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ICF11 Official speeches

Opening Address of the Chairman of the 11th International Conference on Fracture, Professor Alberto Carpinteri

Authorities, Dear Colleagues, Ladies and Gentlemen,

On behalf of the Organising Committee of ICF11, I am very pleased to introduce the 11th International Conference on Fracture, to be held in Turin, Italy, on March 20–25, 2005. ICF11 has been organised under the High Patronage of the President of the Republic of Italy, under the auspices of the Ministry of Infrastructures and Transportation of the Italian Government, and of the National Science Foundation of Italy (CNR), with the scientific support and sponsorship of worldwide leading Institutions in the fields of Fracture, Fatigue, Material Strength and Structural Integrity, like the International Congress on Fracture itself (ICF), the European Structural Integrity Society (ESIS), the American Society for Testing and Materials (ASTM), while the Italian Group of Fracture (IGF), the Politecnico di Torino and the Turin Academy of Sciences have taken the role of host organisations.

The conference is endorsed by a strong scientific programme and by the attendance of senior Scientists and younger Delegates coming from 53 different Countries. Besides the more traditional topics, the scientific programme will cover exciting and new developments such as scaling laws, nanomechanics, smart materials, biomechanics, geophysics and tectonics, infrastructure durability, damage and restoration of historical and monumental buildings.

Twelve Plenary Lectures will be delivered by well-known Speakers during the Opening, Plenary and Closing Sessions. 38 Keynote Lectures will be delivered by leading Scientists in the field of Fracture to characterise the topics of the Mini-Symposia, whereas nearly 1100 presentations are scheduled to take place during 228 Special and Contributed Sessions. This total is obtained by multiplying the 16 parallel sessions by the 14 working time periods of the conference, and adding four further events in the Auditorium. I would like to express my most sincere appreciation to the Organisers of the Special Sessions and Mini-Symposia as well as to the Referees of the papers.

The Lingotto Conference Centre, selected to host ICF11, is one of the largest in Europe, offering first-rate services. In addition, Turin – a very historic and artistic city but also a modern and dynamic one – is ready to receive you in the best way, as it will be for the Olympic Winter Games one year from now. I hope that you will also have an opportunity to visit other beautiful places and cities of Italy during your post-conference tours. I wish you an enjoyable stay in Italy.

Photo 1. Opening Address of Prof. Alberto Carpinteri, Chairman of the 11th International Conference on Fracture.

Photo 2. Opening Address of Prof. Yiu-Wing Mai, President of the International Congress on Fracture.

Opening Address of the President of the International Congress on Fracture, Professor Yiu-Wing Mai

Thank you very much, Professor Alberto Carpinteri. Ladies and Gentlemen, good morning again, welcome to this Quadrennial Conference of the International Congress on Fracture. It is nice to see so many old friends in the audience, but it is even more pleasing to see many new faces, young and dynamic, to join this Congress. It is perhaps timely on this occasion to revisit and reaffirm the aims and the philosophies of the International Congress on Fracture, when it was first founded by Professor Takeo Yokobori and his team of wise men in the 1960's. The three major aims as put up in the next slide have remained even truer today. On the integration of disciplines, the second aim has captured very well those new areas on fracture mechanics of nanomaterials and biomaterials, as well as smart materials used in infrastructure durability, to name but a few. The first aim is particularly valuable if we extend the definition of "public community" to include developing countries with fast economic growth, such as China, the East European block, and some Asian countries, on the necessity and awareness of structural safety, integrity, on codes and standards as enabled by fracture research to avoid disasters and catastrophes.

Over the years, many Presidents of ICF together with their Executive Committees have worked towards achieving those aims and objectives. Professor Yokobori is our Founder President, and he is here amongst us, sitting in the first row. Also present here are the past Presidents, Rob Ritchie and David Taplin. The first ICF was held in Sendai in 1965, and then every four years, in other cities, as shown in this slide. So, started from Sendai, Brighton, Munich, Waterloo, Cannes, New Delhi, Houston, Kiev, Sydney and Honolulu, we are now in Turin. We had eleven ICFs held in different countries spread over the continents. ICF 11 is our 40th anniversary after Sendai in 1965, and we have a very exciting and innovative programme in the next five days, as Professor Alberto Carpinteri already mentioned. I would like to take this opportunity to thank Professor Carpinteri and his team in putting the program together. I hope you will have, over the next few days, a most fruitful and rewarding time to

exchange scientific ideas and technical discussions, to meet new and old friends, and to visit this beautiful city of Turin. So welcome again to ICF11 and thank you very much.

Ceremony of Presentation of the Doctorate Honoris Causa in Civil Engineering to Professor B.B. Mandelbrot and to Professor G.I. Barenblatt by Professor Giovanni Del Tin, Rector of the Politecnico di Torino

It is my great pleasure to open the 11th Conference on Fracture, representing the Politecnico di Torino, which was the first Technical University to be founded in Italy, in the year 1859. Our Institution has always been very much involved in studies regarding material strength, structural integrity and, in recent years, fracture mechanics. Today, fracture mechanics is part of several different Master and Doctorate programs in Civil, Mechanical, Aeronautical, Chemical, Materials, Nuclear Engineering. The research work conducted on fracture at the Politecnico by young Post-Doctoral Research Fellows, as well as by senior Scientists, is remarkable and fruitful, as this significant event will also bear out.

This is the first ICF Conference to be held in Italy. Our manufacturing and infrastructural industries are really interested in the topics addressed at the conference, in that they affect the know-how and development of strategic fields: from aerospace to nuclear engineering, from nanotechnology to civil engineering, from geophysics to the maintenance of the architectural and archaeological heritage. The Italian academic environments are particularly proud of having organised such an important conference in Italy, and even prouder are our Colleagues from the Politecnico, for having brought ICF to the capital of Italian Industry.

Fracture mechanics can be considered – today, and even more so into the 21st Century – not solely as an important section of a discipline – Material Strength Theory – but rather as the discipline in itself. All the significant aspects of material and structural behaviour are described and analysed in terms of fracture mechanics concepts: creep, plastic deformation, ductile failure, brittle rupture, dimensional transitions, etc. At the same time, the range of structural types and materials dealt with by fracture mechanics is great and extremely diversified: from nanotubes to bridges, from metallic alloys to biological tissues, from fibre-reinforced materials to foams. In such a broad and global context, the boundaries between traditional disciplines – mathematics, mechanics, physics, material science, engineering – tend to fade and vanish. Today, in its maturity, Fracture Mechanics appears interdisciplinary and complex, and, for these very reasons, one of the most challenging research topics in Science.

Two eminent and very well-known Scientists, who have made outstanding and seminal contributions to the Science of Complexity, will give today the Opening Lectures of the conference, and, at the same time, their *Lectiones* for a Doctorate Honoris Causa in Civil Engineering from the Politecnico di Torino: Benoit B. Mandelbrot and Grigory I. Barenblatt. Their names are very famous in different areas of human knowledge. They both utilised and, in some cases, created new concepts and tools – such as nonlinear dynamics, deterministic chaos, fractal geometry, intermediate asymptotics – to describe and capture different natural phenomena – such as turbulence and fracture. A common aspect in Fluid and Solid Mechanics, in fact, is the transition from stability to instability with increasing specimen size-scale: in the

former case, we have a transition from laminar to turbulent flow; in the latter, a transition from ductility to brittleness prevails. Such fundamental trends, that no single phenomenological model will fully explain, can only be accounted for by the more comprehensive and synthetic view of dimensional analysis, fractal geometry, intermediate asymptotics, renormalization group theory.

Photo 3. Presentation of the Doctorate Honoris Causa in Civil Engineering to Prof. Benoit Mandelbrot. From left to right: Prof. Mandelbrot, Prof. Carpinteri (Chairman of ICF11), Prof. Francesco Profumo (Dean of the 1st Faculty of Engineering of the Politecnico di Torino), Prof. Giovanni Del Tin (Rector of the Politecnico di Torino).

Photo 4. Presentation of the Doctorate Honoris Causa in Civil Engineering to Prof. Grigory Barenblatt. From left to right: Prof. Carpinteri, Prof. Barenblatt, Prof. Profumo, Prof. Del Tin.

Ceremony of Presentation of the Doctorate Honoris Causa in Civil Engineering to Professor B.B. Mandelbrot and to Professor G.I. Barenblatt by Professor Francesco Profumo, Dean of the 1st Faculty of Engineering

First of all, I would like to say that the 1st Faculty of Engineering of the Politecnico di Torino is really very proud to confer a honorary degree upon Professor Benoit B. Mandelbrot and Professor Grigory I. Barenblatt. They both have been active in several different areas of Engineering, and even in others that are usually considered external to the Engineering context. For this reason, the Doctorate Honoris Causa in Civil Engineering that today will be conferred upon them may even be regarded as exceedingly specific or limited. On the other hand, they both have made outstanding and admirable contributions to Civil Engineering.

Quoting from the minutes of the meeting of the Council of the 1st Faculty of Engineering of June 18, 2004:

> *"Benoit B. Mandelbrot, founder of Fractal Geometry and pioneer of Complex Systems Mathematics, is a figure of outstanding achievement in all the areas of Applied Science. In the field of Civil Engineering, he has made substantial contributions to the sectors of Geomorphology, Orography, Topography and Solid Mechanics. In particular, through the identification of the fractal nature of fracture surfaces, he paved the way for the attainment of fundamental results such as the definition of*

the role of microstructural disorder and the scale effects on the fracture energy of materials".

Professor Mandelbrot can be viewed as the successor to great mathematicians of the past (Cantor, Sierpinski, Menger, von Koch, Hausdorff, Besicovitch, Weierstrass, Peano). They considered as monstrous, pathological or strange the irregular and self-similar sets that represent the rough and jagged character of natural objects. Usually, these sets are characterised by noninteger physical dimensions, intermediate between isolated points and continuous lines, or between lines and surfaces, or between surfaces and volumes.

Quoting again from the same official resolution of the 1st Faculty of Engineering:

"Grigory I. Barenblatt, a scientist characterised by an outstanding range of interests, is an international figure of great stature in different areas of Physics, Mathematics and Engineering. Always grounded in brilliant mathematical insights, his theories have become an absolute term of reference in the literature. In the field of Civil Engineering he has made fundamental contributions to the sectors of Hydraulics, Solid Mechanics and Fracture Mechanics, including, in particular, the cohesive crack model, then successfully applied to most of the materials of technological significance".

Professor Barenblatt extended and generalised the concepts of dimensional analysis, giving a solution to different problems of mathematical physics and an explanation to empirical formulas with noninteger and irrational exponents. He gave a systematic organisation to these problems and showed how his theory of intermediate asymptotics – as well as fractal geometry and renormalization group theory – always lead to power-laws or scaling laws in space and time. Among the problems he addressed we should mention: turbulence, diffusion in porous media, explosions, nonlinear wave propagation, fracture, fatigue. He can be considered as the successor to legendary figures such as Theodor von Karman and G.I. Taylor.

Laudatio to Benoit B. Mandelbrot by Professor Alberto Carpinteri

This Opening Ceremony of ICF11 and the conferring of Honorary Degrees on Benoit B. Mandelbrot and Grigory I. Barenblatt is a consequence of the direction indicated by our Founder President, Professor Takeo Yokobori, to devote future research efforts on the strength and fracture of materials as Complexity Science and Engineering.

"Why is geometry often described as cold and dry? One reason lies in its inability to describe the shape of a cloud, a mountain, a coastline, or a tree. Clouds are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightning travel in a straight line". With these words Benoit B. Mandelbrot opened his well-known essay "The Fractal Geometry of Nature" (1982). In the natural world, he observed and surveyed irregularities, tortuosities and discontinuities, that appeared on any scale and could not be described and analysed

through Euclidean geometry or classical infinitesimal calculus. In this connection, Mandelbrot disagrees with Leibniz's idea: "Natura non facit saltus".

His paradigm of Fractal Geometry, with self-similarity and noninteger physical dimensions of the related sets, strives to reproduce natural phenomena, with their intrinsic roughness and disorder, in space and time.

After studying in Lyon (France), Mandelbrot entered the Ecole Normale in Paris, and then continued his studies at the Ecole Polytechnique (1944) under the supervision of Paul Lévy, an eminent Scientist in Statistical Mechanics. After completing his studies in Paris, Mandelbrot went to the United States, where he visited the California Institute of Technology (1947), and then spent one year at Princeton University, Institute of Advanced Study, under the guidance of John von Neumann (1953). In 1958 he moved to the U.S. on a permanent basis and began his long standing and most fruitful collaboration with IBM at their world renowned laboratories in Yorktown Heights (NY State). This environment allowed him to explore a wide variety of fields and ideas.

Mandelbrot's decision to make contributions to several scientific domains was a deliberate choice, which he made at a young age. During his long scientific life, he has investigated problems in the fields of linguistics, communication errors, computer graphics, fluid dynamics, geophysics, cosmology, finance and economics, and so on. After ritiring from IBM, he found similar opportunities at Yale University (1999), where at present he is Sterling Professor of Mathematical Sciences (first tenured University position). He has also been Visiting Professor at Harvard University and many other prestigious Institutions in the world. Professor Mandelbrot has received numerous honours, including fifteen (15) Honorary University Degrees. The principal motivation is that he seeks a measure of order in physical, biological and social phenomena that are characterized by abundant data but extreme sample variability. In 1994, he delivered the "Vito Volterra Lecture" at the Accademia Nazionale dei Lincei in Rome.

In 1984, with D.E. Passoja and A.J. Paullay, Mandelbrot published his famous paper entitled "Fractal character of fracture surfaces of metals" on the journal *Nature* (Vol. 308, pp. 721–722).

The fractal character of fracture surfaces (invasive fractals of dimension > 2) as well as of cross-sectional ligaments (lacunar fractals of dimension < 2) enabled our research group to recognise a fundamental reason for scale effects on fracture energy and tensile strength.

When the scale of observation approaches zero (as at the micro- or nano-scale), nominal fracture energy tends to zero, whereas nominal tensile strength tends to infinity.

It is therefore with a sense of scientific gratitude that today I can read again a sentence from Professor Mandelbrot's fundamental essay, which encouraged me to work along these lines:

"Almost every case study we perform involves a *divergence syndrome*. That is, some quantity that is commonly expected to be positive and finite turns out either to be infinite or to vanish. At first blush, such misbehavior looks most bizarre and even terrifying, but a careful reexamination shows it to be quite acceptable... as long as one is willing to use new methods of thought" (*The Fractal Geometry of Nature*, W.H. Freeman and Company, New York, 1982, page 19).

Laudatio to Grigory I. Barenblatt by Professor Alberto Carpinteri

"A very common view is that these scaling or power-law relations [in mathematical physics and in engineering] are nothing more than the simplest approximations to the available experimental data, having no special advantages over other approximations. It is not so. Scaling laws give evidence of a very deep property of the phenomena under consideration – their *self-similarity*: such phenomena reproduce themselves, so to speak, in time and space... These powers appeared generally speaking to be certain transcendental numbers rather than simple fractions as for classical self-similarities".

This sentence is taken from the Preface to the well-known book by Professor Barenblatt entitled "Scaling, Self-similarity and Intermediate Asymptotics" (1996), where the Author distinguishes between complete and incomplete self-similarity.

In the former and ideal case, the power-law solutions can be obtained through classical dimensional analysis, whereas in the latter, and more realistic, case, the solutions can be obtained in a more sophisticated way and present anomalous and irrational exponents. This should be considered as an original and fundamental justification for the so-called "empirical" formulas of Applied Science and Engineering.

Grigory I. Barenblatt took his Ph.D. from Moscow University in 1953, under the guidance of Andrej N. Kolmogorov, a famous Scientist in Statistical Mechanics. He became Professor at the same University in 1962. From 1961 to 1975 he was Head of the Division of Plasticity at the Institute of Mechanics. From 1975 to 1992 he was Head of the Theoretical Department at the Institute of Oceanology of the USSR Academy of Sciences.

Since 1990 he has been Visiting Professor at many Western Universities:

Université de Paris VI, Pierre et Marie Curie (1990);
University of Minnesota, Minneapolis (1991);
Rensselaer Polytechnic Institute, Troy-NY State (1991);
University of Rome "Tor Vergata" (1992);
University of Cambridge, G.I. Taylor Professor of Fluid Mechanics (1992–1994) – this was the first time this title was assigned (Emeritus since 1994);
Universidad Autonoma de Madrid (1993);
University of Illinois at Urbana Champaign (1995);
Stanford University, Timoshenko Visiting Professor (1996–1997);
University of California at Berkeley, Professor in Residence (1996–);
Lawrence Berkeley National Laboratory (1997–).

Professor Barenblatt has received numerous honours. He is a Foreign Member of different National Academies, in the US, Denmark, Poland, the UK. He received a Doctorate Honoris Causa from the Royal Institute of Technology in Sweden, and, among many others, two prestigious awards from Italy (both in 1995): the Lagrange Medal from Accademia Nazionale dei Lincei in Rome, and the Panetti Prize from Accademia delle Scienze of Turin.

In 1959 Grigory I. Barenblatt published a series of papers titled "On equilibrium cracks formed in brittle fracture", with different sub-titles. A fundamental

mathematical model of elastic body was introduced, simulating cracks and explicit cohesive closing forces in the crack tip region. Such forces cancel the stress-singularity and make the model stable.

In the following years, G.I. Barenblatt considered self-similarity and scaling laws in fracture and fatigue. In particular, as he will clarify in his *Lectio*, he focused on scaling in fatigue crack growth, with reference to the Paris & Erdogan Law, which is a power-law with an anomalous exponent, m.

As regards Fracture Mechanics, the critical vision of G.I. Barenblatt is very similar to that of B.B. Mandelbrot: fracture is a complex and multiscale phenomenon, that we can fully understand and dominate only by making use of appropriate and refined conceptual tools.

Photo 5. Closing Address of Prof. Robert Ritchie, Member of the Organizing Committee.

Photo 6. Closing Address of Prof. Krishnaswamy Ravi-Chandar, the new President of the International Congress on Fracture.

Closing comments

I am honored and pleased to be elected as President of the International Congress on Fracture for the next 4 years. I share this honor with members of the Executive Committee, Professors Alberto Carpinteri, Bhushan Karihaloo and Robert Goldstein as Vice Presidents, Professors Leslie Banks Sills, Elisabeth Bouchaud, Teruo Kishi, Shou-wen Yu, and Robert McMeeking as Directors, Professor Toshimitsu Yokobori, Jr. as the Secretary General and Professor David Taplin as the Treasurer. Professor Yiu-Wing Mai and his team are to be thanked for their excellent service to ICF during the past 4 years. Also, I would like to thank Professor Alberto Carpinteri and his colleagues for their excellent organization of the 11th International Conference on

Fracture, here in Turin; this conference has been the largest in the series of ICFs and a very stimulating conference.

It would not be an exaggeration to claim that advances in fracture control represent one of the crowning achievements of the 2nd half of the 20th Century. We have developed a deeper understanding of material strength and durability, developed better materials and models, improved methods of analysis, experimentation and simulation, developed strategies for structural integrity assessment and lifetime prediction, etc. So much so, that our scaling laws have enabled us to do better than nature! We have altered the landscape (mostly for the better) and built structures that are large and strong to accommodate our needs; while our methods of locomotion are perhaps not as efficient as nature's own, they certainly are more capable, flexible and reliable. Witness the fact that a thousand delegates from around the world were able to assemble in this venue for the sake of scientific knowledge and information. The safety and reliability of these endeavors are ensured by the fracture theories advanced by this community.

All of these accomplishments have had such an impact that ours may appear to be an aging discipline – sadly, there appears to be an overall decline in funding for fracture research within the United States and other countries are likely to follow soon. Indeed there is a growing sense that there is nothing more to be done in fracture research! However, this 11th quadrennial International Conference on Fracture has pointed out the fallacy of such pessimism. Fracture research is vibrant and it touches vast areas of human endeavor; fracture occurs over a wide range of scales in diverse applications as highlighted by the many plenary lectures: Professor Bill Gerberich on nanoscale problems, Professor Huajian Gao on biophysics applications, Professor Ares Rosakis on geophysical applications, Professor Hiroyuki Abe on microelectronics, Professor Murakami on the effects of fracture on a hydrogen economy, just to mention a few topics. The plenary lectures and the focused symposia at this meeting highlighted all of these areas that have just begun to be explored and remain as fertile ground for us to plough further. So, I am excited about being President of ICF at this juncture and hope to be able to promote the organization and the discipline in these interesting times.

The next conference – the 12th International Conference on Fracture – will be held in July 2009 in Ottawa, Canada, under the able leadership of Drs. Bill Tyson and Mimoun Elboujdaini, and I hope to see all of you there!

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