139 European Study Group with Industry (139 ESGI)

The **139 European Study Group with Industry (ESGI)** was held from 9th to 13th of July 2018 at the Faculty of Mathematics of the University of Santiago de Compostela (USC), thanks to the collaboration between the Spanish Network for Mathematics & Industry (math-in) and the Technological Institute for Industrial Mathematics (ITMATI).

Initiated in Oxford in 1968, Study Groups with Industry provide a forum for industrial scientists to work alongside academic mathematicians on problems of direct industrial relevance. They are an internationally recognized method of technology and knowledge transfer between academic mathematicians and industry.

The success of the ESGI is the unique format which has been copied around the world, in which mathematics community works on reduced groups to study problems, proposed by industry. These problems are presented from any economic sector thanks to the Mathematics’ transversally. The objective is to present the capabilities of Mathematicians and the applicability of Mathematics in a large part of the challenges and needs of the industrial, bringing small, medium and large companies a technology with great potential, with highly qualified researchers and that does not require large investments to use.

This simple format has proved its value again and again: companies from diverse industries have benefitted from the insights gained through mathematical analysis of their problems, while mathematicians with diverse interests have benefited from the exciting research opportunities presented by unsolved problems with practical significance.

Therefore, collaboration between industry experts and researchers is a key to addressing technological innovation problems into a mathematical successful. The realization of ESGI contributes to the promotion of mathematics and awareness of companies to use Mathematics to improve their processes.

**GOALS:**

- to find solutions and insights into existing industrial problems;
- to establish lasting and productive working links between applied mathematicians and industry;
- to propose new lines of research based on business challenges;
- to reinforce the importance of mathematics in industry and to open new jobs of mathematical profile in companies; and
to stimulate greater awareness in the wider community of the power of mathematics in providing solution paths to real-world problems.

INDUSTRIAL PROBLEMS

In the 139 ESGI five problems were presented:

- **PROBLEM 1: Solidification and mechanical coupling in microfracture propagation**

  - **Academic Coordinator:** Marco Fontelos, Associate professor at Universidad Autónoma de Madrid and researcher at CSIC.
  - **Specialist:** Gerardo Enrique Oleaga Apadula, Associate Professor at Universidad Complutense de Madrid.
  - **Business Coordinator:** Ángel Rivero Jimenez, Senior scientist at Repsol Technology Center.
  - **Description:** Consider an interface between two crystalline solids A and B. Phase A allows electrodissolution and electrodeposition and B allows diffusion of the A-dissolved species inside. In this transport process from A to B and its interaction with the free surface A / B, two possible phenomena appear, both of interest;
    - Growth of A and fracture of B. The molecular species A-dissolved is deposited by electrochemical reaction in A (in the interface A / B) in such a way that the deposition front of A is not uniform and a phenomenon of fingering of A happens. This occurs by pressing and compressing B to the point of fracturing and penetrating into B;
    - Dissolution of A. Under other operating conditions A may dissolve (opposite effect to the previous one) and may cause loss of local contact between both phases A and B, reducing the interface area between A / B and therefore the effective area for the electrochemical reaction;
  - **Further information:** 139 ESGI (problem 1).
PROBLEM 2: Improving the efficiency of a retort furnace

- **Academic Coordinators:** Elena Martín Ortega, Associate professor at Universidad de Vigo and affiliated researcher of ITMATI.
- **Specialist:** Fernando Varas Mérida, Associate professor at Universidad Politécnica de Madrid.
- **Business Coordinator:**
  - Anxo Feijóo Lorenzo, General Management and Technical Management at Ecomanagement Technology.
  - Jose Carlos Perez Ramilo, Quality Manager at BorgWarner.

- **Description:** EcoMT is an ICT company dedicated to the implementation of solutions for the control and remote management of installations based on expert systems technology. One of the biggest challenges in the field of materials processes engineering is to integrate technical, economic and environmental considerations in a rational and efficient manner. The company has a retort furnace in which a “brazing” process is carried out, joining pieces from the automotive sector made of different metals with different thicknesses and complex designs.

  The process to reach the correct results follows some guidelines, among them, distance between the pieces and speed of the fixed tape. Hydrogen and nitrogen are blown inside the furnace, which must keep the dew point in a pre-established range so that the pieces do not rust.

  The goal is to model the operation of the furnace to optimize the position and distance between pieces, the speed of displacement of the tape and the gas proportion that must be insufflated to reach a greater efficiency.

- **Further information:** 139 ESGI (problem 2).

PROBLEM 3: Order reduction in dynamic systems using machine learning

- **Academic Coordinator:** Andrés Gómez Tato, Applications & Projects Department Manager at CESGA.
- **Specialist:** Pablo Solano López, PhD student, Applied Physics Department (UPM).
- **Business Coordinator:** Ángel Rivero Jimenez, Senior scientist at Repsol Technology Center.
Description: The goal is to reduce the degrees of freedom of a given problem (a non-linear PDE or a system of non-linear PDEs known) through neural networks (autoencoder or Boltzmann machines type).

Essentially this method of order reduction uses machine learning in 1D canonical problems (with intention to extend the method to 2D and 3D) of continuous media and known dynamics governed by non-linear EDPs (Burgers, Kuramoto-Shivasinskii, Cahn Hilliard or KdV).

Further information: 139 ESGI (problem 3).

PROBLEM 4: Predictive maintenance in a pellet production factory

Academic Coordinator: Manuel Febrero Bande, Full Professor of Statistics and Operational Research (USC) and affiliated researcher of ITMATI.

Business Coordinator: Laura Vázquez Pardo, I+D Manager at Grupo Gestán.

Description: Biomasa Forestal has a factory dedicated to manufacturing wood pellets, which operates 24 hours a day, 365 days a year. Therefore, it is essential to be able to predict and anticipate problems in the machines that lead to unscheduled production stops. Currently, the company collects information about preventive maintenance and breakdowns. In addition, they are equipping the machines with sensors that provide information about their operation (vibrations, energy consumption, etc.)

The aim is to find an algorithm that based on all the information being collected is capable of anticipating the breakdown.

Further information: 139 ESGI (problem 4).

PROBLEM 5: Equivalent thermo-mechanical modelling of the ceramic cup of a Blast Furnace.

Academic Coordinators:
- Peregrina Quintela Estévez, Full Professor of Applied Mathematics in Universidad de Santiago de Compostela and Director of ITMATI.
- Patricia Barral Rodiño, Associate Professor in Universidad de Santiago de Compostela and Affiliated researcher of ITMATI.

Specialist: María Teresa Sánchez Rúa, Centro Universitario de La Defensa (Zaragoza).
Business Coordinator: Miguel Fanjul Cuesta, R&D Engineer in the Refractory Department at ArcelorMittal.

Description: ArcelorMittal has a multitude of Blast Furnaces. In them the primary production of steel is carried out, in other words, the hot metal (molten iron) and slag (by-product) are obtained inside them. These furnaces suffer very high temperatures and they are built with different refractory concrete materials. There are different designs. Some of them have a protective layer in the lower and inner part of the furnace, named ceramic cup, which is formed by refractory bricks and mortar joints (concrete). The development of a thermo-mechanical model of the whole ceramic cup is complex, because it requires drawing the geometry in detail greatly increasing the computational costs when meshing, and being more difficult the model convergence.

So, it is intended, in a small academic example (two bricks with a mortar joint), to study the possibility of, instead of modelling the whole assembly including mortar, being able to develop an equivalent masonry model, so that it behaves thermo-mechanically equal to the brick-mortar-brick set from the macroscopic point of view. It would be necessary to evaluate which of the following methods would be adjusted better to the real case:

- To model only the bricks, oversizing these, so that they include the dimensions of the mortar joints, imposing in the contact between the bricks an equivalent law to the mortar behavior;
- Or, to implement an equivalent law of the whole assembly of bricks and mortar, so that it can be replaced by a material with the same dimensions as bricks and mortar and its thermo-mechanical behavior was practically the same from the macroscopic point of view.

It would be valued the possibility of performing the simulation in a free code software (CODE ASTER) and a commercial one (ANSYS), in order to observe the differences that could appear in the results, as well as the advantages and disadvantages in the implementation when using one software or another.

Further information: 139 ESGI (problem 5).
PARTICIPATING ENTITIES AND ENTERPRISES

- Repsol
- Ecomanagement Technology (EcoMT)
- BorgWarner
- Biomasa Forestal
- ArcelorMittal

SCIENTIFIC COMMITTEE

- Prieto Aneiros, Andrés. Associate Professor in the Department of Mathematics of the Faculty of Computer Science. University of A Coruña. Affiliated researcher of ITMATI.
- Roca Pardiñas, Javier. Associate Professor of Statistics and Operations Research. University of Vigo. Affiliated researcher of ITMATI.
ORGANIZING COMMITTEE

- Prieto Aneiros, Andrés. Associate Professor in the Department of Mathematics of the Faculty of Computer Science. University of A Coruña. Affiliated researcher of ITMATI.


- Sanjurjo García, Martín. Transfer Manager and Assistant Technology Translator, ITMATI.

- Tomoni, Raluca Silvana. Technology Transfer and Innovation Manager, ITMATI.

CALL FOR COMPANIES

An open call for companies who want to present an industrial problem in 139 ESGI was carried out.

Companies from different industrial sectors had the opportunity to benefit from the insights gained through mathematical analysis of their problems. If a company needs to reduce production costs, innovate its processes or improve its services, then could present a problem to the lead mathematicians to brainstorm new ideas and work towards practical solutions.

Each company benefited from the work carried out by the participants, the direct interaction with academics, the participation of international researchers from entities of recognised prestige, and the written report on the problem.

The submission of the industrial problem was free, but there had been a charge for each problem selected by the Scientific Committee for the Study Group. The level set this year for the 139 ESGI was 800 € + VAT (except for math-in associated companies, who have enjoyed a reduced price of 400€ + VAT). This was to cover all organization running costs and to ensure a proper development of 139 ESGI.

Further information: http://www.math-in.net/139esgi/en/call
FURTHER INFORMATION AND SCHEDULE:  http://www.math-in.net/139esgi/en

Opening ceremony:

- Mrs Elena Vazquez Cendón - Dean of the Faculty of Mathematics at the University of Santiago de Compostela.
- Mrs Peregrina Quintela Estévez, Director of Technological Institute for Industrial Mathematics (ITMATI) and President of the Spanish Network for Mathematics & Industry (math-in).
- Mr Andrés Prieto Aneiros - Representative of the Scientific and Organizing Committee of the 139 ESGI. Associate Professor in the Department of Mathematics of the Faculty of Computer Science. University of A Coruña. Affiliated researcher of ITMATI.

Schedule:

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<tr>
<td>Reception of participants</td>
<td>Group Work</td>
<td>Group Work</td>
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<td>09:30-10:00</td>
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<td>Opening Ceremony</td>
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<td>10:00-10:35</td>
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<td>11:10-11:40</td>
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<td>Coffee break</td>
<td>Coffee break</td>
<td>P3 Conclusions</td>
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<td>P3 presentation</td>
<td>Group Work</td>
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<td>P5 presentation</td>
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<td>Lunch</td>
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<td>15:25-15:55</td>
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<td>Distribution of the Groups</td>
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Instituto Tecnológico de Matemática Industrial

www.itmati.com
Edif. Instituto Investigaciones Tecnológicas, planta -1
Rúa de Constantino Candeira s/n.
15782 Campus Vida / Santiago de Compostela.
itmati@itmati.com | Telf: +34 881 813 357
SUMMARY OF THE ACTIONS

139 ESGI concluded with a successful participation and results: the participating researchers managed to find solutions to the five industrial problems. The challenges related to metallurgy, the automotive industry and the improvement of industrial processes were posed by five multinational companies: Repsol, ArcelorMittal, Biomasa Forestal, EcoMT and BorgWarner. In all cases, mathematics was the answer. Technologies such as big data, machine learning and MSO (Modeling, Simulation and Optimization) are behind the solutions, since to reach the automation of the processes first mathematical methodology is needed. Converting a sum of complex calculations in a simplified model without losing accuracy, finding the expression of a physical phenomenon in which numerous variables participate or looking for the relationship between the data collected by sensors are some of the tasks that a mathematician has to address before the machines can get to do their job.

This edition had 52 participants from 5 different countries (Austria, Spain, Ecuador, Italy and United Kingdom) who managed to find solutions to the five industrial problems: 11 participants from companies, 10 PhD students and 19 researchers and teaching staff.
PROMOTIONAL POSTER OF THE ACTION

Opening Ceremony for the 139 ESGI

1st Problem presentation: Solidification and mechanical coupling in microfracture propagation.
2nd Problem presentation: Improving the efficiency of a retort furnace.

3rd Problem presentation: Order reduction in dynamic systems using machine learning.
4th Problem presentation: Predictive maintenance in a pellet production factory.

5th Problem presentation: Equivalent thermo-mechanical modelling of the ceramic cup of a Blast Furnace.

Instituto Tecnológico de Matemática Industrial

[Address and contact information]

www.itmati.com

| Telf.: +34 881 813 357 |
Problem 1 Working Group: Solidification and mechanical coupling in microfracture propagation.

Problem 2 Working Group: Improving the efficiency of a retort furnace.

Problem 4 Working Group: Predictive maintenance in a pellet production factory.
Problem 5 Working Group: Equivalent thermo-mechanical modelling of the ceramic cup of a Blast Furnace.
MENTIONS IN MEDIA

- SINC (17/07/2018)
- Código Cero (17/07/2018)
- La Voz de Galicia (14/07/18)
- Cinco Días (10/07/18)
- La Voz de Galicia (10/07/18)
- Código Cero (06/07/18)
- RSME
- SGAPEIO
- USC
- ECMI (22/05/18)
- SCCB
- MATH-IN (28/06/18)
- MI-NET (26/06/18)
- MI-NET- Twitter (27/02/18)
- SGAPEIO
- MATH-IN
- ECMI

PRESS RELEASES

- PRESS RELEASE: “Five days for five challenges: mathematics for solving industrial problems” (click here)
- PRESS RELEASE: “Mathematics as an effective tool to solve problems in metallurgy, automotive sector and industrial processes” (click here)
ORGANIZERS


COST Action TD1409, Mathematics for Industry Network (http://mi-network.org/), granted by the European Cooperation in Science and Technology (http://www.cost.eu/), co-financed this event.

Cost is supported by the EU Framework Programme Horizon 2020

The 139 ESGI was also co-funded by:

- the Ministry of Economy, Industry and Competitiveness – State Research Agency with the nº of reference MTM2016-81745-REDT through the Thematic Network RTMath-in, granted within the call “Networks of Excellence” 2016,
- the Regional Ministry of Culture, Education and University Planning of the Regional Government of Galicia through the Technological Network of Industrial Mathematics (TMATI Network) and through the agreement that ITMATI has with this Regional Ministry;
- the Strategic Network in Mathematics with the nº of reference MTM2016-81711-REDE and by
- ROMSOC project, financed by the EU within the Horizon 2020 Research and Innovation Programme under the Marie-Skłodowska-Curie grant agreement No 765374.
In this occasion CIEDUS from USC recognized this activity as a training course in the Doctorate Programs: “Mathematical Methods and Numerical Simulation in Engineering and Applied Sciences (USC-UVigo-UDC)” and “Statistics and Operational Research (USC-UVigo - UDC)”, with two modalities: Basic 139 ESGI (1.5 ECTS) and Advanced 139 ESGI (4 ECTS) depending on the involvement of the PhD students in the preparation of the conclusions and the proceedings of the event.

The appropriate procedures were also carried out so that this event could be considered as a training course for all the participating researchers of the three Galician universities. Furthermore, this activity was also recognized by the UDC, USC and UVigo as a training activity for the teaching staff.
PREVIOUS ESGIs

Since 2013 the Spanish Network for Mathematics & Industry (math-in) and the Technological Institute for Industrial Mathematics (ITMATI) have been developing European Study Groups with Industry in close collaboration. These are the previous events co-organized between the two entities:

- 97 ESGI
- 110A ESGI
- 122 ESGI

All the information related to this event is available on the 139 ESGI website: [http://www.math-in.net/139esgi/en](http://www.math-in.net/139esgi/en)