

Theoretical and Applied Mechanics 1992

edited by

S.R. Bodner
J. Singer
A. Solan
Z. Hashin

IUTAM



North-Holland

THEORETICAL AND APPLIED MECHANICS 1992

INTERNATIONAL UNION OF THEORETICAL
AND APPLIED MECHANICS

THEORETICAL AND APPLIED MECHANICS 1992

*Proceedings of the XVIIIth International Congress of Theoretical and Applied Mechanics,
Haifa, Israel, 22-28 August 1992*

Edited by
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PREFACE

This book contains the Proceedings of the XVIIIth International Congress of Theoretical and Applied Mechanics, held at the Technion, Israel Institute of Technology, Haifa, August 22-28, 1992. The Congress was held under the auspices of The International Union of Theoretical and Applied Mechanics (IUTAM) by invitation of The Israel Society for Theoretical and Applied Mechanics and Technion, Israel Institute of Technology and under the sponsorship of the Israel Academy of Sciences and Humanities.

The full text of the two General Lectures, of introductory lectures of the three minisymposia and of sectional lectures, according to the list on pages xi, xii, are included in this volume. The contributed papers are listed by author and title; most of them will be published in appropriate scientific journals.

The publication of these Proceedings has been handled promptly and very capably by Elsevier Science Publishers B.V. and their editors to whom we are very grateful.

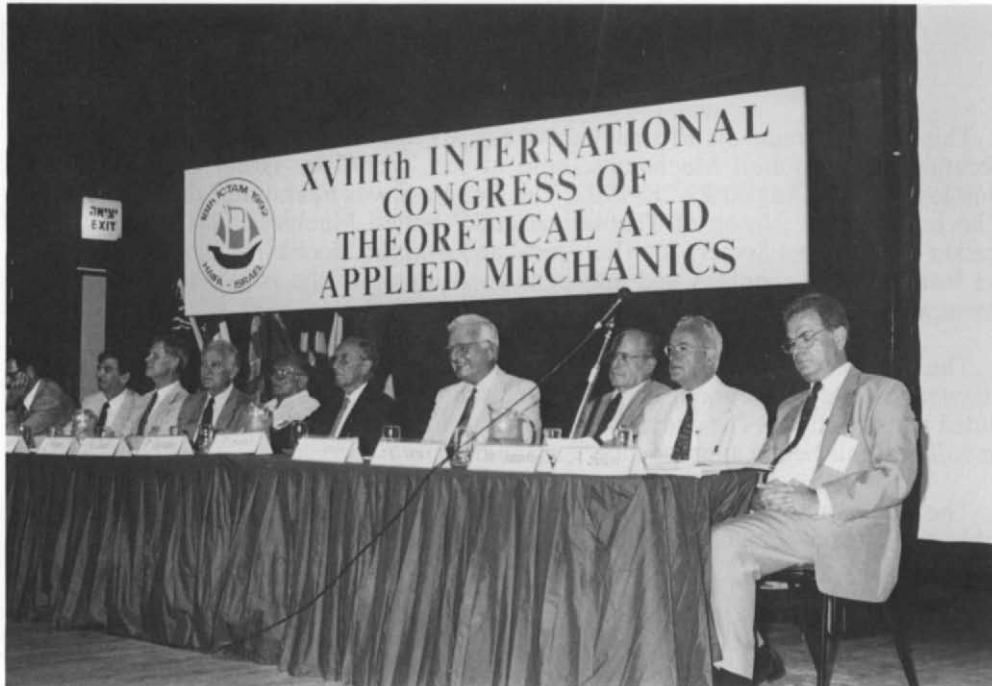
Josef Singer

Sol R. Bodner

Alexander Solan

Zvi Hashin

Haifa
December 1992



The Opening Ceremony, on the podium from right to left:
A. Solan, L. van Wijngaarden, S.R. Bodner, J. Lighthill, P. Germain,
Mayor A. Gurel, J. Singer, H.K. Moffatt, Z. Hashin, W. Schiehlen.



View of the audience at the Opening Ceremony



Professor J. Singer, Chairman of the Local Organizing Committee



Professor P. Germain, President of IUTAM



H.K. Moffatt and M. Kiya



L. van Wijngaarden, Z. Hashin and M. Sayir



Mrs. N. Bodner, G.I. Barenblatt, S.R. Bodner



J.T. Stuart and T. Tatsumi

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The following academic, public, and industrial organizations have provided financial support:

- The Israel Academy of Sciences and Humanities
- Technion, Israel Institute of Technology
- Ben Gurion University of the Negev
and the Pearlstone Center for Aeronautical Engineering Studies
- Tel Aviv University
- Zurich Chapter of the Swiss Technion Society

- Israel Ministry of Defense, (MAFAT)
- Israel Ministry of Science and Technology
- Israel Ministry of Trade and Industry
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Support for the

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was provided by the

- European Office of Aerospace Research and Development, United States Air Force

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REPORT ON THE CONGRESS

Josef Singer

The decision to accept the invitation from Israel to hold the XVIIIth International Congress in Haifa was taken by the Congress Committee of IUTAM during its meeting in Grenoble in August 1988. It was decided that the format of the Congress would follow the one adopted for the recent successful Congresses in Lyngby and Grenoble. The Congress would cover the entire field of mechanics with special emphasis on three selected topics to constitute the so-called minisymposia.

The Congress Committee selected the following three topics for these minisymposia:

1. Instabilities in Solid and Structural Mechanics.
2. Sea Surface Mechanics and Air-Sea Interaction.
3. Biomechanics.

The Congress Committee also selected two general lecturers: Professor Anatol Roshko (USA) to present the Opening Lecture and Professor G.I. Barenblatt (Russia) to present the Closing Lecture; as well as 15 Sectional Lectures. The chairmen of the Minisymposia further selected 9 Introductory Lectures for their symposia.

As in Lyngby and Grenoble, the contributed papers were presented in parallel sessions, either as 25 minute lectures or in poster-sessions which were scheduled separately from the lectures. There were lively discussions both after the lectures and in the poster-sessions, where the second half of the sessions were devoted to general discussions guided by the chairmen.

The Opening Session of the Congress was held in the Churchill Auditorium of the Technion at 10 o'clock on Sunday, 23rd August, 1992. The Session was opened by Professor Josef Singer, Chairman of the Local Organizing Committee of ICTAM '92, with the following words:

"Distinguished Members of the Dais, Ladies and Gentlemen,

It gives me great pleasure to open the 18th International Congress of Theoretical and Applied Mechanics and to greet this outstanding gathering of scientists and engineers which will ensure the success of the Congress.

Welcome to Israel, to Haifa and to the Technion, Israel Institute of Technology.

Let me also greet you in Hebrew (welcome to participants).

I think you will understand me better if I do not continue in Hebrew. Maybe by the time we come to the Closing Session, your Hebrew will be good enough to permit me to address you all in our language.

So let me introduce you to the Dais:

I will start at the far end of the Head Table. There are the Deans of the two Technion Faculties which are most active in Mechanics:

Professor Blech, Acting Dean of the Faculty of Mechanical Engineering, and Professor Shinar, Dean of the Faculty of Aerospace Engineering.

Next, the Secretary-General of IUTAM, Professor Schielen of Stuttgart University, who is entrusted with the many IUTAM Symposia and other IUTAM activities.

To his left, the President of the Israel Society for Theoretical and Applied Mechanics, Professor Hashin of the Faculty of Engineering of Tel Aviv University, an active member of our Organizing Committee.

Next, the Secretary of the IUTAM Congress Committee, Professor Moffatt of Cambridge University, whose guidance and tireless efforts have been essential to the success of the scientific program and the preparations of the Congress.

To his left, the Mayor of our beautiful city, Haifa, Mr. Gurel, who graciously supports our meeting and many other international activities.

Then our IUTAM President, Professor Germain, of the French Academy of Science, whom many of you also remember as the Organizer of the successful Congress in Grenoble in 1988.

To his left, Professor Paul Singer, Senior Vice President of Technion, who will soon bring to you the greetings of the Technion President.

Then the IUTAM Vice President, Sir James Lighthill, the past IUTAM President and former Vice Chancellor of University College London.

To his left, Professor Bodner of our Faculty of Mechanical Engineering, the Co-Chairman of our Local Organizing Committee, who gave his time and knowledge untiringly and thus contributed so much to our Congress.

Then the Treasurer of IUTAM, Professor van Wijngaarden of the University of Twente in The Netherlands, whose importance is self-evident.

And last, but certainly not least, the wonderful Secretary of our Local Organizing Committee, Professor Alex Solan, Technion Vice President for Academic Affairs, with whom most of you have already corresponded and without whose outstanding and never ending work we could not have carried out the preparations for the Congress.

ICTAM Participants, as I look around me I see many friends, the top scientists of the international mechanics community, the international mechanics family. I am sure that our deliberations will not only advance our field, but will also weave many new collaborations and friendships.

For the benefit of the delegates who are new to ICTAM, I would like to ask some of the former IUTAM Presidents to please rise: Professor Frithiof Niordson of Denmark, and Professor Daniel Drucker of U.S.A.

To finish the introductions, it gives me great pleasure to see here among us, my former teacher and good friend, Professor Nicholas Hoff of Stanford University, who taught me the meaning of theoretical and applied mechanics and much more, and whom many of you will remember as the President and Organizer of our 1968 Congress at Stanford. Please rise Nicholas.

Friends, I may have taken up some time with these introductions, but I remember that at the first ICTAM I attended in Stresa in 1960, seeing the great names in the flesh was, indeed, a great experience!

Ladies and Gentlemen, we Israelis are honored and happy to host the 18th International Congress of Theoretical and Applied Mechanics in our old-new Land.

Though the ancient Israelis are better known for their Monotheism than for their achievements in mechanics, one finds that they tried their hand in some large scale experiments in mechanics.

For example, in the Book of **Exodus** we hear that in their flight from Egypt, the Children of Israel (with some assistance from the Almighty) experimented with sea-air interactions, for we read in Exodus 14/21,22:

"And Moses stretched out his hand over the sea and the Lord caused the sea to go back by a strong east wind and made the sea dry land and the waters were divided".

"And the Children of Israel went into the midst of the sea upon the dry ground, and the waters were a wall unto them on their right and on their left".

Would this not fit into our second Minisymposium?!

Or, in the Book of **Joshua**, we hear of an early experiment in the dynamics of sound waves, for we read in Joshua 6/5:

"And it shall come to pass, that when they make a long blast with a ram's horn, and when ye hear the sound of the trumpet, all the people shall shout, and the wall of the city shall fall down flat".

So, there was some mechanics activity here 3,500 years ago!

In modern times, Israel has a small but very active mechanics community, whose presence and achievements are known internationally, and whose participation in IUTAM Congresses and Symposia has been very significant.

At the Technion we were fortunate to have had Professor Marcus Reiner, well known as one of the Fathers of Rheology, active here from 1947-1976. He built a thriving department of mechanics, that later diffused into other departments.

In 1961 Professor Reiner organized an IUTAM Symposium on "Secondary Effects in Elasticity, Plasticity and Fluid Dynamics", in Haifa (by the way, my wife worked with him on the organization of that symposium) a symposium which was the occasion of the first visit to Israel for some of you.

In 1985 Professors Bodner and Hashin organized another IUTAM Symposium on "Mechanics of Damage and Fatigue", at Technion, which was also very successful.

Hence, an ICTAM at Haifa seem to follow logically. Well, some of us in the audience have aged a bit since the first time Israel offered to host ICTAM many years ago, but I am happy that we all made it finally!

We have, I believe, an excellent scientific program thanks to you the contributors and to the excellent work of our International Papers Committee. As you know, the choice was difficult and the 600 papers chosen out of 1,183 submitted originated in 48 different countries. However, as we had many and continuous changes, even in the number of countries, the program you have could be finalized only two weeks ago.

The flags on the platform represent all the countries from which papers were accepted. The flags indicate origins of papers, but we are all here as individuals, contributing to theoretical and applied mechanics. Individuals whose friendship and collaboration will be reinforced by this Congress and who will assist in bringing our nations closer and improve their relations.

Before closing, I would like to thank the IUTAM Congress Committee, and in particular its Executive Committee, the IUTAM Bureau, the International Papers Committee, as well as the different National Committees. I will express my gratitude to my local collaborators, who worked so hard to prepare the Congress, in more detail at the Closing Session. For now, only

sincere thanks to you, my colleagues of the Local Organizing Committee and to the devoted staff of the Technion and Kenes teams who will also look after us in the coming days.

I would also like to thank the Israel Academy of Sciences and Humanities, the various Israeli government ministries, our municipality, and the Haifa Tourist Board, the universities and industrial companies, whose names appear on the program and, in particular, the U.S. Air Force European Office of Aerospace Research and Development, and the U.S. Army European Research Office, for their generous support.

As you know, the Israel Academy is one of the sponsors of our Congress. Its President, Professor Joshua Jortner, who is abroad, sent us his greetings which I would like to read to you:

"The Israel Academy recognizes the important contribution international meetings make to the advancement and excellence of research, by providing a forum for direct contact between scientists and engineers engaged in high quality scientific endeavor.

I am confident that the 18th International Conference in Theoretical and Applied Mechanics will contribute to the advancement and the enhanced cooperation in these exciting and important fields of scientific and technological research. The integration of science and technology which is so well reflected in your Conference is of prime importance for Israel and for the international community at large.

Please convey my compliments, on behalf of the Israel Academy of Sciences and Humanities, to all the participants.

I wish you a fruitful and stimulating meeting."

Ladies and Gentlemen, I concur with Professor Jortner, and wish us all, delegates and accompanying persons, a fruitful and enjoyable Congress, and a very pleasant stay in Israel. Thank you."

Professor Singer then called on Professor Solan, the Secretary of the Local Organizing Committee, to introduce the speakers who followed.

Mayor Gurel then brought the greetings of the Municipality of Haifa to the Congress participants and wished them successful deliberations and a pleasant stay in Haifa and Israel.

Since the President of the Technion was abroad, the Senior Vice President, President Paul Singer, greeted the assembly with the following words:

"Distinguished Guests and Friends,

It is my privilege and honor to welcome you, participants of the International Congress of Theoretical and Applied Mechanics to the Technion - Israel Institute of Technology, with the traditional Hebrew greeting - "Blessed be those who came". - This Congress is the XVIII th in a series which started in Delft, Netherlands and carries with it by now a most famous tradition. We are therefore *very proud* and consider it a great distinction, that for the first time the Congress convenes in Israel, and the Technion Management is especially proud that our scientists have been entrusted with the task of organizing and hosting this event.

But, there is another "FIRST" which I would like to point out to you. A perusal of the previous sites shows that you are meeting for the first time at an altitude of several hundred meters above the sea level, - I am confident this will bring to this Meeting "Scientific heights" previously unknown. You have certainly chosen a very unique location: Mount Carmel (on one of its hills we are here) - was mentioned already a few thousand years ago. For instance, in the Book of Jeremiah one finds "To the CARMEL by the sea, - one comes". This mountain is perceived and mentioned from very, very old times as a "SAFE SHORE". The ancient

Egyptians used to call it "The Holy Summit" and the famous Egyptian Emperor (Pharaoh) Ramses the Second, nicknamed it in the 13th Century B.C., "The Mountain of Strength". Possibly the most famous personality associated with it is the Prophet Elijah who used to prophesize and build his favorite models and theories and indoctrinate his followers right here on these hills. I mention this, since in the Ninth Century B.C., during the reign of King Ahab of Israel, a very famous Assembly was organized by the Prophet Elijah on Mount Carmel in the presence of the King, possibly the precursor of the subsequent scientific conferences held on this mountain. About 850 people attended that famous Assembly, not very different from the attendance of this Congress, at which some ideological differences (theories or approaches in our present language) were confronted. Well, here the parallel stops, since meetings in those times could have very violent endings as happened in the Assembly convened by King Ahab.

Interestingly, the location of Prophet Elijah's home-cave is determined to be in two different places, some 300 meters apart, by the Christian and Jewish faith. Given the distance of nearly 3000 years on the time scale, this is pretty good accuracy.

Referring anew to your Congress series, I was struck by an interesting historical coincidence. The first ICTAM took place in DELFT in 1924, and in the very same year our University, the Technion, opened its gates for business, enrolling its first 14 students with 7 Faculty members (a pretty good ratio we did not succeed in maintaining) - as the first University in modern Israel - it was followed less than a year later by the Hebrew University of Jerusalem. So, the date of your first Congress is also a cornerstone in the history of Modern Israeli Culture.

Today, we have 19 Faculties and Departments, and a number of Research Institutes, in most fields of Engineering and Sciences, as well as Architecture and Medicine. There are now over 10,000 students at the Technion, among them nearly 3,000 postgraduate students researching and studying for higher degrees. We have about 700 full-time Faculty members and many hundreds of associated scientists and adjunct teachers. I hope you will have the chance to visit and meet some, though this is the week of our annual vacation.

As you know, Israel is a country of small size and limited natural resources. As such, we put special emphasis on Science and Technology, the prime component in our strive to economic independence and the building of an advanced society. In this context, we considerably value international cooperation of which scientific congresses are an important form.

The recent political changes in the world have opened new avenues for international cooperation and for us in Israel they have significant implications. A sizable part of the scientific world was practically unreachable for us; this has changed completely during the last couple of years, - as the composition of this assembly, I believe, shows. Moreover, the energetic pace of European unification and the related developing of special technological and scientific collaboration schemes of international impact is also of great relevance for us. As a result, we are undergoing here a process of orientation towards a multitude of new opportunities, and I am confident that the outcome will benefit all those involved.

Maybe I should also mention that on historic scales (I already mentioned history before) the direction of international exchanges has gone through cycles. Today, there is no doubt that the leading Mecca's for Science and Technology are mostly in Europe and the United States of America. In his Nobel acceptance speech in 1979, the Pakistani physicist, Abdus Salam, from Imperial College, London, described through individual examples the clear direction of technology transfer in the early centuries of this millennium. He mentioned the cases of Michael the Scott and the Danish physician Henrik Harpestraeng who travelled in the 13th Century from the underdeveloped countries of the North to the flourishing Universities of the South, Toledo, Cordoba. In these places the Arabic and Hebrew Scholarship was then at its peak, and scholars were attracted to these and other Southern Universities from both the developed countries of the Middle East and Middle Asia, as well as from the developing northern countries.