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Project Deliverable Report

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Mapping, Educating, Training, Applying models in continuous CASTing

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1. INTRODUCTION

As mentioned in the Project Grant Agreement, METACAST, as a RFCS Accompanying Measure, intends to develop a comprehensive view of numerical modelling in continuous casting and to offer it to the European steel community, including all the stakeholders from the top managers of steelmaking companies to the researchers and students in universities. This approach includes mapping key expertise in Europe and the rest of the world, organising dissemination events, and providing training. In fact, Objective 6 of the EU's Research Fund for Coal and Steel (RFCS) for the steel sector focuses on ‘talent attraction, skill development, and workforce management, aiming to equip the industry with the necessary expertise for a sustainable, low-carbon future, addressing issues like new skills for digital and green transitions, ensuring health & safety, and fostering a just transition for workers ’.

METACAST addresses the mentioned point by exploiting actions to provide guidance to managers and personnel in the steel industry on how to apply modelling results for improving the quality (both bulk and surface) of cast products and the workers skill as well. As a matter of fact, the social impact of a more widespread use of modelling in the industrial environment can include a better acceptance of operational innovations and adaptations with the operational staff at the production plants, and more informed decision making by process engineers, R&D research personnel and managers, leading to smoother workflows in steel companies.

Indeed, the events held hade in general a ‘multi-fold’ role. When dealing with ‘fundamental’ topics sessions, also some ‘ training’ sessions were held, in order to make fruitful the participation of the audience, often composed in a relevant part by academics/students/young researchers of the Centers involved in the event organisation. As a result, in this report after a general overview of the events held, more details are paid to the specific topic of the deliverable (‘Fundamental Modelling’) leaving the reader to the other corresponding deliverables (e.g., D4.2 dealing with Training Events).

2. ACTIVITY PERFORMED

The events held and previously mentioned, consisted of training events either held online and in presence on modelling application to continuous casting of steel.

As functional to the educational leg of the project, four events were held with training purposes in 2025:

- the '6th Simulation Event', held by K1-MET on 23rd of April;
- 1st Seminar jointly organized by SIDENOR and SWERIM on the 1st of July focused on CFD modelling
- 2nd Seminar jointly organized by SIDENOR and SWERIM on the 28th of November focusing on solidification modelling
- the webinar 'From fundamental to Problem solving' organised by RINA-CSM on 4th December.

The activity is fully compliant with the claimed KPI-objectives as in the Grant Agreement '*To organize at least three online/ hybrid and open access events with invited professors from leading research groups worldwide*': Among the lecturers:

- In the first event, Prof. Christian Bernhard (Universität Leoben - Austria), Prof. Menghuai Wu (Universität Leoben – Austria),
- in the second and third, Prof. Pavel Ramirez Lopez – (Associate Professor at KTH, Sweden),
- in the last, Prof. Carlo Mapelli – Politecnico di Milano, Italy (see details in figure 5)

More details, videos included, can be found in the project website https://metacast-project.eu/

2.1. Event at K1-MET

The 6th K1-MET Simulation Conference took place in a hybrid format at TU Wien on 23 April 2025. This year it was jointly organized with the METACAST project Consortium, and the overarching theme was "Simulation and Modelling of Continuous Casting'.

The programme featured engaging presentations from research and industry partners and provided a valuable platform for expert exchange and live discussions.

After a project outline cared by K1-Met (Dr. Gruber), the event had a 'fundamental' leg, driven by the event-involved Professors mentioned above, and a 'training' part relating the subsequent validation approach of the models. This topic was supported by contribution of BFI (Kersten Marx) and K1-MET (Dr. Vakhrushev and Dr. Jakurek). As mentioned, more details on the 'training' issues will be described in the dedicated deliverable (D4.2).

Pictures of the events are shown in **Figure 1**.

Figure 1. Images from of the '6th Simulation Conference'.

The in-person audience consisted of about 55 people, with an additional 30 participants attending online. The event featured talks on real-time analysis of casting and fast data-driven mold simulations, multiphase MHD phenomena in the casting mold, solidification in the as-cast structure as well as the application of models in the steel and refractory industry for quality prediction and model validation with water experiments and plant data. Also, the METACAST project and its scope and goals was introduced to the audience.

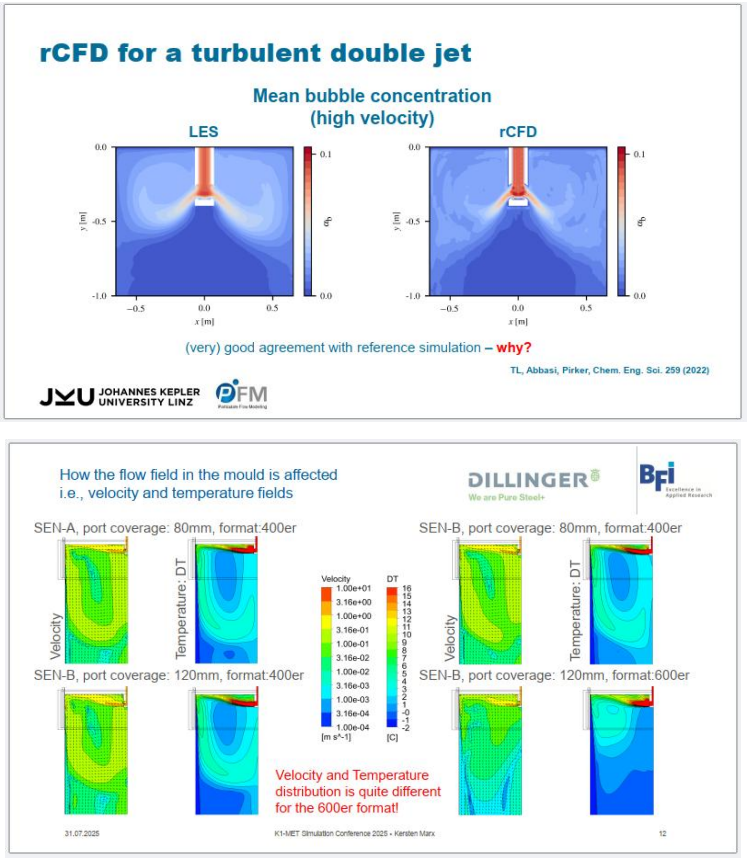


Figure 2. Images from of the '6th Simulation Conference'. CFD simulations of SEN and mold flows (contributions by PD Dr. Thomas Lichtenegger and DI Kersten Marx, MHD simulations (contribution by Dr. Alexander Vakhrushev), and water model validation (contribution by Dr. Mirko Javurek).

2.2. 1st SIDENOR and SWERIM Seminars: CFD for Continuous casting

This seminar was jointly organized by SIDENOR and SWERIM focused on Computational Fluid Dynamics (CFD) and took place at the Sidenor Innovation Hub on July 1, 2025. The event was broadcast in a hybrid format. The speakers were Pavel Rámirez López, Associate Professor at

KTH; Diana Mier Vasallo, Process Manager at Sidenor R&D; and Raquel Arias Pérez, Process Researcher at Sidenor R&D.

Similarly to the previous event, this had a 'multifold' role. As a matter of fact, the event was divided into three sessions.

The first ('*CFD for Continuous Casting'*), led by Prof. P. Ramirez Lopez, was mainly 'fundamental', starting from the pillars of thermo-fluid dynamics involved in continuous casting modelling, and involved also the steel properties physics for its role in the solidification phenomenon.

The second, also held by Prof. Ramirez Lopez, dealt with the use of Digital Twins in Continuous casting, examining how digital twins support the modelling and resolution of industrial challenges in continuous casting and should be classified as 'application' leg as training on the tool use in problem solving.

The same classification can be ascribed to the third session, focused on industrial success stories of casting modelling application at SIDENOR, led by Diana Mier and Raquel Arias, showcasing how applied research and numerical modelling have been used to solve complex industrial problems.

Among the 25 participants present on site, the audience was predominantly composed of university students, early-stage researchers, plant specialists, technologists, and engineers, corresponding to the primary target groups identified for the event. A further 30 participants attended the session remotely.

In support of the project's educational objectives, a preliminary training activity was organised for students with the aim of providing essential background knowledge on continuous casting. The training, delivered in Spanish, consisted of three modules:

- **Fundamentals of Continuous Casting**
- **Continuous Casting Operations at Sidenor**
- **Introduction to Numerical Modelling**

Images on the I seminar event are shown in Figure 3. The images illustrate key aspects of the computational fluid dynamics analysis discussed, as well as the properties of steel relevant to describing the solidification phenomenon. In the background of the images, the event's audience can be seen.

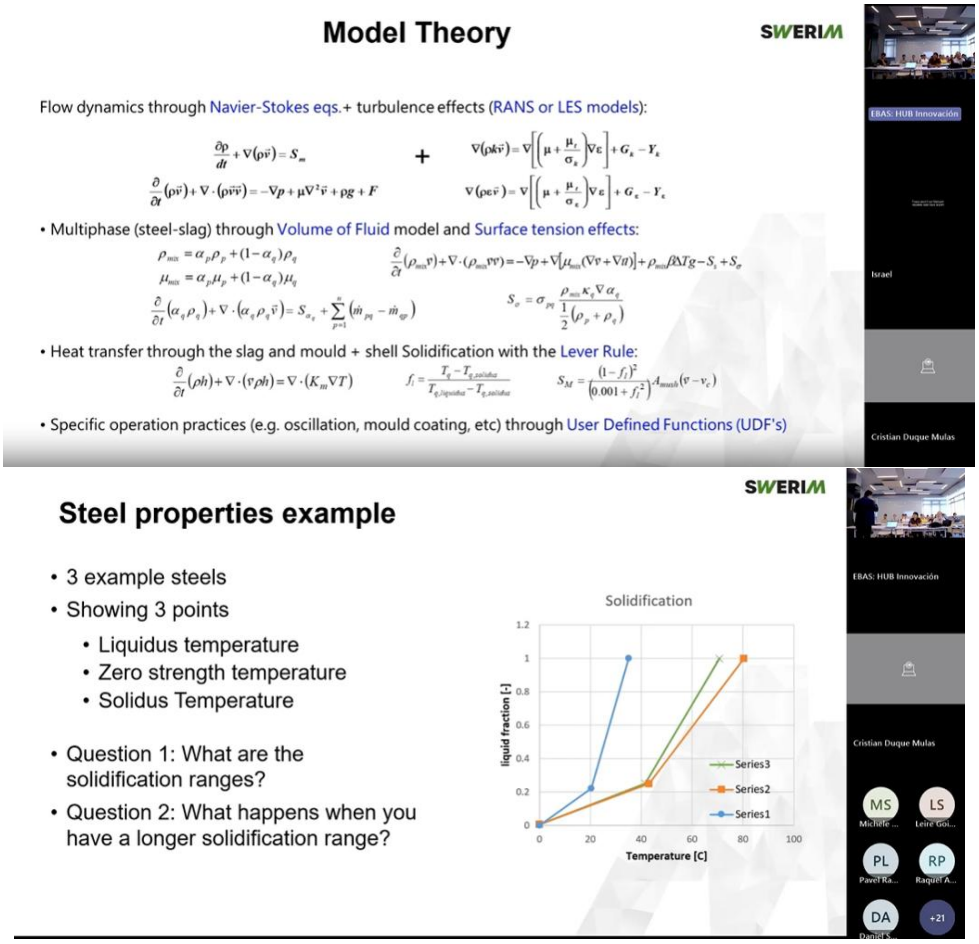


Figure 3. Images from of the 'CFD Modelling Event" – Session I.

A total of 25 people attended the event in person, most of them university students, early-stage researchers, plant experts, technologists and engineers, he groups the event aimed to engage. An additional 30 participants connected remotely.

2.3. 2nd SIDENOR and SWERIM Seminars: Solidification modelling

The second event jointly organized by SIDENOR and SWERIM was held on November 28 in a hybrid format, combining in-person participation at SIDENOR and University of Lulea. The sessions were streamed live from both Oulu University and the Sidenor Innovation Hub, with the same target groups than in the previous event.

The speakers were Pavel Rámirez López (SWERIM) and Nora Egido and Beñat Elorrieta, Process Researchers at Sidenor R&D.

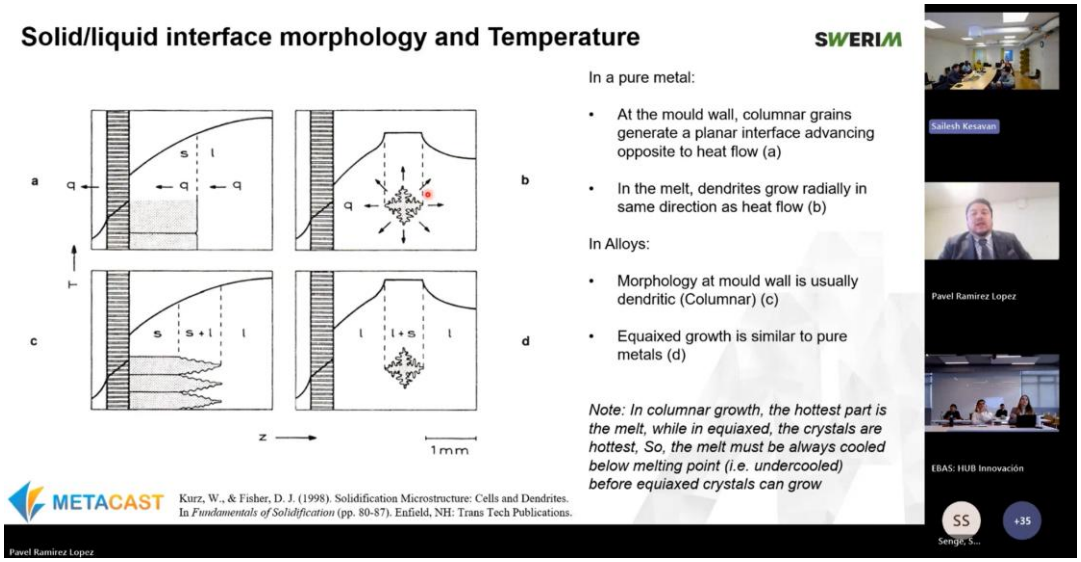
A live Q&A session followed, chaired by Raquel Arias Pérez (Sidenor R&D) and Sailesh Kesavan (Swerim AB)—providing space for discussion, experience sharing, and technical exchange.

Similar to the previous event, the agenda included three sessions.

The first (*Solidification fundamentals*) and the second *(Introduction to Solidification Modelling)* w, both led by Prof. Ramirez Lopez, were of '*fundamental*' nature, including all involving continuous casting phenomena theory, from fluid flow principles to key concepts functional to solidification description as nucleation, heat and mass transfer, microstructure modelling, stress–strain analysis, and advanced characterization and validation techniques.

The third (*Industrial measurements techniques*:) presented by Nora Egido and Beñat Elorrieta from Sidenor R&D, provided an industrial perspective and focused on measurement techniques used for model validation. More devoted on training and application to industrial continuous casting field, as in 3rd session of the event in the previous section, will be detailed in the related deliverable 4.2.

Images of the two 'fundamental modelling' session are shown in Figure 4 as regard to the solidification theory at the interface solid/liquid steel vs temperature, and in Figure 5 for an outline of the multiscale phenomena governing the formation of the solidification front within the physical scenario produced by the operational conditions of steel continuous casting.



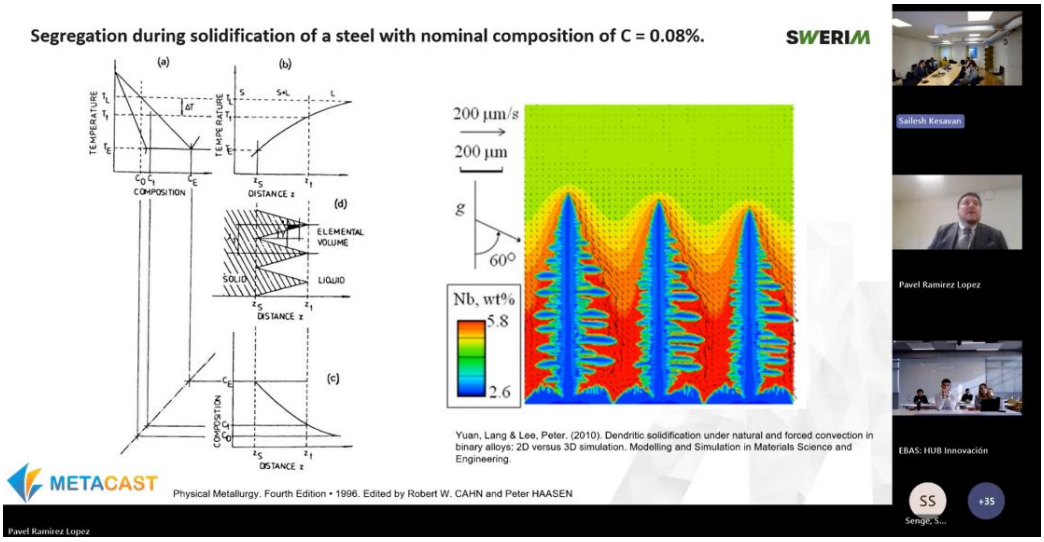
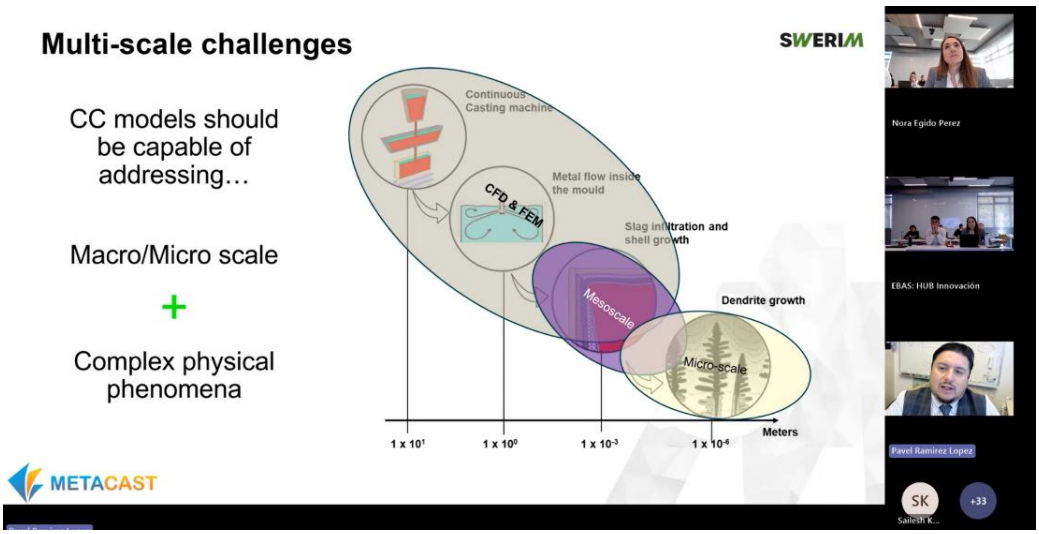


Figure 4. Images from of the ‘”Solidification modelling” event – Session I.



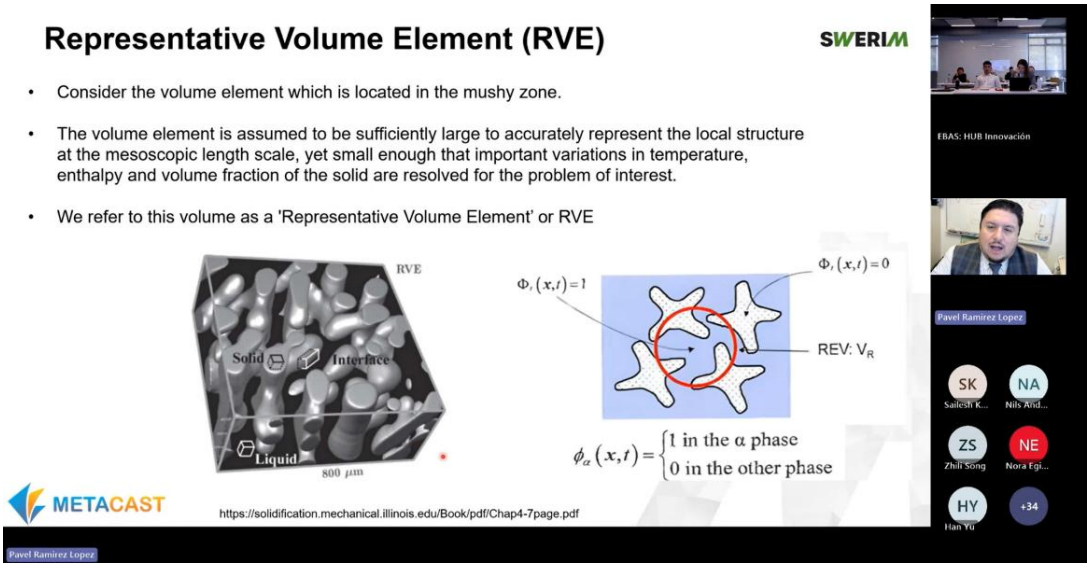


Figure 5. Images from of the '"Solidification modelling" event – Session II.

For this second session, the Sidenor Innovation Hub gathered 20 in-person attendees, representing the same audience profiles as in the initial event, university students, early-career researchers, plant professionals, technologists and engineers. In addition, at Luleå University, 15 students took part in the event.

2.4. Event organised by RINA-CSM (webinar)

The event was organised by RINA-CSM. The title was '*Modelling Experience in Continuous Casting – From Fundamentals to Problem Solving*', with registration of 80 people.

The webinar was intended to explore how fundamental principles are evolving into problem solving and practical tools that solve real-world challenges in steelmaking, in a sort of journey from academic research to industrial implementation, from physics-based insights to plant-level applications.

As a result, the approach was mainly following the line 'fundamental'- 'application', showcasing the industrial examples as fruitful application of the models and tolls developed.

Speakers & Topics were (contributor and presentation, see also figure 6):

- Prof. Marco Mapelli (Politecnico di Milano) – Simulating billet casting and solidification: the role of EMS to prevent central segregation (images in Figure 7),
- Arianna Gotti – Coupling thermo-mechanics and solid shell formation: fundamental steel properties and physical approach (images in Figure 8),

- Michele De Santis (RINA) – Steel intermixing: from reactors mixing fundamentals to on-line process tools (images in Figure 9)

A Q/A session with audience: experiences, suggestions, feedback was chaired by Edoardo D'Amanzo (RINA).

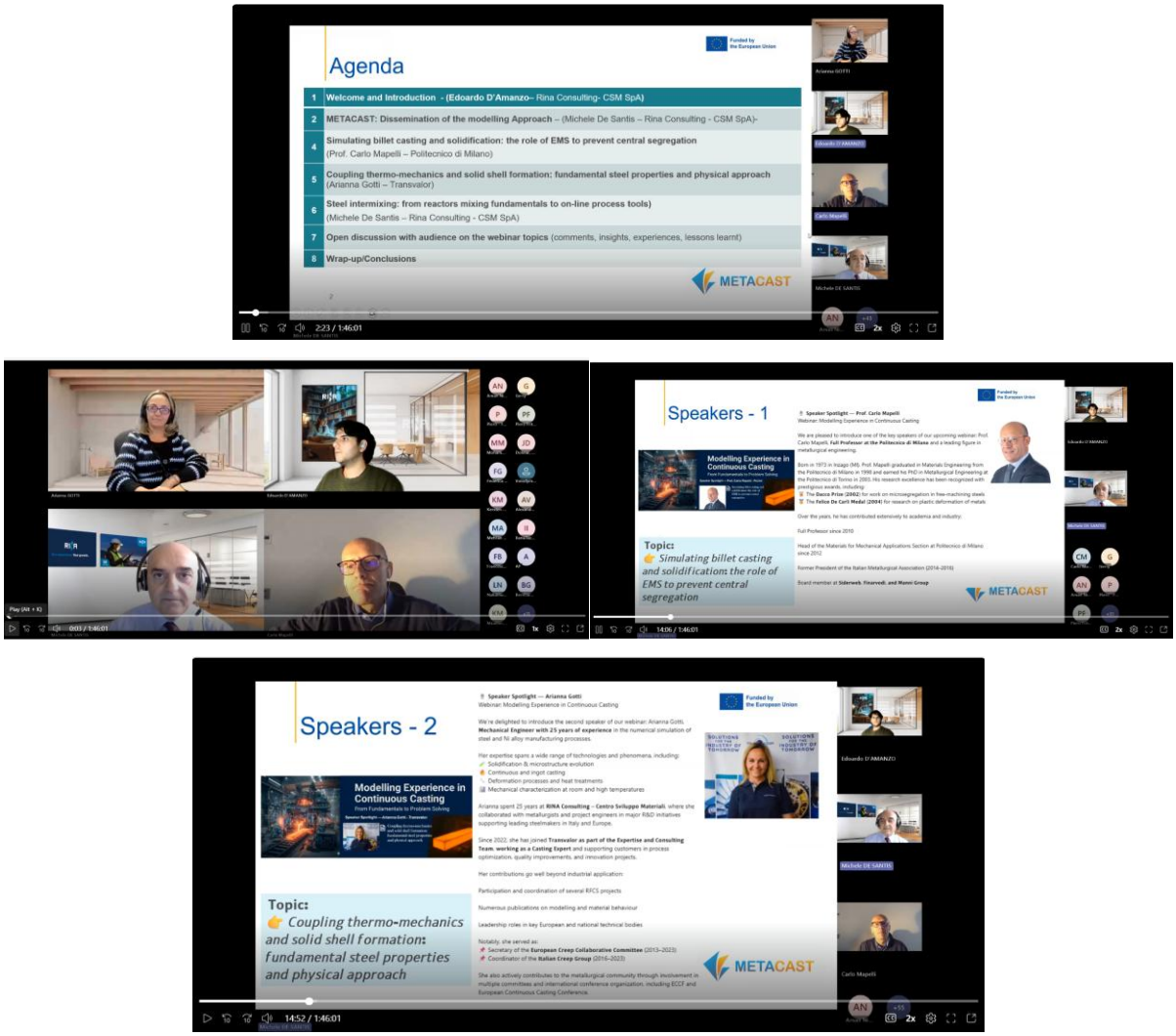


Figure 6. Webinar 'From Fundamentals to Problem Solving'. Agenda & Speakers.

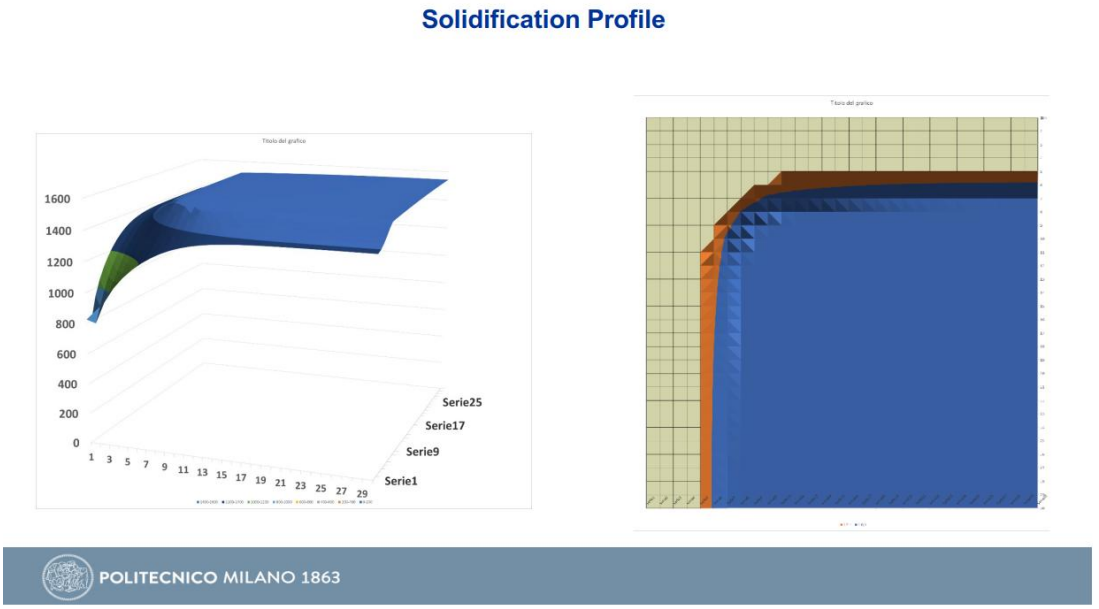
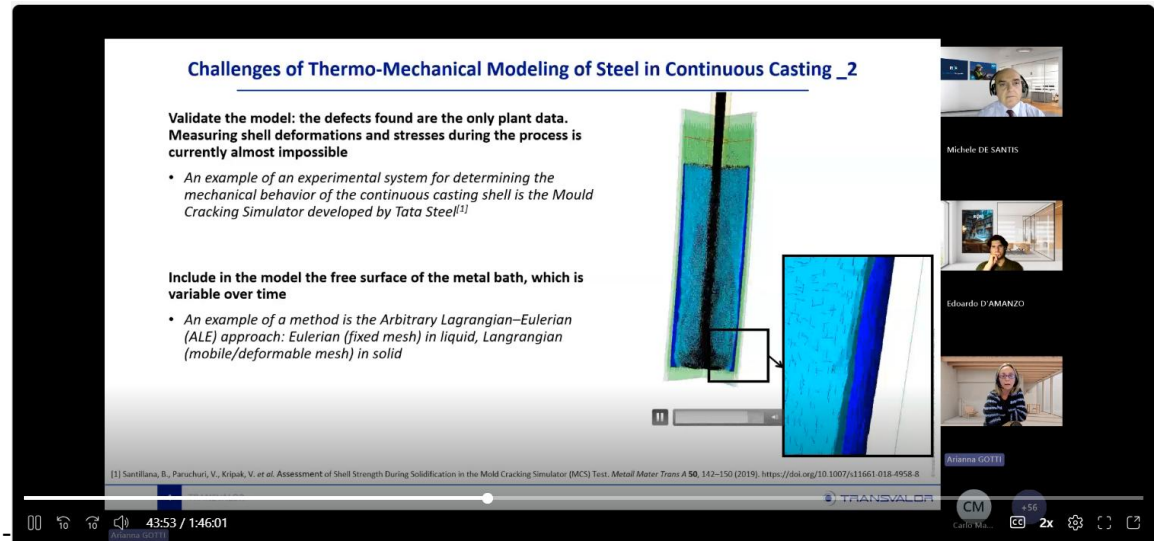


Figure 7. Webinar 'From Fundamentals to Problem Solving'. From Prof. Mapelli contribution.



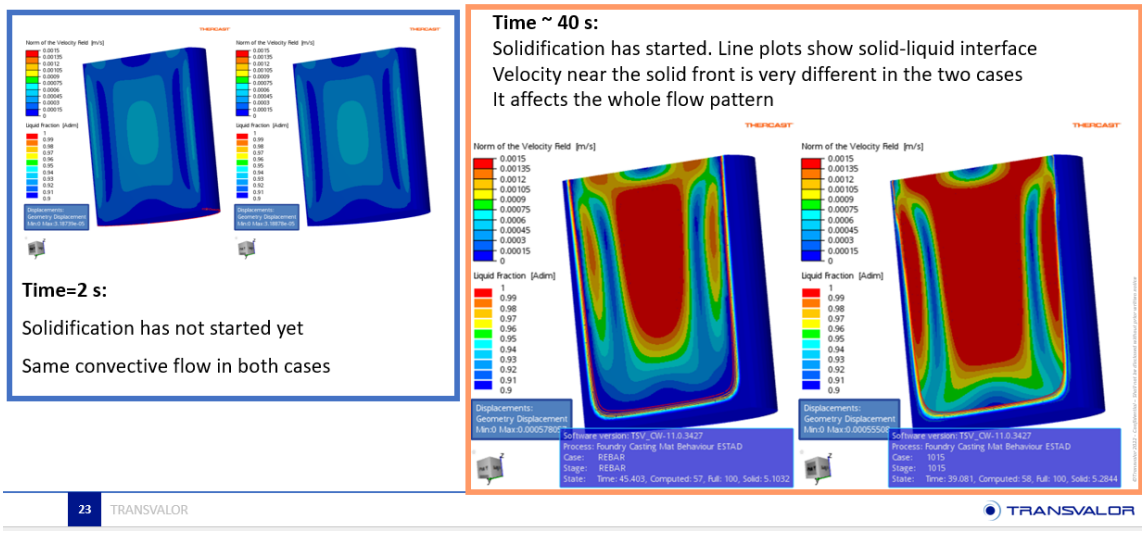


Figure 8. Webinar 'From Fundamentals to Problem Solving'. From ing. Gotti (TRANSVALOR) contribution.

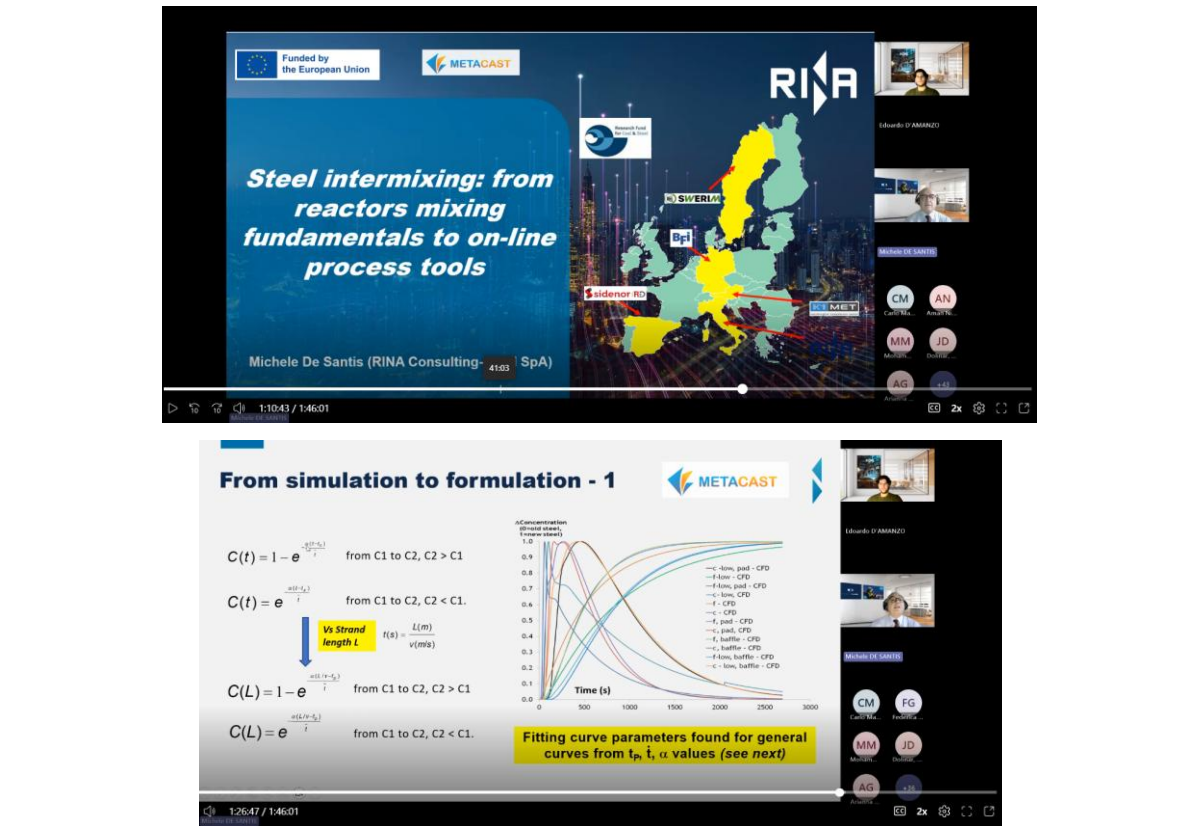


Figure 9. Webinar 'From Fundamentals to Problem Solving'. From RINA-CSM contribution.

As outcome of the discussion, the speakers, based on their experience, highlighted the increasing awareness of the stakeholder's management of the fundamental role of modelling to boost innovation and problem solving in casting issues. Present challenges were identified for an increasing success of modelling approach, mainly represented by model validation with reliable databases set up, e.g. with lab tests. This calls for a strong awareness of the importance of fundamental research supporting this activity, and hopefully continuously boosted and supported with institutional support in the funding programs.

3. CONCLUSIONS AND FUTURE WORK

The document showed at a glance the activity performed by the Consortium concerning training events in the project frame. The events:

- involved the presence of relevant academics, as claimed in the Project Grant Agreement;
- were either online (full in the case of the webinar organised by CSM) and in presence in hybrid mode with session with students and researchers' audience;
- focused on all phenomena involved in continuous casting, from fluid flow features to heat transfer, solidification, shell stress, segregation, and linking fundamentals to problem solving.

Indeed, the events organised in the project frame had session at a 'multi-fold' character, including sessions where the fundamental modeling was turned into tools or strategies for problem solving, as 'training' intended as boosting awareness of the powerful role of modelling. In this view, details on this are given in another dedicated project deliverable (D4.2).