

Preface

Computational techniques and methods are evolutionary field from macroscopic-level to nano-level, using continuum and discrete mechanics. It is necessary for scientist and engineers to come together every two years in a relaxed environment to discuss new ideas and developments in the area of computational methods and applications, especially in the topic of fluid dynamics, heat and mass transfer in nonreactive and reactive processes. Also, it is good opportunity for new scientist and engineer to explore the art of computational methods.

The main topics of the *XI International Conference on Computational Heat, Mass and Momentum Transfer ICCHMT 2018* were the following: Advanced Numerical Methods, Aeronautical and Space Applications, Bio-Fluidics and Biomedical Engineering, Bio-Inspired Flow and Heat Transfer, Complex Chemical Reaction Modeling, Compressible Flows, Convection and Buoyancy-Driven Flows, Double Diffusive Convection, Fluid Flow and Heat Transfer in Biomedical Devices and Biotechnology, Fluid Machinery, Granular Flows, Heat and Mass Transfer in Manufacturing and Materials Processing, Heat and Mass Transfer in Nuclear Applications, Heat and Mass Transfer in Particle-Laden Flows, Heat Exchangers / Heat Pipe, Internal Flow and Heat Transfer, Micro / Nano Heat and Mass Transfer, Mixing Devices and Phenomena, Multi-Phase Flows, Optimization in Thermal Engineering, Reactive Flows and Combustion, Steam and Gas Turbines, Technology for Renewable Energy Sources, Thermal Flow Visualization, Thermal Fluid Machinery, Transport Phenomena in Porous Media, Waste Management and Waste Disposal, and Any Other Related Topics.

In this Proceedings, selected papers covering the above topics, mainly related to heat, mass and momentum transfer, heat exchangers, fluid dynamics, nanofluids, renewable energy, and modeling of the energy and industrial processes are presented. Proceedings contains a total of 116 papers.

Tradition is that the engineers and scientists come together to share experiences every two years on the international conference. In 2018 **the Institute of Thermal Power Engineering of the Cracow University of Technology** fell the honour of organizing the conference in Cracow, Poland. We hope that this meeting was productive not only for the exchange of experiences, ideas and changes in methods and applications computational in the topics of fluid dynamics and heat and mass transfer, but also was a good opportunity for young engineers and scientists to learn about new trends in computational methods.

We hope, that the readers of this Proceedings will find the presented papers useful and stimulating for their studies in the area on heat, mass and momentum transfer realized in various processes.

Kraków, Poland
November 2018

Editors:
Sławomir Grądziel
Stanisław Łopata
Tomasz Sobota
Wiesław Zima

Opening address

The 11th edition of the International Conference on Computational Heat, Mass and Momentum Transfer (ICCHMT 2018) took place on 21-24 May 2018 in Kraków (Poland). The conference was organized by the Institute of Thermal Power Engineering of the Cracow University of Technology in cooperation with the University of Calgary (Canada), the Sapienza University of Rome (Italy) and the Paris Saclay University LMT Cachan (France).

The topics of the conference included issues related to numerical methods in solving Navier-Stokes equations, numerical modelling of single- and multiphase flows, modelling of conjugated heat transfer problems in solids and liquids, and nanofluid heat transfer. The aim of the conference was to present the results of scientific research, exchange experiences, as well as to build a platform for cooperation between the scientific community and industry.

Representatives of the world's leading scientific institutions involved in computer modelling of heat and mass transfer processes were invited to participate in the conference. These issues find a practical application in the design and modelling of heat exchangers, both micro-scale and industrial energy systems, air conditioning and refrigeration systems, as well as many others.

The venue of the conference was the Galaxy hotel at Gęsia Street in Cracow, Poland. During the plenary sessions, world-renowned specialists in the field of numerical modelling of heat and mass transfer processes delivered their lectures. A total of 24 thematic sessions and 3 poster sessions were held.

The chairpersons of the ICCHMT2018 were: Prof. Jan Taler (Cracow University of Technology), Prof. Wen-Quan Tao (Xi'an Jiaotong University, China), Prof. Abdulmajeed Mohamad (University of Calgary, Canada) and Prof. Ali Cemal Benim (Duesseldorf University of Applied Sciences, Germany).

ICCHMT 2018 was held under the honorary patronage of:

- Ministry of Energy (Poland),
- President of the City of Kraków Jacek Majchrowski,
- Committee on Thermodynamics and Combustion of the Polish Academy of Sciences.

Committee of the XI International Conference on Computational Heat, Mass and Momentum Transfer

Honorary Committee:

Prof. Jan Kazior	Cracow University of Technology	Poland
Prof. Tadeusz Tatara	Cracow University of Technology	Poland
Prof. Wen-Quan Tao	Xi'an Jiaotong University	China
Prof. Ulrich Gross	TU Bergakademie Freiberg	Germany
Prof. Shen Yu	Chinese Academy of Sciences	China
Prof. Pradeep Bansal	Satya International Ltd./Bansal Engineering Associates	USA
Prof. Afshin Ghajar	Oklahoma State University	USA
Prof. Henrik Lund	Aalborg University	Denmark
Prof. Tadeusz Bohdal	Koszalin University of Technology	Poland
Prof. Simeon Oka	University of Belgrade	Serbi

Steering Committee:

Prof. Abdulmajeed Mohamad	University of Calgary	Canada
Prof. Jan Taler	Cracow University of Technology	Poland
Prof. Rachid Bennacer	ENS Cachan Paris-Saclay	France
Prof. Sang-Ho Suh	Soongsil University	South Korea

International Committee:

Bayazitoglu Y.	Rice University	USA
Benim A. C.	Duesseldorf Univ. Applied Sciences	Germany
Bennacer R.	ENS	France
Biringen S.	University of Colorado	USA
Bontoux P.	CNRS, les universités d'Aix Marseille	France
Cheng P.	Shanghai Jiaotong Univ.	China
Chikh S.	University USTHB	Algeria
Chorowski M.	Wroclaw Univ. of Sci. & Tech.	Poland
Chung J. T.	Korea Univ.	Korea
Corcione M.	Sapienza Univ. Roma	Italy
Costa V.	University of Aveiro	Portugal
Cruchaga M.	Univ. de Santiago de Chile	Chile
De Lemos M.	Instituto Tecnológico de Aeronautica	Brazil
Duic N.	Univ. of Zagreb	Croatia
Epple B.	Technical Univ. of Darmstadt	Germany
Ferreira J.	ANSYS	Germany
Fue-Sang Lien	Univ. of Waterloo	Canada
Ghajar A.	Oklahoma State University	USA
Gnutek Z.	Wrocław University of Tech.	Poland
Gross U.	TU Bergakademie Freiberg	Germany
Günes D.	Bilgi University	Turkey
Hamed M. S.	McMaster Univ.	Canada
He Y-L	Jiaotong University	China
Jasak H.	Univ. of Zagreb	Croatia
Jin Y.	Zhejiang Sci-Tech Univ.	China
Joos F.	Helmut Schmidt University	Germany
Kakac S.	TOBB Univ. of Econ and Tech	Turkey
Kanna R.P.	Velammal College of Engi. and Tech.	India
Kim H. D.	Andong Nat'l Univ.	Korea
Kim S. J.	KAISTDaejeon,	Korea
Kim Y. J.	Sungkyunkwan Univ.	Korea
Klemeš J. J.	Brno University of Technology	Czech Republic
Kinoue Y.	Saga Univ.	Japan
Lewis R. W.	Swansea University	Great Britan
Li J.	Xi'an Jiaotong Univ.	China
Lund H.	Aalborg University	Denmark
Merlen A.	Univ. Sciences et Technologies de Lille	France
Nagano Y.	Nagoya Inst. of Tech.	Japan
Nagatama G.	Kyushu Inst. of Tech.	Japan
Ocloń P.	Cracow University of Tech.	Poland
Ohara T	Tohoku University	Japan
Oka S.	VINČA Institute of Nuclear Sciences	Serbia
Olsen J.E.	SINTEF	Norway

Orfi J.	KSU	Saudi Arabia
Pasqualotto E.	ALSTOM	Switzerland
Pop I.	University of Cluj-Napoca	Romania
Saeid N.	Institut Teknologi Brunei	Brunei
Stanek W.	Silesian University of Technology	Poland
Suh S.H.	Soongsil University	Korea
Sunden B.	Lund University	Sweden
Sheremet M. A.	Tomsk State Univ.	Russia
Suryan A.	College of Eng. Trivandrum	India
Syed K.J.	ALSTOM	Switzerland
Tao WQ	Xian Jiaotong University	China
Taler J.	Cracow University of Tech.	Poland
Taler D.	Cracow University of Tech.	Poland
Rao R.V.	SV NIT	India
Vallati A.	Sapienza Univ.	Italy
Viskanta R.	Purdue University	USA
Wang B.C.	Univ. of Manitoba	Canada
Wang G.	Beijing Inst. Of Tech.	China
Watanabe S.	Kyushu Univ.	Japan
Wiedermann A.	MAN Diesel&Turbo	Germany
Yamamoto K.	Nagoya University	Japan
Yan J.	KTH Royal Institute of Technology	Sweden
Younis L. B.	SNC.LAVALIN	Canada

Local Organizing Committee:

Bohdan Węglowski DSc PhD	Cracow Univ. of Tech. Poland
Dawid Taler DSc PhD	Cracow Univ. of Tech. Poland
Piotr Duda DSc PhD	Cracow Univ. of Tech. Poland
Wiesław Zima DSc PhD	Cracow Univ. of Tech. Poland
Stanisław Łopata DSc PhD	Cracow Univ. of Tech. Poland
Sławomir Grądział DSc PhD	Cracow Univ. of Tech. Poland
Piotr Wais PhD	Cracow Univ. of Tech. Poland
Tomasz Sobota PhD	Cracow Univ. of Tech. Poland
Magdalena Jaremkiewicz PhD	Cracow Univ. of Tech. Poland
Anna Korzeń PhD	Cracow Univ. of Tech. Poland
Artur Cebula PhD	Cracow Univ. of Tech. Poland
Paweł Ocioń DSc PhD	Cracow Univ. of Tech. Poland
Damian Muniak PhD	Cracow Univ. of Tech. Poland
Piotr Dzierwa PhD	Cracow Univ. of Tech. Poland
Marcin Trojan PhD	Cracow Univ. of Tech. Poland
Karol Majewski PhD	Cracow Univ. of Tech. Poland
Marzena Nowak-Ocioń PhD	Cracow Univ. of Tech. Poland
Piotr Cisek PhD	Cracow Univ. of Tech. Poland
Marcin Pilarczyk PhD	Cracow Univ. of Tech. Poland
Karol Kaczmarski MSc	Cracow Univ. of Tech. Poland
Marek Majdak MSc	Cracow Univ. of Tech. Poland
Monika Rerak MSc	Cracow Univ. of Tech. Poland
Vincenzo Spena	DIAEE Sapienza University of Rome, Italy
Elisa Ricci	DIAEE Sapienza University of Rome, Italy