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Project Deliverable Report



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Technical Group: **TGA2**

Mapping, Educating, Training, Applying models in continuous CASTing

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Author(s):	N. Egido Pérez, R. Arias Perez (SIDENOR I+D) M. De Santis, E. D'Amanzo (RINA- CSM), K. Marx (BFI), P. Ramirez Lopez (SWERIM), C. Gruber (K1-MET),

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1. INTRODUCTION

According to the Project Grant Agreement, METACAST—an RFCS Accompanying Measure—aims to foster the uptake of numerical modelling for continuous casting across the European steel sector. Aligned with Objective 6 of the EU Research Fund for Coal and Steel—on talent attraction, skills development for the digital and green transitions, health & safety, and a just transition—METACAST has designed actions that translate modelling results into practical guidance for decision-making, product quality improvement (bulk and surface), and operator competence. A broader and more informed use of modelling in the industrial environment also supports positive social outcomes, including greater acceptance of process innovations on the shop floor, more effective collaboration between production and R&D, and smoother day-to-day workflows.

The project's dissemination and training events have therefore played a dual role. Alongside sessions covering foundational scientific content, many activities were purpose-built to deliver hands-on, application-oriented insights—maximising relevance for mixed audiences frequently including industrial practitioners and academic participants. Accordingly, this report provides an overview of those activities and develops the practical, training-focused elements in depth.

For readers seeking the underlying scientific framework and fundamental modelling concepts, the complementary deliverable D2.2 (Fundamental Modelling) presents the theoretical background, modelling assumptions, and core physical principles that underpin the applications discussed here, whilst this deliverable (D4.2) addresses the application and training dimension of that mission. It focuses on how modelling methods and simulation outputs can be integrated into industrial practice and skills development, targeting stakeholders ranging from plant managers and production engineers to early-career researchers and students.

2. ACTIVITY PERFORMED

The training activities conducted within METACAST consisted of a series of events—both online and in-person—designed to strengthen practical skills in applying numerical modelling to the continuous casting of steel. These sessions formed a key component of the project's educational strategy and supported the transfer of modelling knowhow to industrial and academic participants.

During 2025, three events involving training aspect were organised:





- **6th Simulation Event**, hosted by K1-MET on **23 April**, focusing on the practical use of simulation tools in continuous casting.
- **1st SIDENOR–SWERIM Seminar** on **1 July**, devoted to applied **CFD modelling** and its industrial relevance.
- **2nd SIDENOR–SWERIM Seminar** on **28 November**, addressing the application of **solidification modelling** techniques.

Some event sessions, more related to ‘modelling fundamentals’, are detailed in the corresponding Project Deliverable D2.2 and a general introduction for each event is quickly given at each start of section for sake of completeness and clarity. Then, as previously highlighted, focus is given on the ‘training’ aspects.

Recordings, extended materials, and additional information on all training events are available on the project website: <https://metacast-project.eu/>

2.1. Event at K1-MET

The **6th K1-MET Simulation Conference** was held in hybrid format at **TU Wien** on **23 April 2025**, in collaboration with the METACAST Consortium. For this edition, the conference placed particular emphasis on **the practical use of simulation and modelling tools for continuous casting**, aligning closely with the training objectives of the project.

The programme brought together speakers from both research institutes and industry, offering a platform for interactive knowledge exchange and discussions on how modelling approaches can support day-to-day process optimisation. Following an introductory presentation by **Dr. Gruber (K1-MET)**, the event transitioned from the scientific overview to a series of **application-focused training contributions**. These sessions showcased how numerical models can be validated and applied in operational contexts, with targeted inputs from **BFI (Kersten Marx)** and **K1-MET (Dr. Vakhrushev and Dr. Jakurek)**.

This training component represented a core element of the conference, demonstrating how modelling methodologies presented in the project can be translated into practical tools for industrial use. A detailed account of these training activities and their outcomes is provided in the present deliverable (D4.2).

Figure 1 presents a selection of images from the event, including the project introduction to the audience.

The conference attracted **around 55 participants on site** and **approximately 30 online attendees**, illustrating the strong interest in modelling-based approaches to continuous casting. Presentations covered several topics of direct industrial relevance, including:

- real-time casting analysis and fast data-driven mould simulations;
- multiphase MHD phenomena in the mould;
- solidification processes and their impact on the as-cast structure;
- practical applications of modelling tools in steel and refractory production, including quality prediction and model validation using water-model experiments and plant data.

In this sense, the ‘training touch’ was ascribed to the powerful message of having via modelling-based tool, instruments functional to problem solving and process control management.



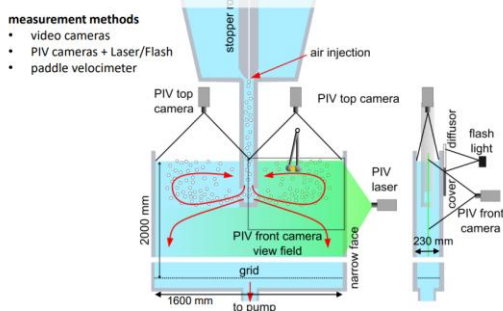
Figure 1. Images from of the ‘6th Simulation Conference’. Project introduction to the audience (C. Gruber, K1-MET)

The event provided a comprehensive overview of recent advances in process-modelling research relevant to the casting industry. Presentations addressed innovative approaches for real-time

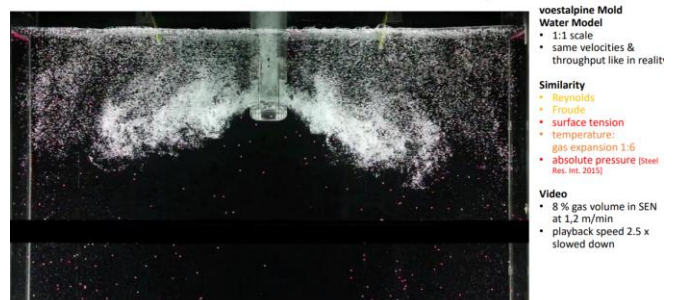
analysis of casting operations and the development of rapid, data-driven mold-flow simulations capable of supporting decision-making in industrial environments. Further contributions examined the complex behaviour of multiphase magnetohydrodynamic (MHD) phenomena within casting molds, as well as solidification mechanisms and their influence on the resulting as-cast microstructure.

In addition to methodological developments, several talks focused on the practical application of computational models within the steel and refractory sectors, particularly for process optimisation and quality forecasting. A recurring theme throughout these contributions was the **critical importance of robust validation**, highlighting that the reliability of predictive tools depends on systematic verification strategies. An example is shown in Figure 2 taken from the contribution presented by M. Jakurek concerning fluid flow validation¹. Speakers emphasised the need for comprehensive training datasets and the combined use of controlled water-model experiments and plant-scale operational data to ensure that numerical models remain accurate, trustworthy, and transferable to real industrial conditions.

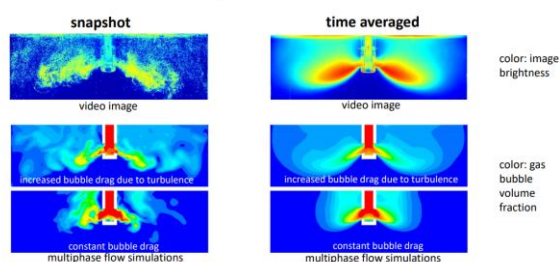
Water Model of Continuous Casting Mold



Water Model of Continuous Casting Mold



Video Camera Images: Bubble Distribution



PIV velocity measurements: two-phase flow

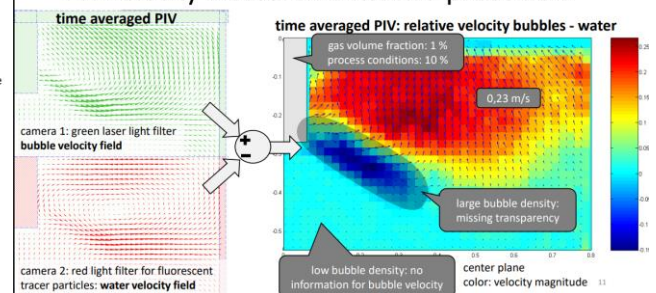


Figure 2. Images from of the ‘6th Simulation Conference’. Fluid flow Validation features in mould continuous casting with water modelling support (Jakurek et al.).

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

The first SIDENOR–SWERIM seminar, dedicated to **Computational Fluid Dynamics (CFD)**, was held on **1 July 2025** at the **SIDENOR Innovation Hub**, with hybrid broadcasting to facilitate broad participation. The event brought together academic and industrial perspectives through contributions from **Prof. Pavel Rámirez López (KTH)**, **Diana Mier Vasallo**, and **Raquel Arias Pérez** (Sidenor R&D).

Reflecting the structure of previous METACAST events, the seminar combined scientific insights with applied and training-oriented content. As mentioned in the ‘Fundamental Modelling’ Deliverable D2.2., the programme was organised into three sessions:

- **Session 1 – “CFD for Continuous Casting”**, led by **Prof. Ramirez López**, provided the scientific background to CFD modelling for continuous casting, including the fundamentals of thermo-fluid dynamics and the physical properties of steel influencing solidification.
- **Session 2 – “Digital Twins for Continuous Casting”**, also delivered by **Prof. Ramirez López**, shifted the focus toward application. The talk illustrated how digital twins can support troubleshooting, scenario evaluation, and model-based decision-making in industrial continuous casting, offering participants practical insight into the use of these tools.
- **Session 3 – Industrial Case Studies**, presented by **Diana Mier** and **Raquel Arias**, showcased successful examples of numerical modelling applied to real production challenges at SIDENOR. Both the second and third sessions served a clearer **training function**, strengthening participants’ understanding of how modelling tools can be applied effectively in industrial environments. These components contributed directly to METACAST’s objective of enhancing modelling literacy within the steel sector. The specific training aspects of the seminar are further detailed in the present deliverable (D4.2).

Images of the ‘training modelling’ session are shown in **Figure 2** as regard to the issues related to digital twin use for process control.

Digital Twins application for Process improvement

SWERIM

Modelling is used in 3 different ways:

- 1) As main research tool supported by extensive validation
- 2) As support to experimental activities to fill missing information gaps
- 3) As theoretical foundation for describing key physical phenomena

Models are applied to a variety of "interests" such as:

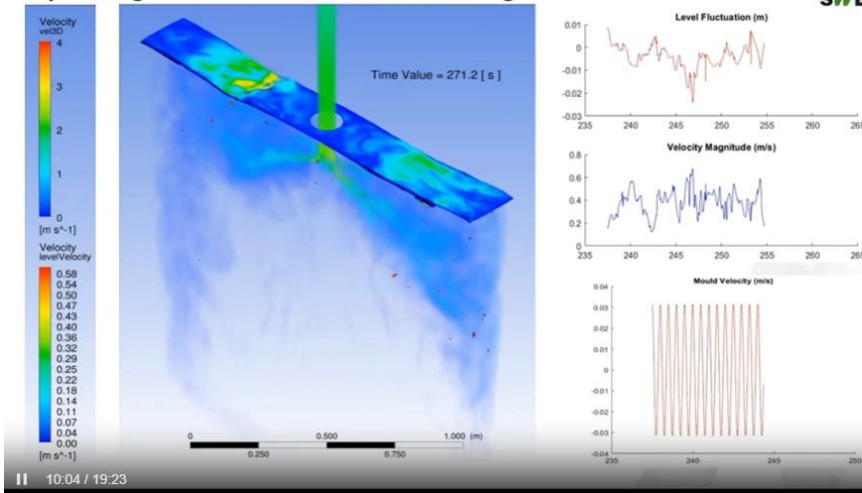
- Optimizing metal level stability to avoid issues such as slag entrapment or bubbles trapped in the shell
- SEN, stopper and mould re-design for flow optimization to avoid abnormal shell formation leading to cracks or depressions
- Determining the heat transfer in the mould to optimize slag selection and appropriate cooling strategies to avoid cold spots, stickers and/or eventually breakouts

II 6:12 / 19:23



Liquid Slag Entrainment Continuous Casting

SWERIM



II 10:04 / 19:23



Figure 3. Images from of the “CFD Modelling Event” – Session II. Training issues related to digital twin use for process control.

As mentioned, the final session, given by Diana Mier and Raquel Arias, presented real-world examples from Sidenor, showcasing how applied research and numerical modelling have been used to solve complex industrial problems (see pictures in **Figure 3**). These case studies highlighted how simulation supported approaches have been used to solve complex operational issues and improve process performance.

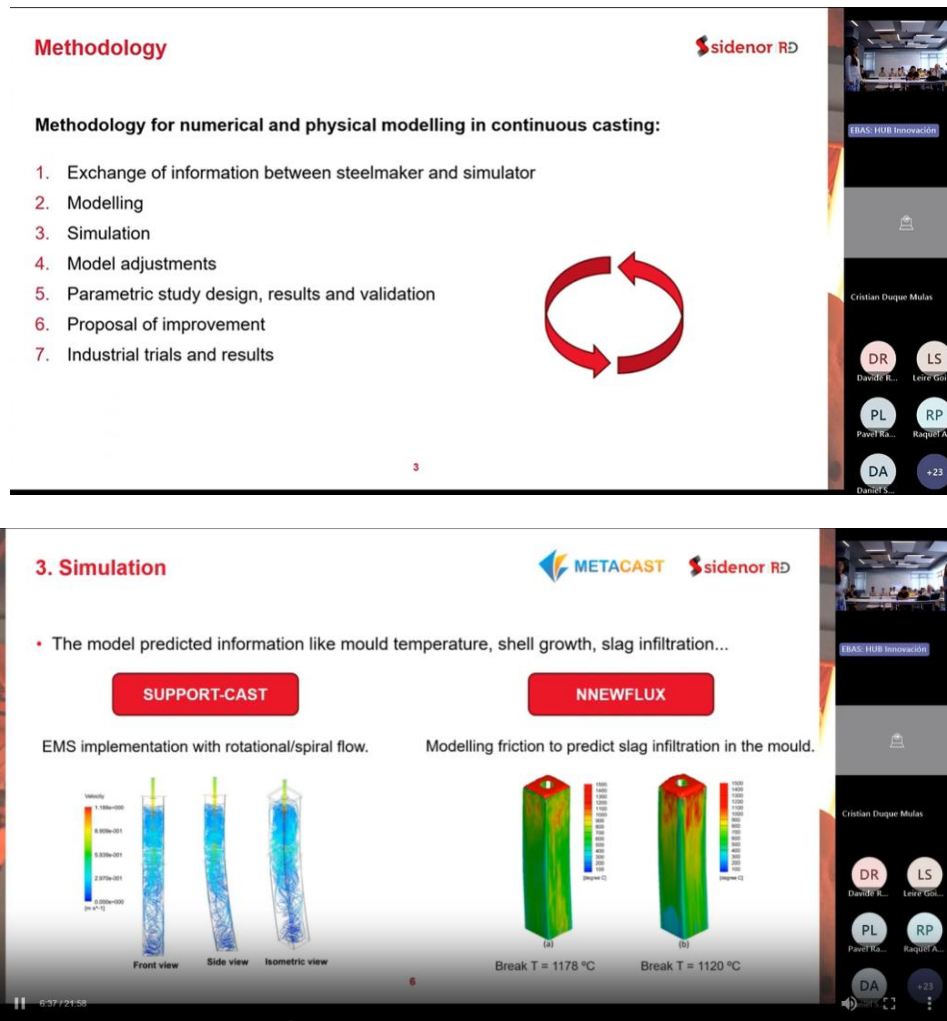


Figure 4. Images from of the “CFD Modelling Event” – Session III . Methodology strategy for application at industrial level as training from the model tool to problem solving.

Among the 25 on-site attendees, the main audience consisted of university students, young researchers, plant specialists, technologists, and engineers, which were the targeted groups for the event. Additionally, 30 participants joined online.

To support the educational component of the project, a preliminary training session was held for students, aimed at providing foundational knowledge on continuous casting.

This session, conducted in Spanish, included three modules:

- *Introduction to Continuous Casting,*
- *Continuous Casting at Sidenor, and*
- *Introduction to Numerical Modelling.*

A photo-shot of the session is provided in **Figure 4**.



Figure 5. Image from the “CFD modelling” training session at Sidenor Innovation HUB.

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 contributions included all the fundamentals involving continuous casting phenomena, from fluid flow principles to key concepts as nucleation, heat and mass transfer, microstructure modelling, stress–strain analysis, and advanced characterization and validation techniques.

The speakers were Pavel Ramirez 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 (Swetim AB)—providing space for discussion, experience sharing, and technical exchange.

For this second event, the Sidenor Innovation Hub brought together 20 on-site participants, representing the same target groups as in the first session: university students, young researchers, plant specialists, technologists, and engineers. Additionally, at Luleå University, 15 students attended the fundamental sessions presented below.

Again, as outlined in the deliverable D2.2, the first two sessions (*Solidification fundamentals*) and the second (*Introduction to Solidification Modelling*), both led by Prof. Ramirez Lopez, were of

‘*fundamental*’ nature, covering the full range of theoretical aspects of continuous casting, from the fundamentals of fluid flow to the key elements needed to describe solidification—such as nucleation, heat and mass transfer, microstructure evolution, stress–strain behavior, and the related characterisation and validation methods. On the other hand, the third session (*Industrial measurements techniques*), presented by Nora Egido and Beñat Elorrieta from Sidenor R&D, contributed an industry-oriented perspective, with particular attention to the measurement procedures supporting model verification and validation.

The technologies discussed included thermographic cameras, pyrometers, mould fibers, and laser vibrometers, among others and the objective was to present their applications, advantages, and limitations in detail. Additionally, examples from various RFCS projects where these techniques were implemented were showcased.

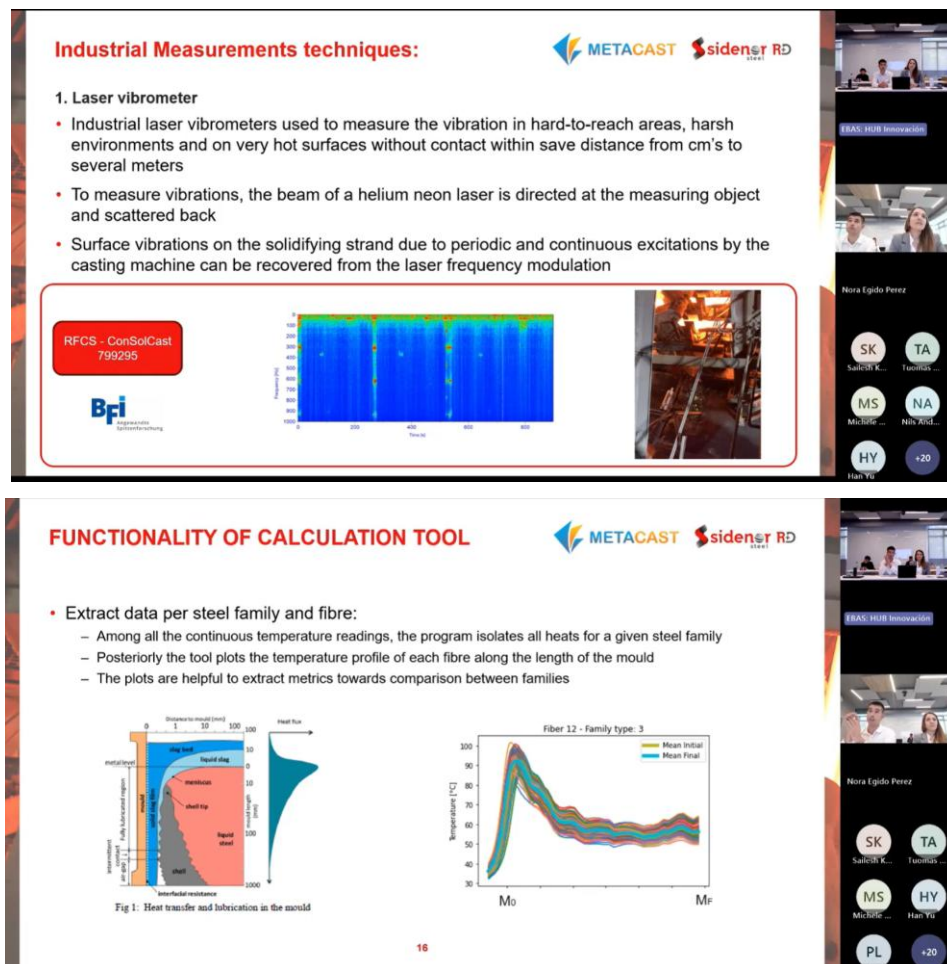


Figure 6. Images from of the “Solidification modelling” event – Session III. On training to link modelling data and approaches to on-field info.

Another qualifying aspect of the event was the further ‘clustering’ activity performed by showcasing as case studies, highlighting practical applications and research insights from the already ‘coupled’ EU-funded RFCS projects—Shell-Crack and SUNSHINE. As a matter of fact, by clustering projects on modelling for the continuous casting of steel, the industry gains a coherent platform that enhances knowledge transfer, builds operational know-how, and supports comprehensive skills development—while maximising EU-driven benefits for producers through improved product quality and greater process regularity

As a final comment, the discussion underscored a growing recognition within industry that numerical modelling is becoming an essential instrument for driving innovation and addressing operational challenges in continuous casting. Drawing on their experience, the speakers emphasized that stakeholders increasingly view modelling not merely as a research tool, but as a practical asset for improving process performance and supporting informed decision-making on the shop floor.

At the same time, the need for robust **model validation** emerged as a central challenge for achieving wider industrial adoption. Ensuring the reliability of simulations requires high-quality reference data, often obtained through laboratory experiments, dedicated measurements, or structured plant-level databases. Strengthening these validation resources is therefore a key step toward enhancing confidence in model-based solutions.

The discussion also highlighted that effective validation and meaningful application relies on a solid scientific foundation. Continued investment in **fundamental research** remains crucial to support the development and refinement of modelling tools used in training and industrial problem solving. Sustained institutional commitment and funding programmes will play an important role in maintaining this long-term capability across the sector.

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:

- were three and involving the presence of relevant academics, as claimed in the Project Grant Agreement;
- were in hybrid mode (apart from the SID Innovation internal HUB session in Spanish) with session with students and researchers’ audience;
- included a session (in the frame of the SIDENOR-SWERIM event) focused on clustering action with the ongoing RFCS projects on continuous casting SHELL-CRACK and



SUNSHINE. This action was compliant with the indication of the project Officer and Reviewer, after the I Review Meeting, to go ahead in the clustering actions to foster modelling approach in R&D, aimed at continuous casting quality and productivity improvement, to support European stakeholders in keeping successfully the market level gained and helping them to enlarge their portfolio in a wider sustainability frame.

