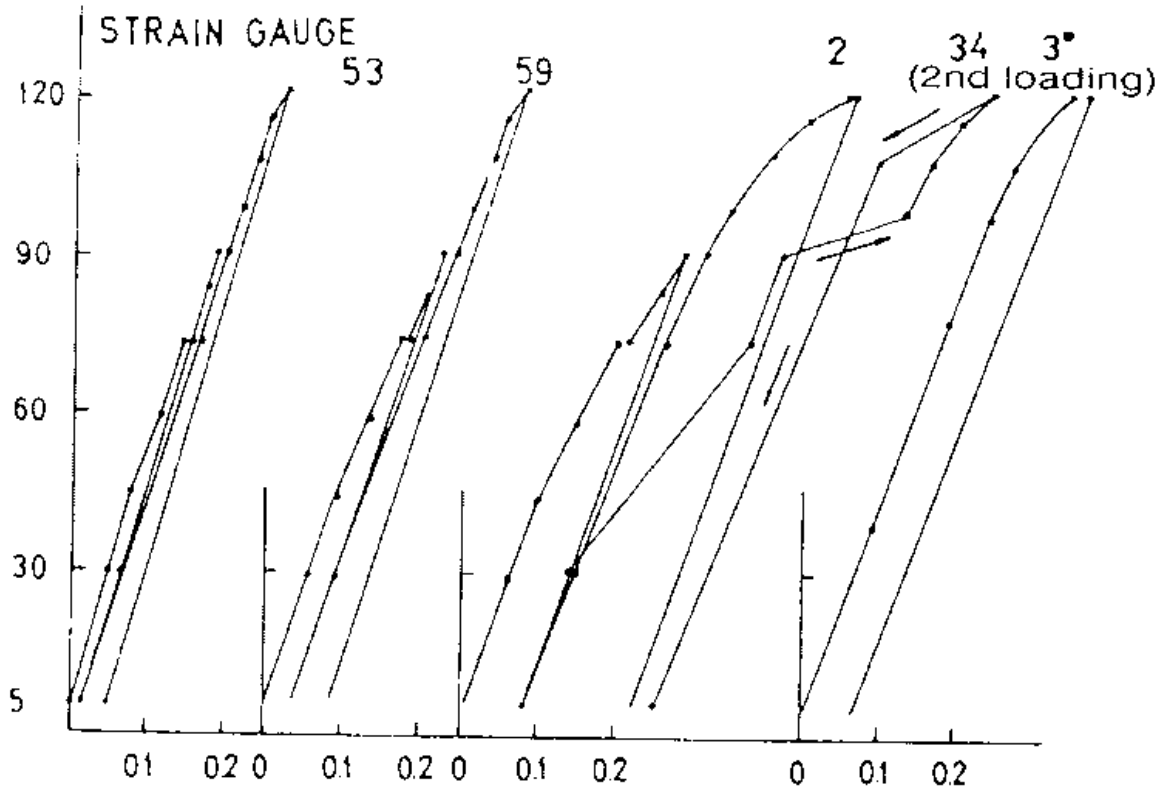
101 - 111 - Moiré Grids

E - Specimens for Explosion Bulge Test

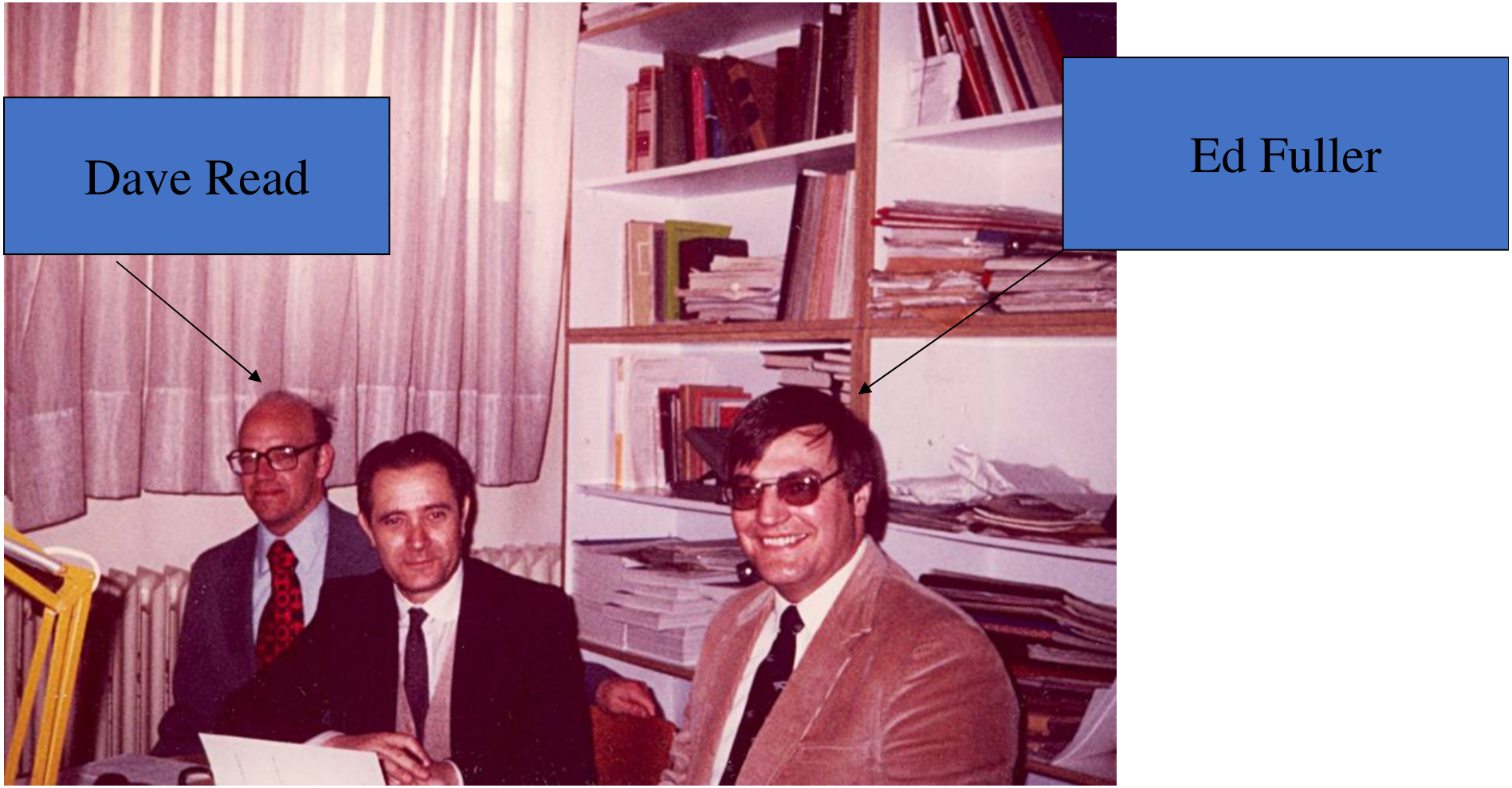
5 - 8 Samples for Specimens



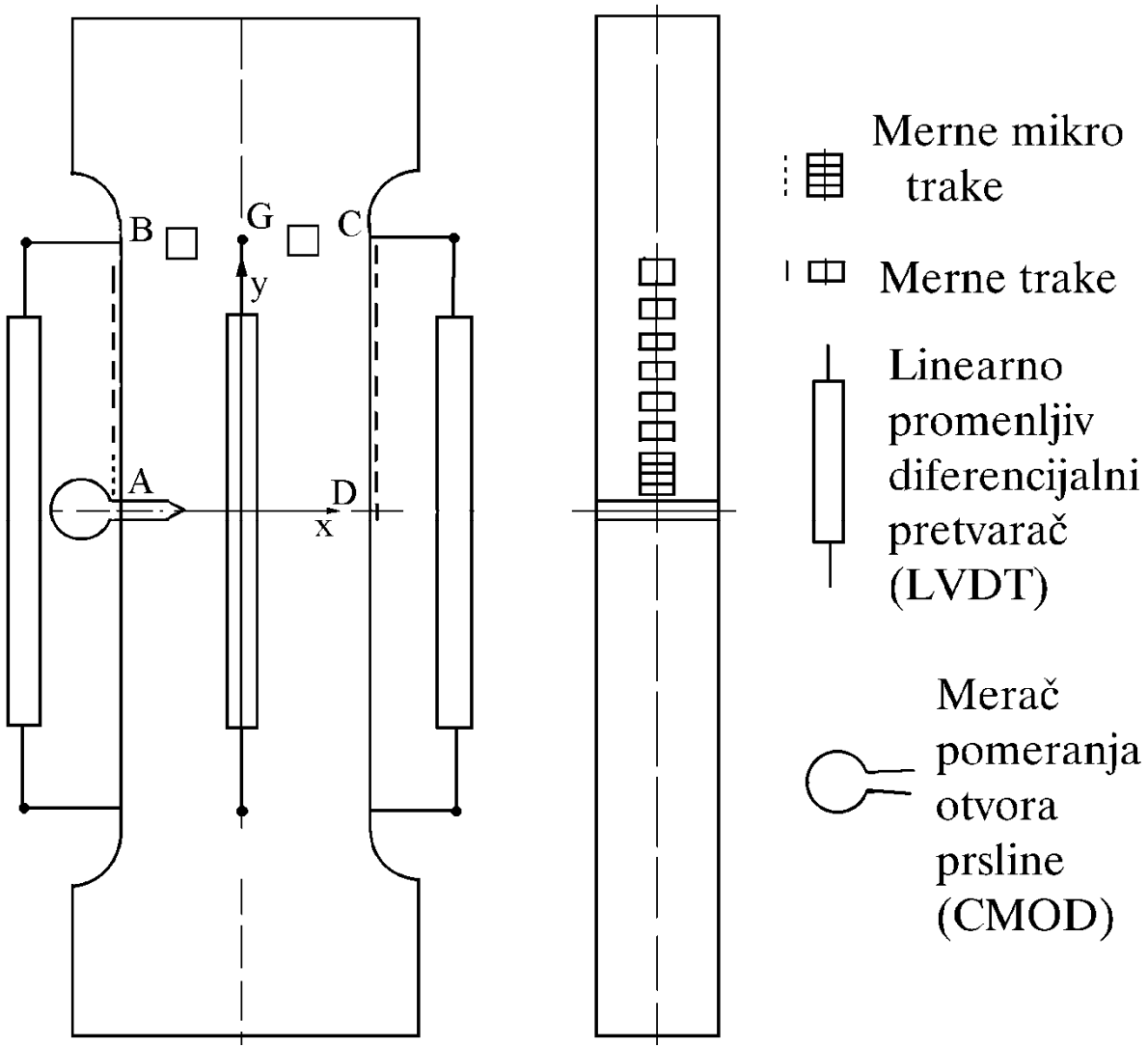
Pressurizing of the model had been performed in two stages. In the first stage the pressure reach-ed 90.2 bar (σ_t=399 MPa), corresponding to working pressure, meanwhile model was held under pressure of 73.5 bar for two hours. After unloading, model was tested by the pressure of 120.6 bar (σ_t=533 MPa) in the second stage, that is close to the total working and water hammer load. For selected location and strain gauges, the measures of developed strain are presented.



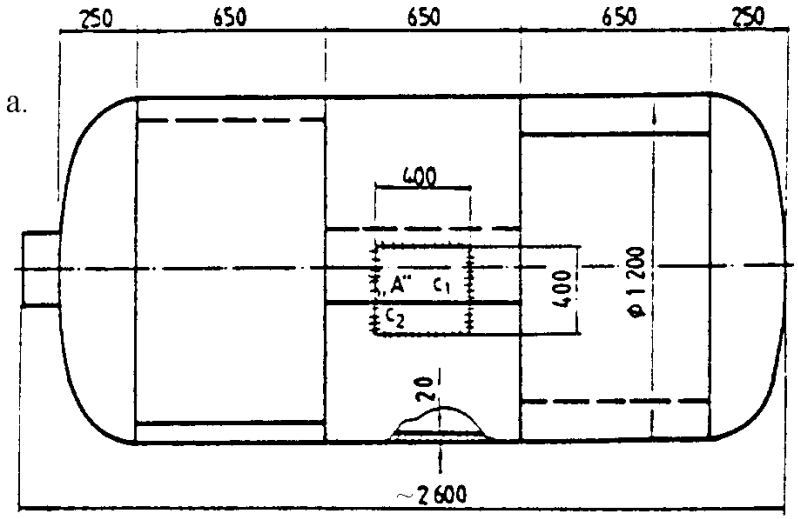
- **USA – exYu project on Weldment Fracture Mechanics 1982-1990**
- Participants: Serbia (TMF, FTN Novi Sad), Slovenia (FME Maribor), Bosnia (Energoinvest Sarajevo), Croatia (Đuro Đaković Slavonski Brod), Montenegro (FME Skopje) and Montenegro (FME Podgorica) and American partner: NIST – National Institute for Standards and technology, Boulder and Gettysburg

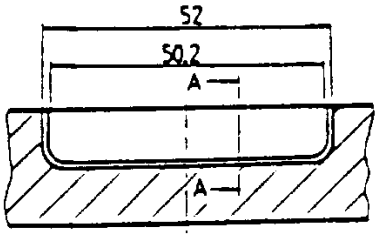


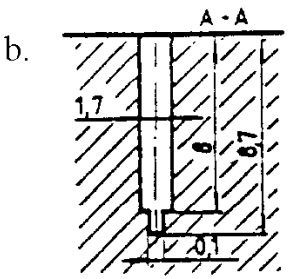
- direct measurement of J integral

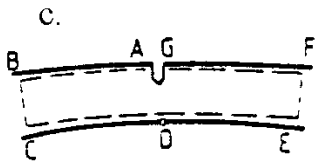


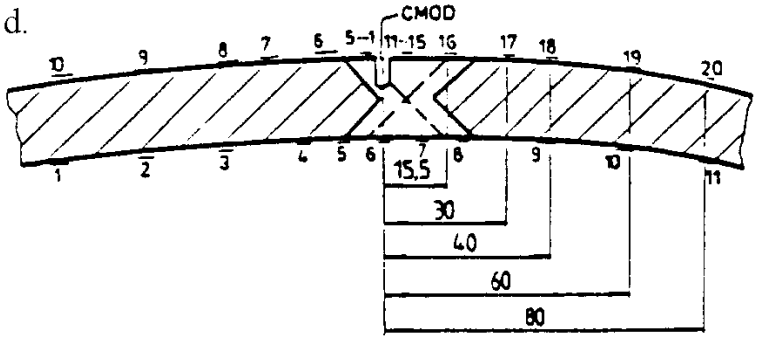
- direct measurement of J integral

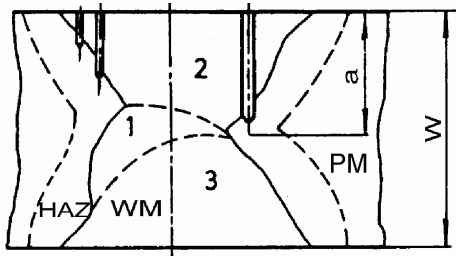


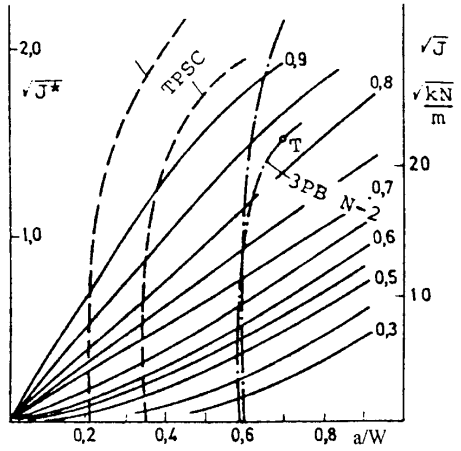


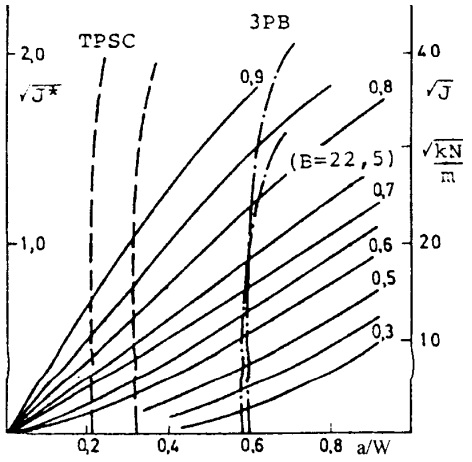


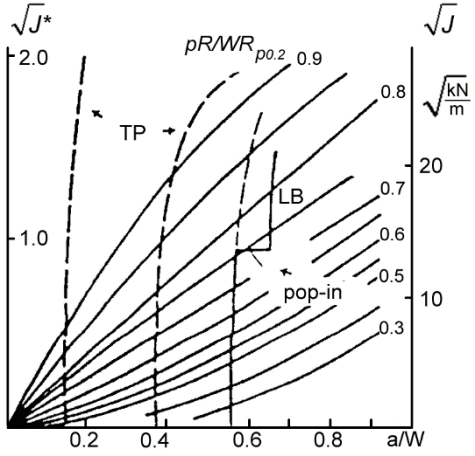


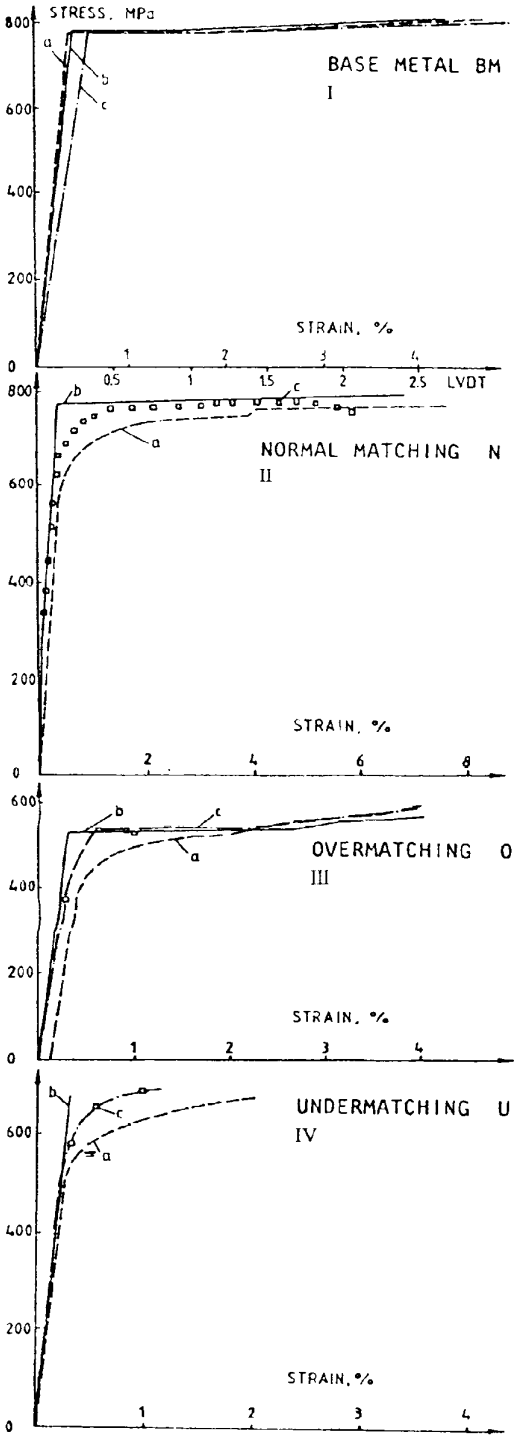


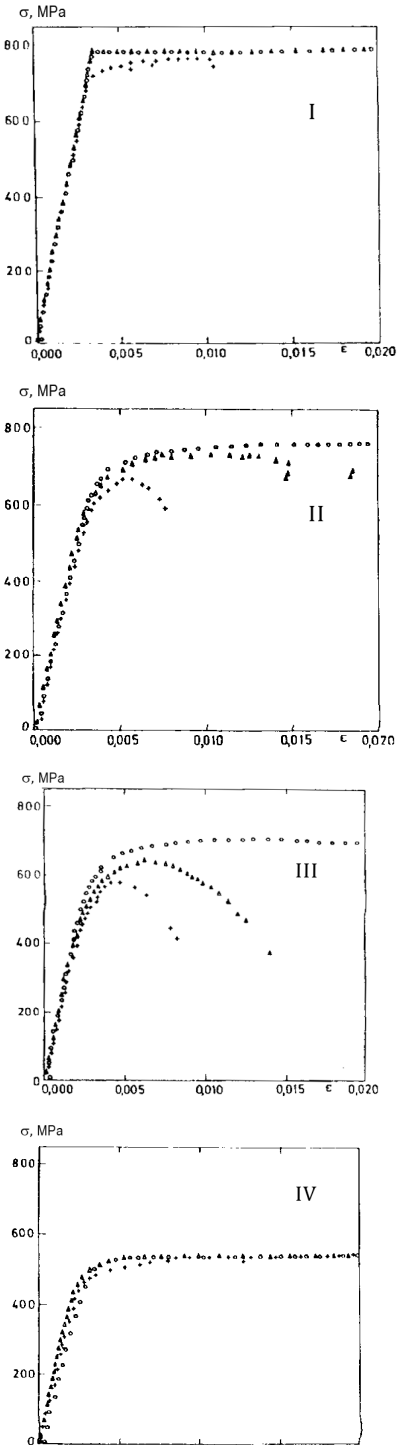




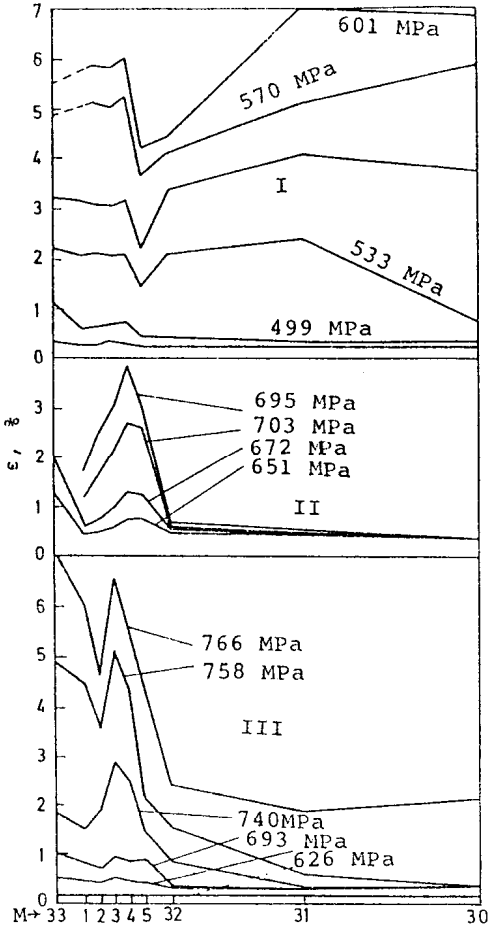








mismatching of welded joints



So the stage was all set up by the end of Year 2000…

The necessity to establish the Society for Structural Integrity and Life (in Serbian: Društvo za Integritet i Vek Konstrukcija - DIVK) in Yugoslavia is encouraged by the intention of European Structural Integrity Society (ESIS) to extend the activity in coming years, as it has been decided during ECF 13 in San Sebastian in September 2000. It should be remembered that Yugoslavia was successful organizer of 9th European Conference on Fracture (ECF 9) in 1992, despite the fact that the Conference had to be moved from Yugoslavia to Varna in Bulgaria. The choice for Yugoslavia to organize ECF 9 was a consequence of the activity of members from Yugoslavia in ESIS and an extended participation in previous conferences, starting with ECF 4 in Leoben in 1982. Despite very difficult situation in our country, we saved contacts with ESIS and papers from Yugoslavia have been presented at every ECF after ECF4.

Establishing the Society for Structural Integrity and Life

Initiative for DIVK foundation gathered 27 experts on January 31st, 2001. The conclusion was that conditions for organized scientific and professional consideration of structural integrity and life problems are fulfilled after more than **20 years of intensive activity on introduction and application of fracture mechanics and fruitful cooperation with ESIS.** This was continuation of practical application of fracture mechanics, treated in seven International Fracture Mechanics Summer Schools (IFMASS), held from 1980 up to 1997. Destroyed infrastructure and factories during the NATO aggression and **necessity to reconstruct damaged and destroyed objects** increased the interest for structural integrity and life among the experts in Yugoslavia. In addition, during last 15 years industrial recession in Yugoslavia significantly contributed to deterioration of machines and equipment due to **improper maintenance and service condition.** Therefore, experts from the industry (Electricity of Serbia, Oil and Chemical Process Industry, Welded Structures producer) were invited.

The Governing Board had nominated presidents of in 2001:

1. Materials – Katarina Gerić
2. Fracture mechanics and damage mechanics: Marko Rakin and Milorad Zrilić
3. Welded and other metal structures: Miodrag Arsić
4. Concrete structures: Miodrag Pavišić
5. Quality assurance of structures in manufacturing and service: Antun Fertilio
6. Strength calculation and numerical methods: Taško Maneski
7. Behaviour of structures in service: Vera Šijački-Žeravčić
8. Structural safety and reliability: Milosav Ognjanović
9. Structural life assessment: Ivo Blačić

Intended as a basic activity at first, activities in sections narrowed down to lectures and individual presentations.

Katarina Gerić held the first lecture “Mechanical properties and fracture of ceramic materials” in November 2001 at sections 1 and 2. The second lecture “Examples of structural component failure and case analysis,” with his own failure analysis and life prediction was presented by Ivo Blačić in March 2002 at sections 1; 2 and 9. The Plenary lecture “Mechanical properties and fracture mechanics of composites” by Zijah Burzić was held at the First Annual Assembly.

After seminars and meetings that discussed structural integrity aspects of European directives for pressurized equipment, a thematic commission was led by Dr. Miodrag Arsić in 2003.

Seminars

The Oil Refinery Pančevo hosted the seminar "**Engineering methods for processing equipment integrity and life prediction**" in November 2002, dedicated to practical problems in service and maintenance. An extended discussion followed after four presentations (S. Sedmak, Z. Burzić, T. Maneski, A. Sedmak) in February 2003. A problem of proof pressure levels was considered and its importance for integrity in pressurized equipment testing.

The third seminar "**The application of fracture mechanics in design and manufacturing of pressurized equipment**" was held in December 2003 at Minel Boilers Factory.

Regional Economy Chamber (RPK) – Pančevo in cooperation with DIVK had organized symposium "**Production, service and testing of pressurized equipment (OPP**)" – new approach, in October 2004. After introductory exposures more than 80 representatives of many companies from the Southern Banat region presented their experiences and problems in service.

Special attention at the First DIVK Conference in 2004 has attracted by the presentation on "**Standardization, accreditation, technical codes**". Two daily seminars followed afterwards. The first, entitled "**New solutions for quality assurance**," was held in December 2004, and the other "The significance of accreditation and certification in European directives application" in February 2005, with more than 80 participants and large discussion.

A 40-hour course "**Testing of pressurized equipment (OPP) in service and life assessment**" (according to requirements in PED 97/23/EC and Law of Energetics) was held in March 2005 in JKP Beogradske elektrane.

A one-day seminar "**Determination of strains and stresses by indirect methods testing and modelling**" with 7 lectures on testing and 2 on modelling was held in March 2006 for 25 co-

DIVK guests and invited lectures

A significant number of invited lectures from foreign guests was organized. The first lecture, held on 22nd March 2002, “Dynamic strain hardening and plastic instability” by **Dr Siniša Mesarović**, Assistant Professor at the Washington State University, Pullman, USA, was invited by the Section for Metallurgy of the Serbian Chemical Society and DIVK.

During 2004, DIVK organized visits of five foreign experts. Prof. **Surya Kalidindi**, Drexel University, Philadelphia, USA, held two lectures: “Microstructural sensitive design” and “Modeling micro and macro texture evaluation in polycrystalline materials.” Mr. **Saadoun Eshwili** from Libya was DIVK guest in July. Talks were held about cooperation in the field of non-destructive testing and structural integrity assessment. Prof. **Guy Pluvinage** and Dr Philip Jodin, University of Metz, France, were guests in October. They attended the First DIVK Annual Conference. Prof. Pluvinage also presented the lecture “Notch fracture mechanics”. Prof. **Berndt Michel** was DIVK guest in December when he gave two lectures: “Microreliability, nanoreliability – fracture mechanics from micro to nano?” on the 14th, and “Development in micro- and nanotechnology, reliability, testing and application” on 15th December.

In the year 2005, the following presentations were held: Prof. **Duško Krajčinović**, Arizona State University, USA: “New achievements in damage mechanics,” on 18th May. Prof. **Abdel-Monem El-Bataghy**, Cairo, Egypt: “Introducing the Central Metallurgical R & D Institute” and “Education and Training in Welding Field in Egypt”

The seminar “Integrity of civil engineering structures” at the Second Annual Conference, October 2005, included 10 lectures. Two guests gave lectures: ESIS president Prof. **Alberto Carpinteri**, Turin, Italy (Non-linear fracture mechanics models for concrete and reinforced concrete and Fractal models for size effects of concrete structures: the application of Euro standards and codes), and Prof. **Dan Constantinescu**, Bucarest, Romania (Hardening mechanism effect at sandwich structure fracture).

In 2006, Prof. **Mahmoud Nili Ahmadabadi**, dean at the Technical Faculty and Prof. **Seyed Ahmad Nourbakhsh**, director of Turbomachine Institute, University of Tehran, Iran, presented “Processing of cast iron in semi-solid state”, and

Prof. **Nenad Gubeljak**, Faculty of Mechanical Engineering, University of Maribor, Slovenia (Use of stereometric measurement for continuous strain monitoring).

Later on our guests were also **Leslie Banks-Sills, Francesco Iacoviello, Per**

Activities in European Structural Integrity Society (ESIS)

Most important DIVK international activities are cooperation with ESIS and participation at European Conference of Fracture, and other ESIS events. The number of ESIS members through DIVK was 83 in 2006, 80 in 2020, and 50 otherwise.

Close cooperation is established by the participation of our representatives S. Sedmak and M. Rakin at ECF 14 in Cracow, Poland (2002), and S. Sedmak at ECF 15 in Stockholm, Sweden (2004), and through the attendance at ESIS Board meetings.

Special symposia were organised at the 16th European Conference of Fracture (ECF16) in Alexandroupolis, Greece, in July 2006, attracting more than 1000 participants.

At IFMASS 8 the cooperation of Southeast European countries has been initiated for founding regional forum for structural integrity and life under auspices of ESIS. During IFMASS 9 a new document of regional cooperation is drawn, but this idea has not been realised so far.

Later on, ECF17 in 2008 (Brno, S. Sedmak and Lj. Milovic), ECF18 in 2010 (Dresden, M. Rakin and A. Sedmak) were followed by significant increase in participants from Serbia, ECF19 (Kazan, 10), ECF20 (Trondheim, 9), ECF21 (Catania, 12) and, naturally, over 70 in Belgrade 2018, ECF22.

We are also active in number of TCs: TC1 (Rakin, Sedmak), TC3 (Sedmak, Grbovic), TC8 (Grbovic, Sedmak), TC12 (Sedmak, Kirin), TC15 (Milosevic, Milovanovic), TC18 (Sedmak)

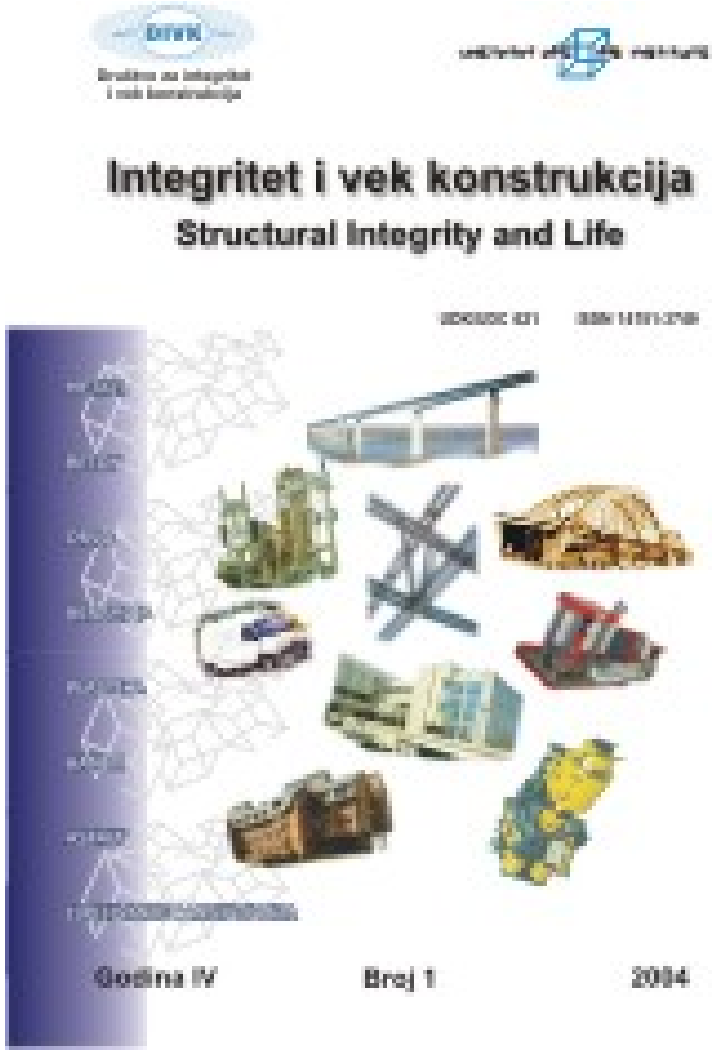
Also in conferences supported by ESIS: ICMFM, NT2F, IRAS, ICSID, ICSI, CP, MSMF….

Our journal is OA, affiliated with ESIS:

https://www.structuralintegrity.eu/site/events/journal-2

CONTENTS No. 2 Vol. 21, 2021

CiteScore of our journal for 2020 is **1.9 (ranking 70/153 in Material Science - Metal and Alloys)** according to the Elsevier SCOPUS service



22nd European Conference on Fracture - ECF22, 26-31.8.2018, Belgrade, Serbia: “Loading and Environment Effects on Structural Integrity” organized by the European Structural Integrity Society and Society for Structural Integrity and Life "Prof. Dr. Stojan Sedmak". 560 participant from 49 countries. Introductory plenary lecture by Jim Rice. **Summer School 25-26. August, 2018.** Two days event for PhD students, young researchers and engineers. 90 participants. Special lecture by Jim Rice on the ccasion of the 50th anniversary of J integral.

ESIS-Elsevier Young scientist Award
ESIS Awards - Call for proposals
Award for the best paper on WFM Galip
ESIS Support for Researchers Announcement*

ECF22-Belgrade

DIVK VIRTUAL CONFERENCE

Dedicated to 80th Birthday of J.R Rice

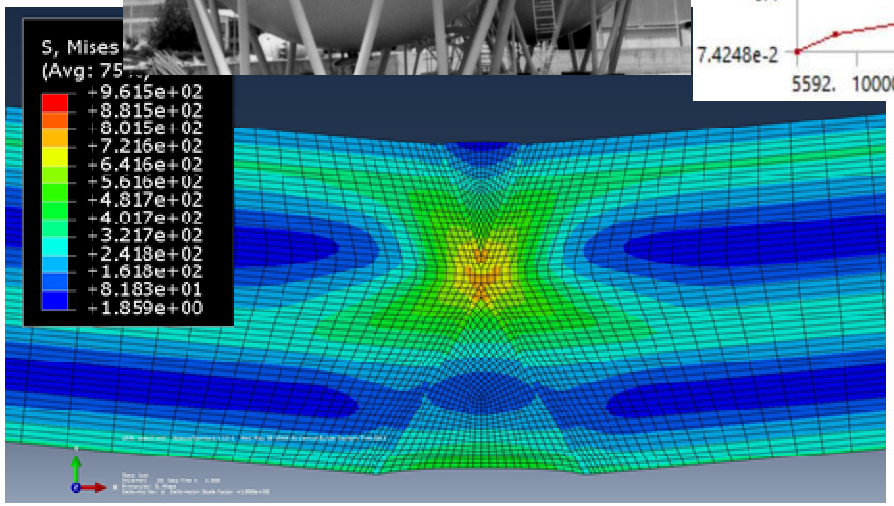
3. decembar 2020. godine

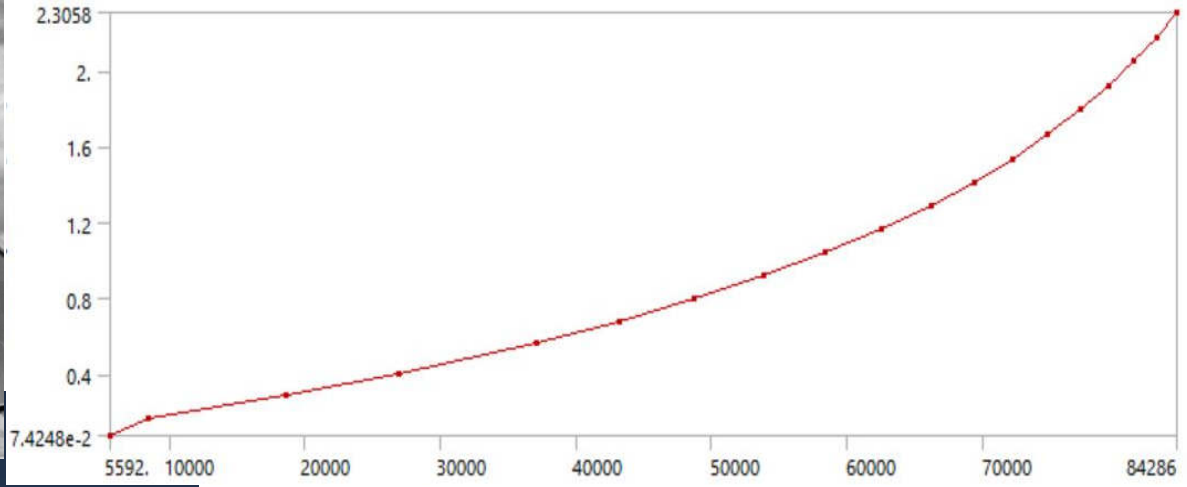
Youtube link: **LINKU.**

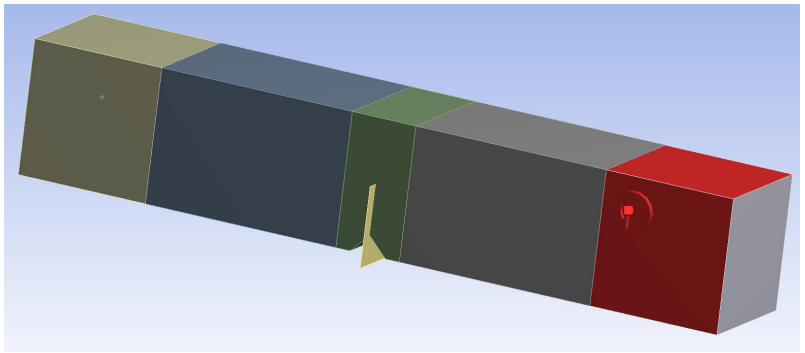
3.00 - 3.10 pm Introductory address –Francesco Iacoviello, ESIS president
3.10 - 3.40 pm Interface fracture mechanics –Leslie Banks-Sills, former ESIS president
3.40 - 4.00 pm J integral and its role in fracture mechanics - Aleksandar Sedmak, ESIS vice-president, DIVK president
4.00 – 4.20 pm Direct measurement of J integral for welded joint – Blagoj Petrovski, University of Belgrade
4.20 – 4.40 pm Interfacial energy as the driving force for diffusion bonding of ceramics – Sinisa Mesarovic, Washington State University
4.40 - 5.00 pm Fracture resistance of dental polymers - Miloš Milošević & Aleksa Milovanović, Innovation center of the Faculty of Mechanical Engineering, Belgrade
5.00 – 5.20 pm Fatigue of additively manufactured materials - Aleksandar Grbović, University of Belgrade
5.20 - 5.40 pm Instrumented Charpy testing and impact toughness - Vencislav Grabulov, director of the Institute of material testing, Belgrade

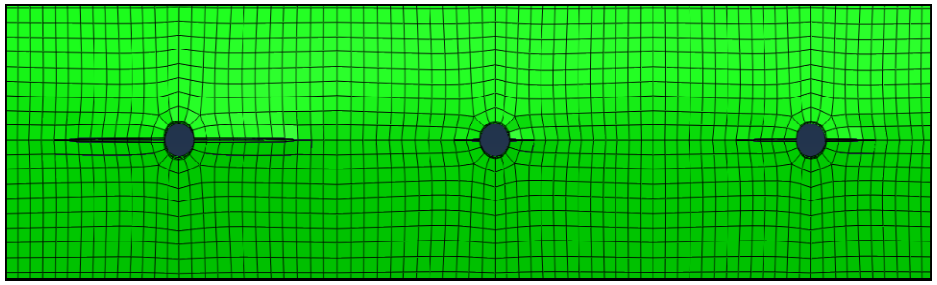
Recent activities

- More recent activities include numerical analysis of new and old experiments, e.g. Numerical Modeling of Full-Scale Penstock Model Testing in 2013 and later, presented at ECFs, TCs meetings, Summer Schools and conferences supported by ESIS.
- Experimental and numerical analysis of biomaterials (hip, fixing plates, teeth and fillings) – structural integrity and life estimation
- Experimental and numerical analysis of FCG, especially in welded joints
- Risk analysis of critical structures

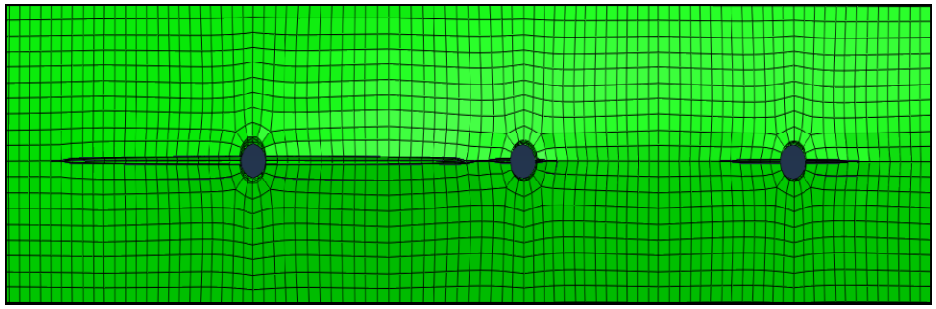




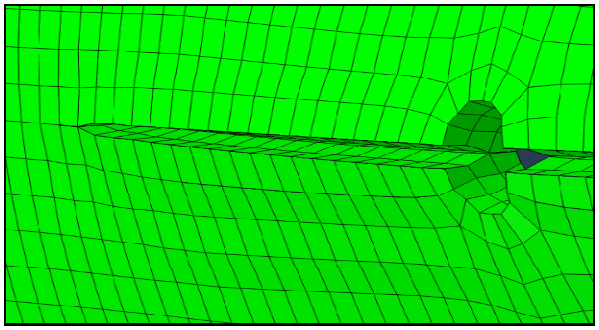




XFEM model after cracks opening (step 15), D=2.4 m

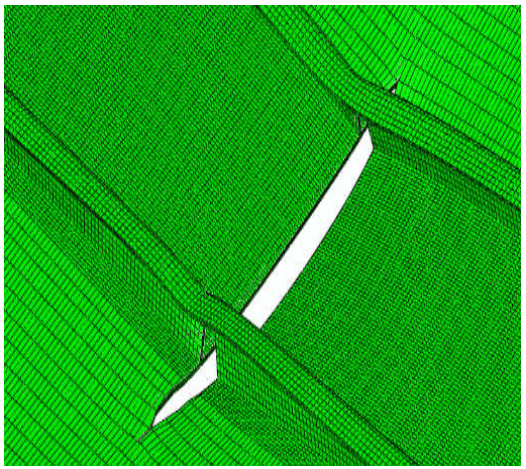
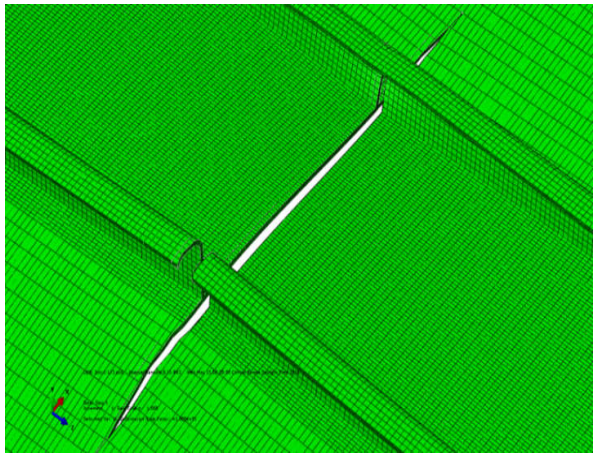


XFEM model after cracks opening (step 36), D=2.4 m

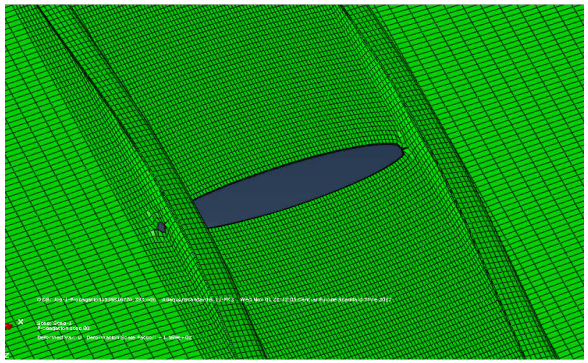
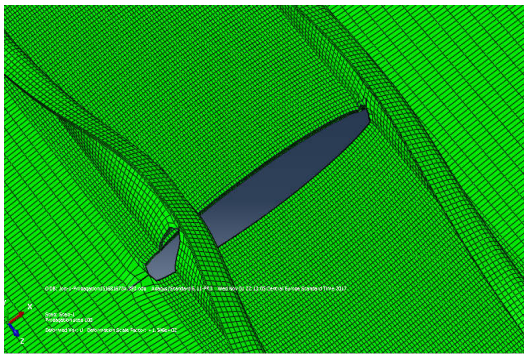
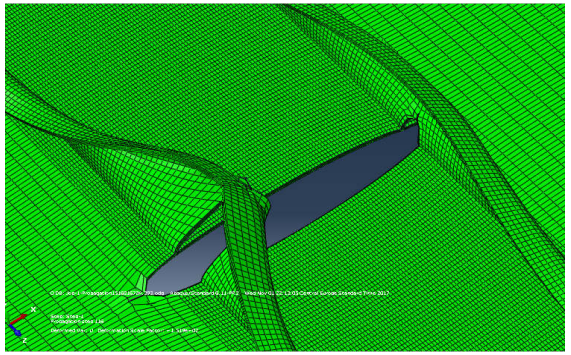


XFEM model presence of tearing mode (step 36), D=2.4 m

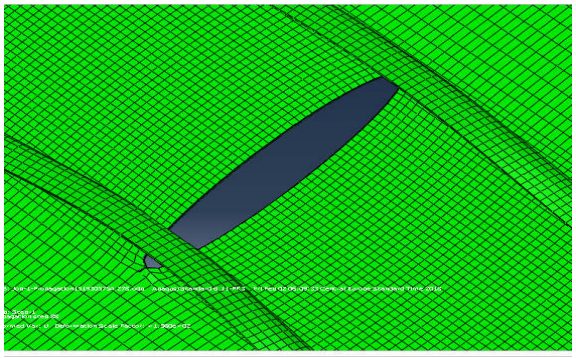
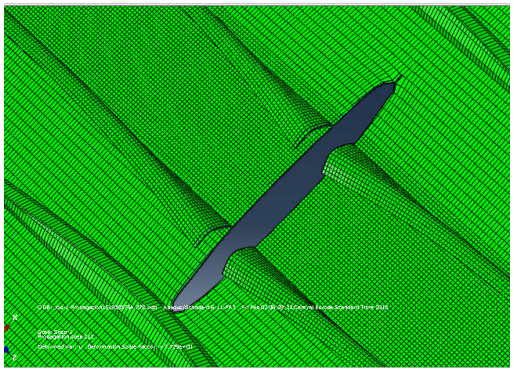
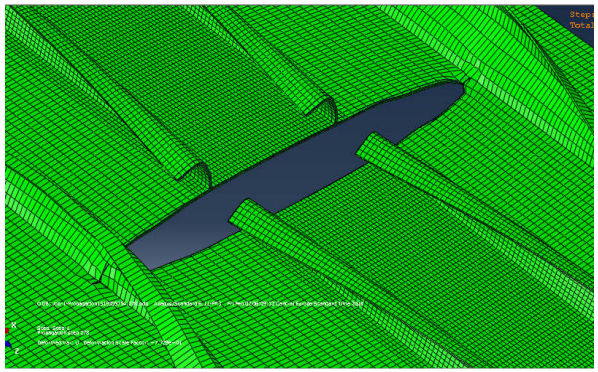
FCG in plate with 4 stringers
Mesh 1 mm 130, 160 steps

Mesh 2 mm 80, 100, 117 steps

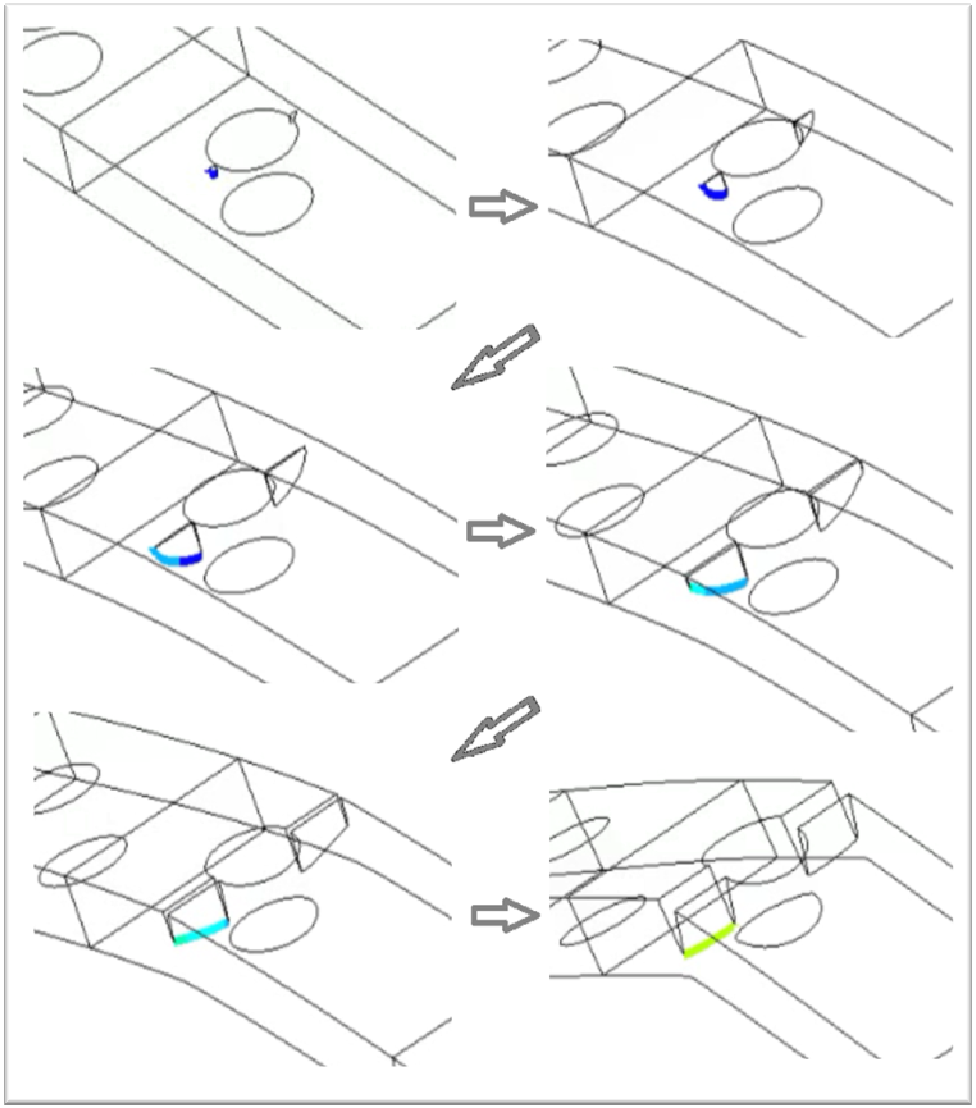




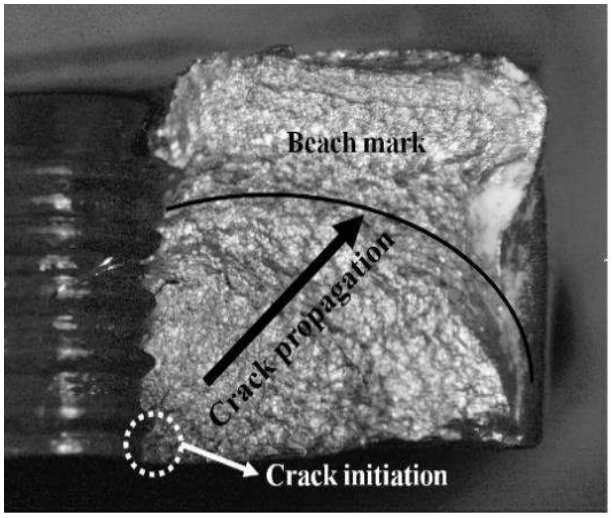
Mesh 4 mm 88, 212, 278 steps

FCG in orthopaedic plates

Maximal obtained crack length is more than 2 mm longer than the plate thick-nesses. This is explained by showing the crack propa-ga-tion path of plate A, given in figure right. In the begin-ning, crack propagates equally through the plate thickness and along the surface, up to the point where the crack predominantly starts propagating along the surface. When the crack gets along the surface to the full width of the plate it then continues with fast propagation through plate thickness, thus making the longer path then just 4 mm of the plate's thickness. Same crack path (striation marks) was noticed by 4-point bend testing of orthopaedic plate made of 316L stainless steel made by Mohajerzadeh S. et al. (2018).





Fatigue crack propagation in HIP implant 1st VECF, 2020

Fatigue crack growth was monitored, until the failure, as shown in Figures after 10 and 21 steps.

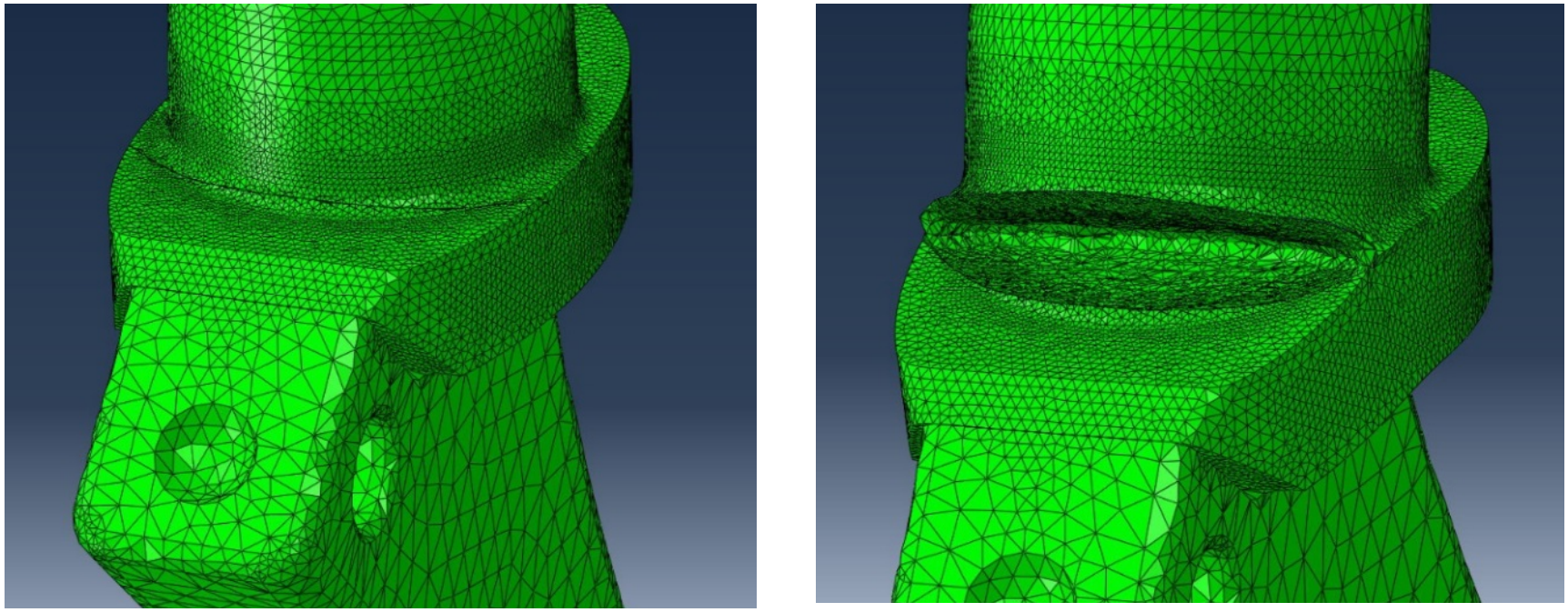


Fig. 18. Maximum value of crack length - step 10, crack growth over the entire length of prosthesis - step 21.

Fracture mechanics testing of AMM

I am just watching you….so we have to do our best!