10th European Conference on Continuous Casting

Bari · Italy
20-22 October 2021

Organised by
ASSOCIAZIONE ITALIANA DI METALLURGIA

Cracks in continuous casting: the roadmap for future research proposed by the VALCRA RFCS project

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SUMMARY

Introduction to VALCRA RFCS project

VALCRA method for the Roadmap

Cracks as a central issue in research

Results of past RFCS projects: “where we are”

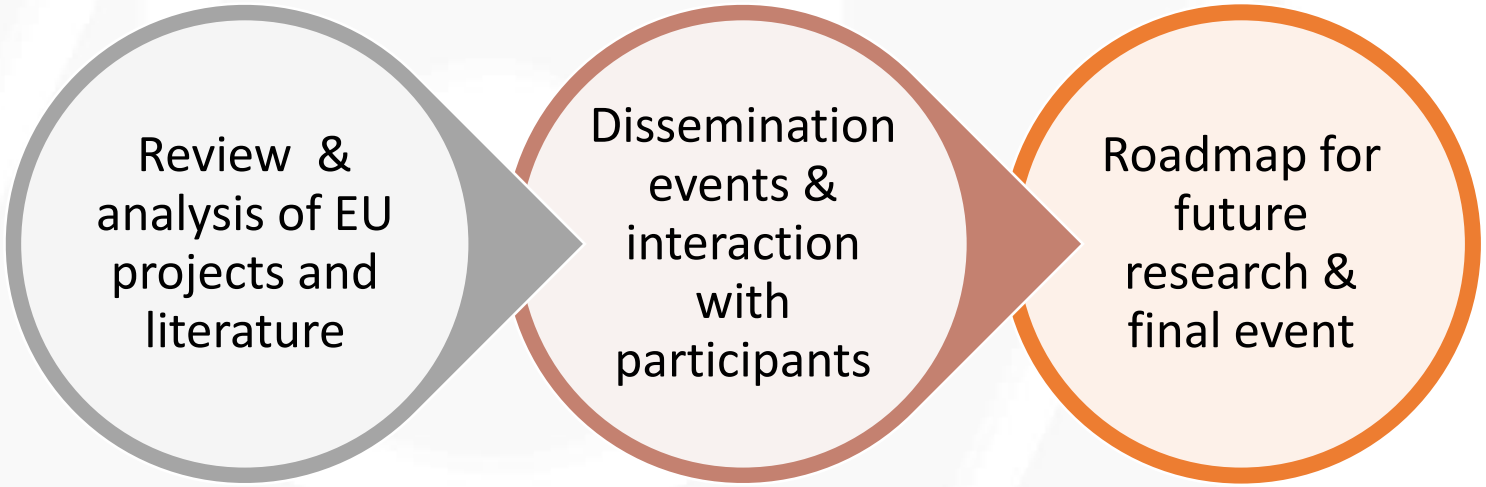
Future research trends on cracks according to VALCRA results: “where we go”

VALCRA Roadmap for future research

VALCRA: a RFCS dissemination project

"VALorisation and dissemination of RFCS projects results and experience in steel surface quality issues: on as-cast CRAcks formation"

The three project phases



All project documents, videos of the events and presentations openly available at:

www.valcra.eu

VALCRA dissemination events

Technical workshops - Interactive round table - Roadmap events

Openly available to participants worldwide. Large attendance from industry and R&D

Micro-alloyed steels and cracks in continuously cast billets

March 2020

Cracks in continuous casting: highlights of 25 years of RFCS research

June 2020

Measuring techniques in continuous casting

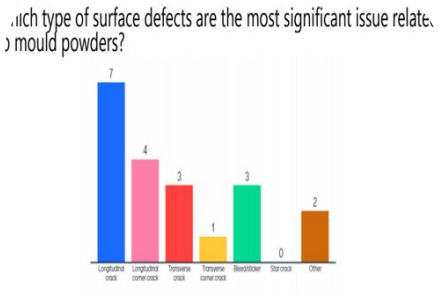
July 2020

Mould powders and operating conditions

September 2020

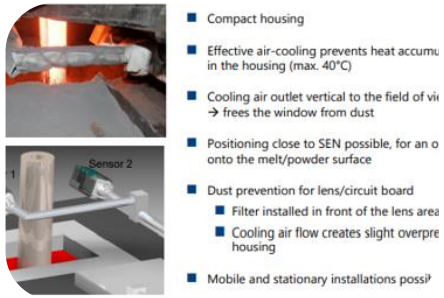
Modelling in continuous casting

September 2020



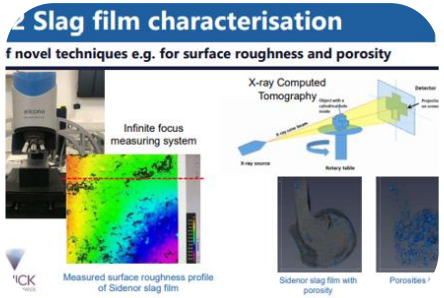
Roadmap Interactive workshop - Phase 1

28th October 2020



Measuring Techniques (Plant)

5th Nov 2020

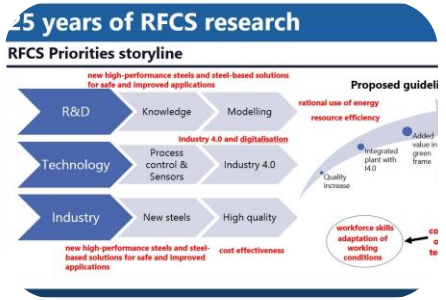


Casting parameters and mould

11th Nov 2020

Roadmap Interactive workshop - Phase 2

16th Nov 2020



Discussion of draft roadmap - Phase 3

2nd Dec 2020

VALCRA method for the Roadmap

The VALCRA Roadmap is based on the following elements:

- Analysis of the state-of-the-art literature on the subject: ECSC/RFCS projects and international research work **(deliverable D3.1, available at www.valcra.eu)**
- Future developments envisaged by the past ECSC/RFCS projects
- Discussions during technical dissemination events
- Survey submitted to participants of dissemination events
- Questions asked during the **roadmap-interactive-webinar**
- Requirements identified in a devoted roundtable with the **EU steel producers**
- Next challenges and research trends identified in the RFCS Monitoring and Assessment report 2011-2017
- Direct experience of the project participants

Cracks as a central issue in research

Why are cracks still a problem?

1. Increased complexity of steels → to fulfill more demanding applications
2. Cost reduction → higher yield, defect reduction
3. Increase in customer quality requirements, based on better crack detection techniques in downwards production process
4. Near-net-shape products → intrinsically relevant for yield and reduction of waste, if quality is ensured
5. Increased productivity → increased speed and product size

What has been achieved thanks to (+30) ECSC/RFCS projects in 25 years?

- Development of fundamental knowledge
- Development of numerical models
- Spread of technology application (EMS, oscillation, secondary cooling, etc.) – for project participants
- Diffusion of control systems and sensors

What could have worked better?

- Spread of project results (generally limited to project participants)

RFCS: Where we are

Basic Knowledge

Fundamentals of the crack formation occurrence, involving all the chemistry and physics of the change of state also related to the cooling pattern imposed by the operating conditions and the steel grade features

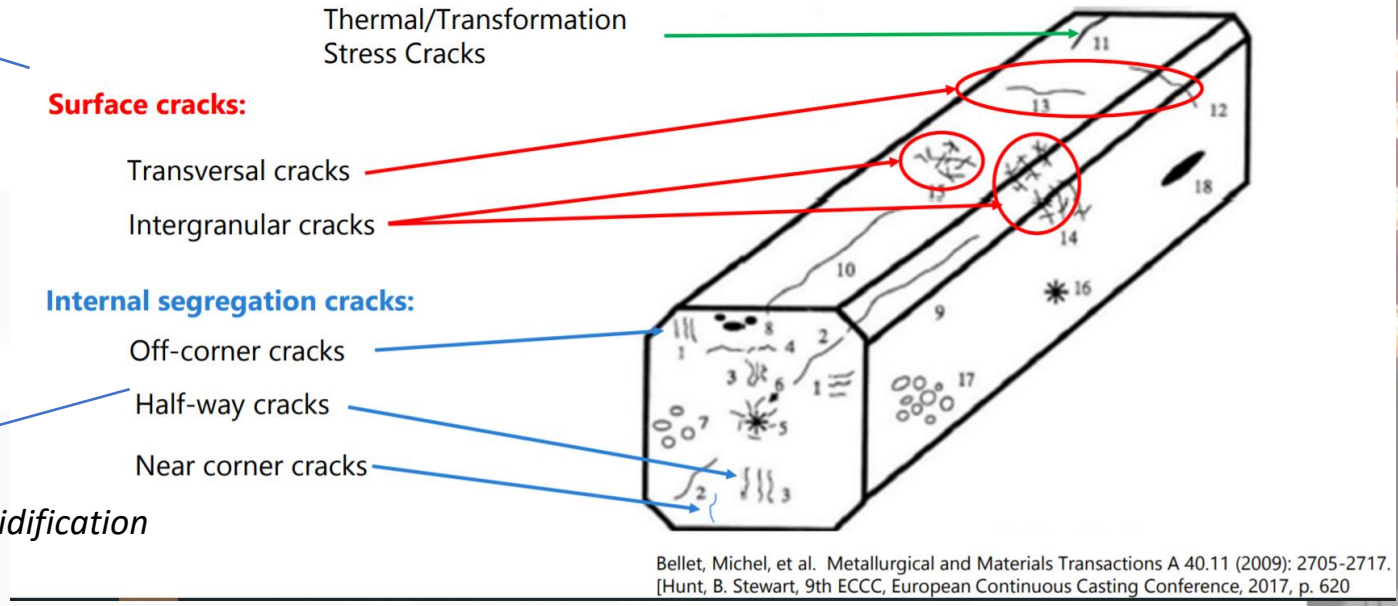
- *PMAP*

C, Cr and Mn, combined with microalloyed elements that precipitate during austenite transformation

Crack prevention in Continuous Casting

- *PRECIPITATION*
- *PMAP*
- *KINPCC*

Microalloyed steels with Al, Ti, N, V, B, Nb



Bellet, Michel, et al. Metallurgical and Materials Transactions A 40.11 (2009): 2705-2717.
[Hunt, B. Stewart, 9th ECCC, European Continuous Casting Conference, 2017, p. 620

Study on brittleness of carbon steels during solidification

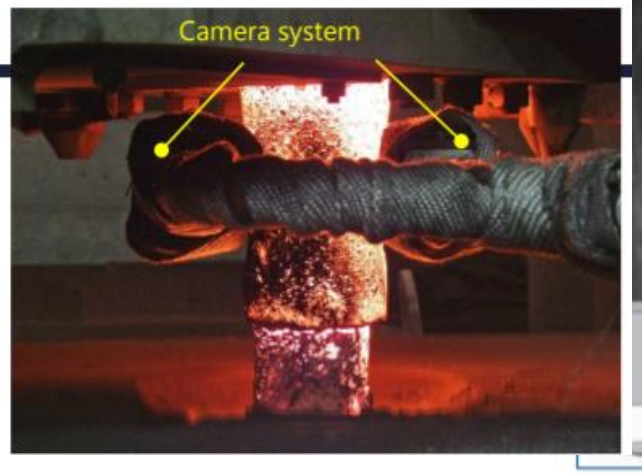
- *ICCRACK*
- *PMAP*

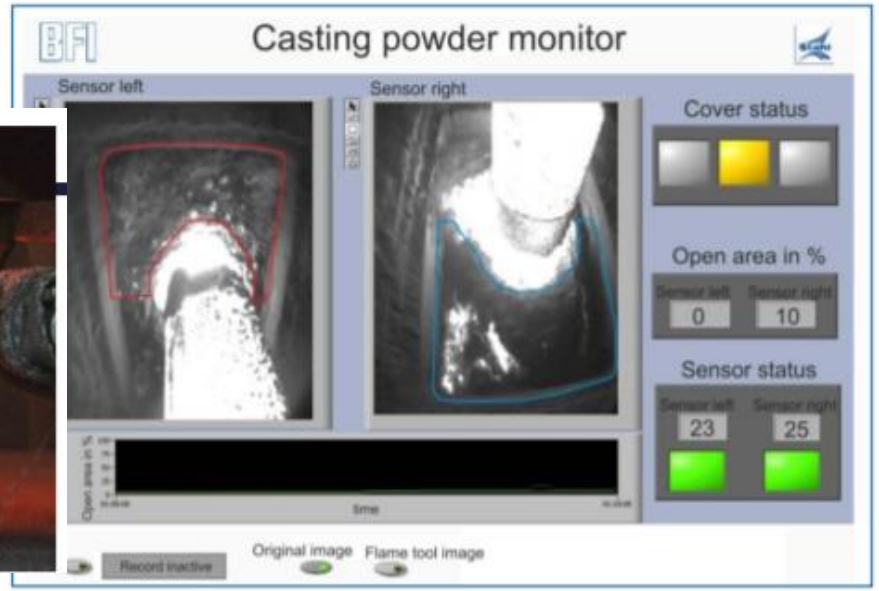
C, S [Mn/S], B, casting conditions

RFCS: Where we are

Mould Powders

- **Consumption Rate**
  - linked with lubrication properties
- **Composition of Mould Powders**
  - interaction with steel composition
- **Powder feeding**
  - consistent and reliable feed through closed loop control
- **Modelling of mould powder**
  - directly integrated with general modelling topic





- Fluorine- & Carbon-free powders
- Non-Newtonian powders → **NNewflux**

POWDER COMPOSITION

Further techniques for control of heat flux at meniscus

(not directly related to powders)

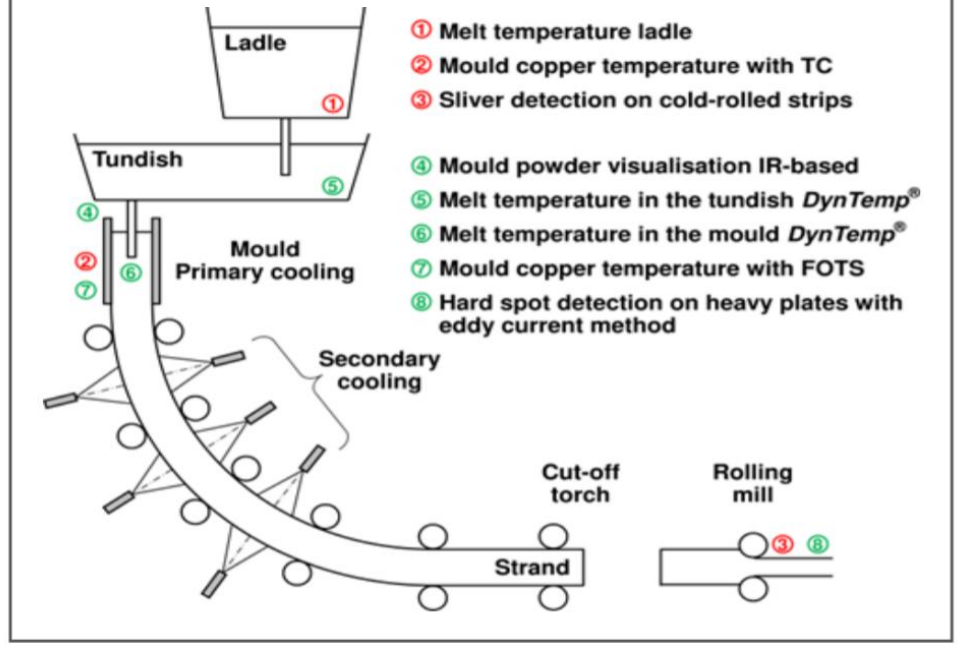
- Grooved mould surface → **Innosolid**
- Intumescent mould coating → **OptilocalHT**, **SupportCast**
- Iron particles addition into the flux (no composition change) → **OptilocalHT**

RFCS: Where we are

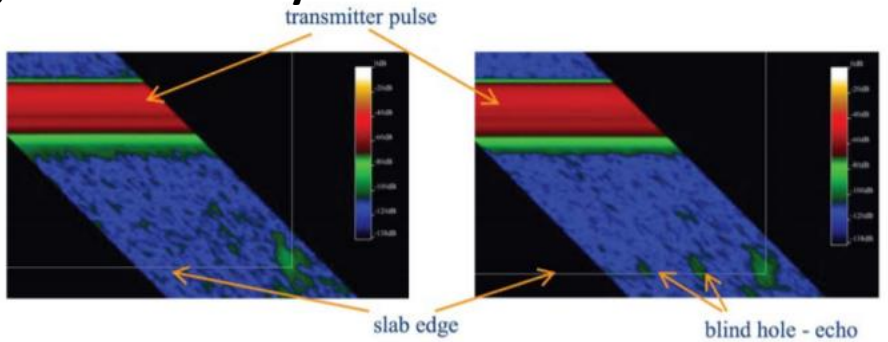
Process control and sensors

- **Sensoring,** for better process control
- **Mould powder monitoring,** IR Camera Measurement of mould powder cover
- **Fibre Optical Temperature Sensors,** for mould **dense** thermal monitoring
- **Continuous Temperature Measurement in the Melt,** (DynTemp®)
- **Detection of surface defects**
  - development of the EMAT-EMAT [Electromagnetic Acoustic Transducer] system
  - conoscopic holography

RFCS: RealTimeCastSupport



RFCS: NDT Casting EMAT-EMAT system

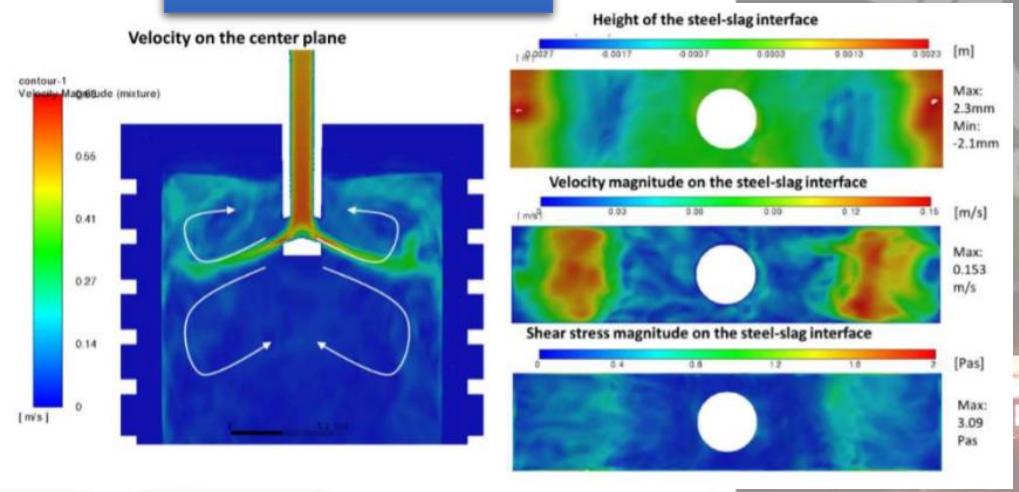


RFCS: Where we are

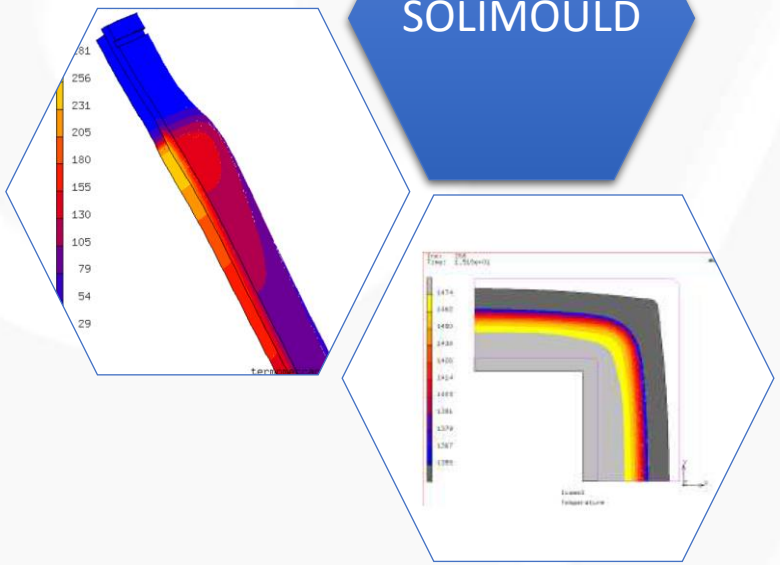
Modelling

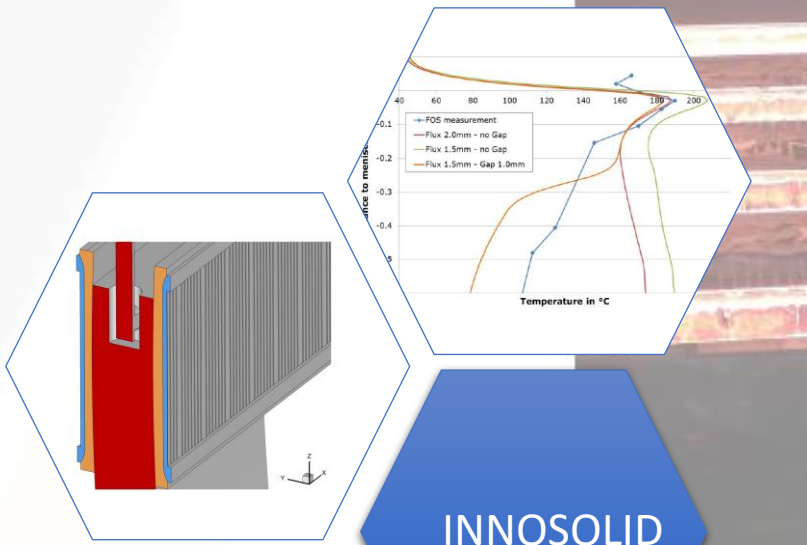
- In-mould steel solidification (2D and 3D FEM/CFD)
- Numerical model for new cooling strategies
- Evaluation of as–cast microstructure
- Modelling of mould flux behaviour
- Modelling of new mould geometries
- 3D numerical models in FEM to simulate bending
- Full strand inter-roll bulging model

NNEWFLUX



SOLIMOULD





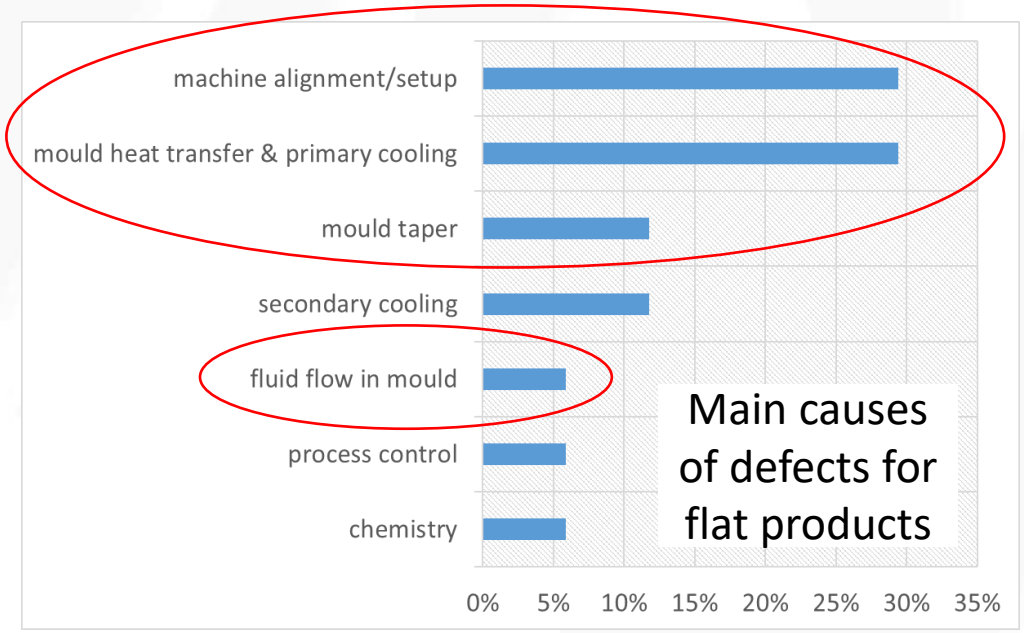
INNOSOLID

Cracks in continuous casting: where we go

Research focus: *Solidification in the mould*

Drivers

- Increasing complexity of steel grades
- High quality
- Cost reduction



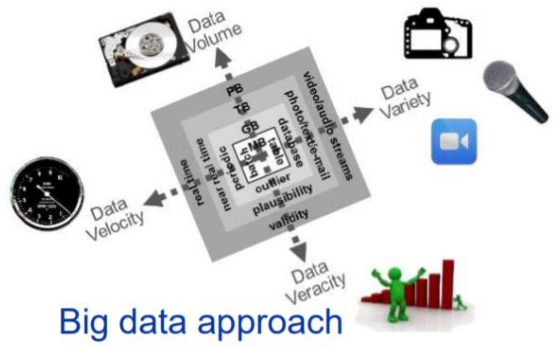
Opinions of Valcra audience

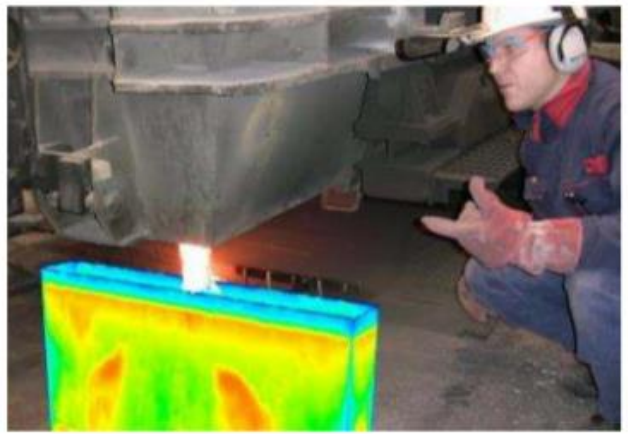
What we need:

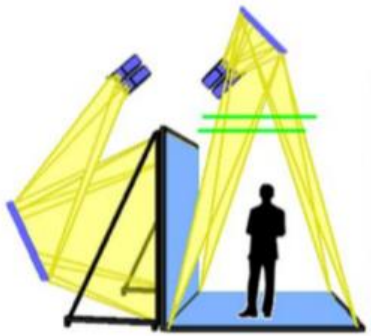
- *Mould thermal monitoring (dense measuring points)*
- *Monitoring of mould powder layer*
- *Innovative sensors*
- *Inclusion control & fluid-dynamics*
- *Mould coating/Mould design (geometry, channels, water flowrate)*
- *Automatically refining of oscillation settings*

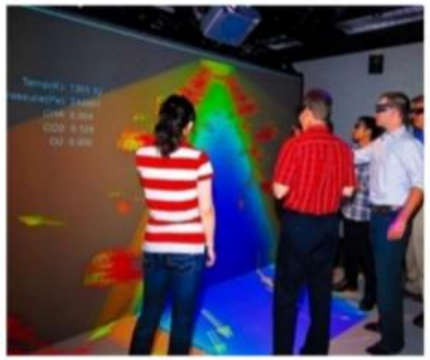
Cracks in continuous casting: where we go

Request of new and reliable models









What we need

- *Digital twins*
- *Characterization of material thermo-mechanical behavior as a function of process conditions*
- *Online metallurgical based models*
- *Strong connection with* ***material characterization***
- *Implementation of big data analysis*
- *Implementation of models to cast new steel grades*
- *Ease of use, fast response,* ***low CPU time***
- ***Virtual reality*** *for* ***training*** *and technical* ***decision making***

Cracks in continuous casting: where we go

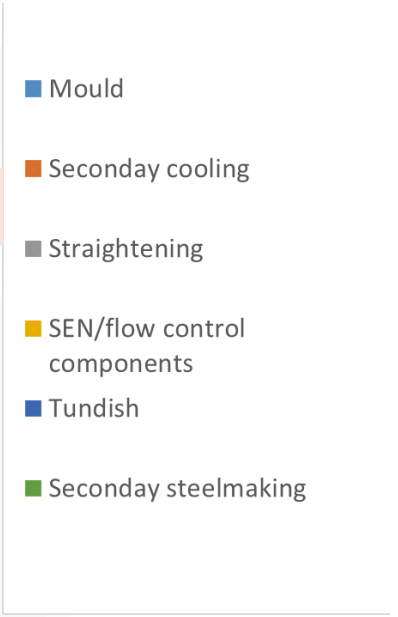
Solidification in the mould: *primary importance of modelling*

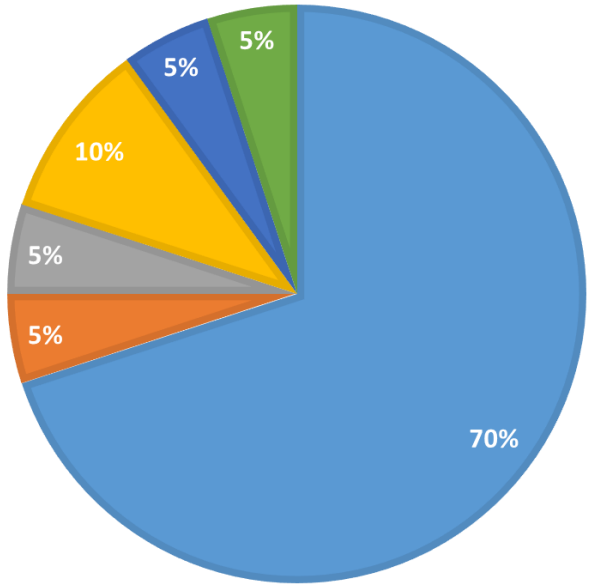
What models?

- **shell** development
- **thermo-mechanical** with crack evolution in mesh
- **transient** mould **flow**
- **powder interaction with steel** - heat transfer and fluid flow
- **fluid** flow and heat transfer
- **solidification** and **fluid** flow
- **fluid** flow at mould top

Opinions of Valcra audience

What part of process/caster to model?



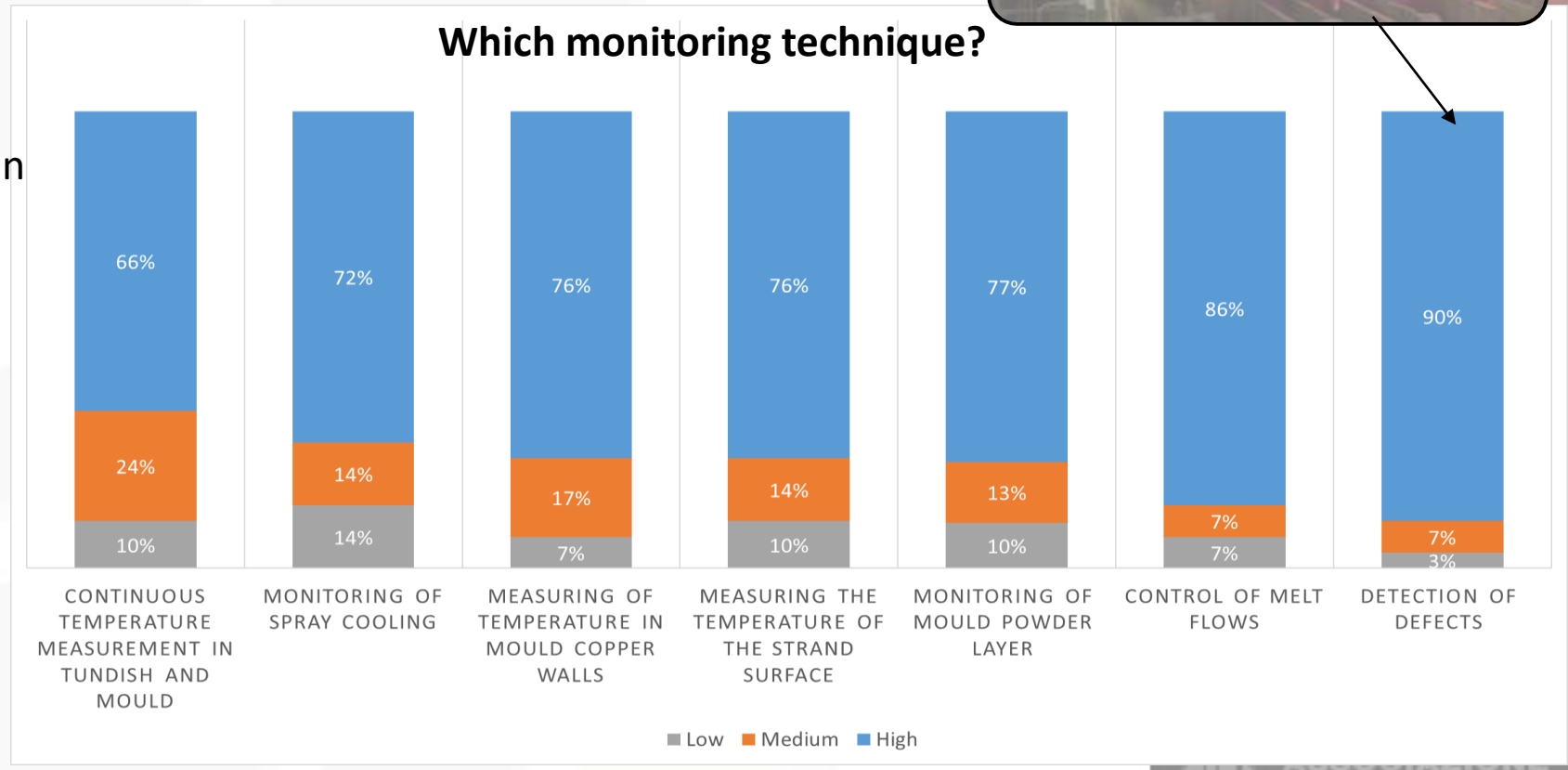


Opinions of Valcra audience

Cracks in continuous casting: where we go

Sensors, monitoring and control

- *Drivers*
  - Safety
  - Energy and raw material savings
  - Reduction of defect occurrence on the final product
- *Requirements*
  - Cost effectiveness / level of investment
  - Reliability and accuracy (e.g. reduce false-positive readings in defect detection)
  - Independent of specific application



Interest of Valcra audience

Cracks in continuous casting: where we go

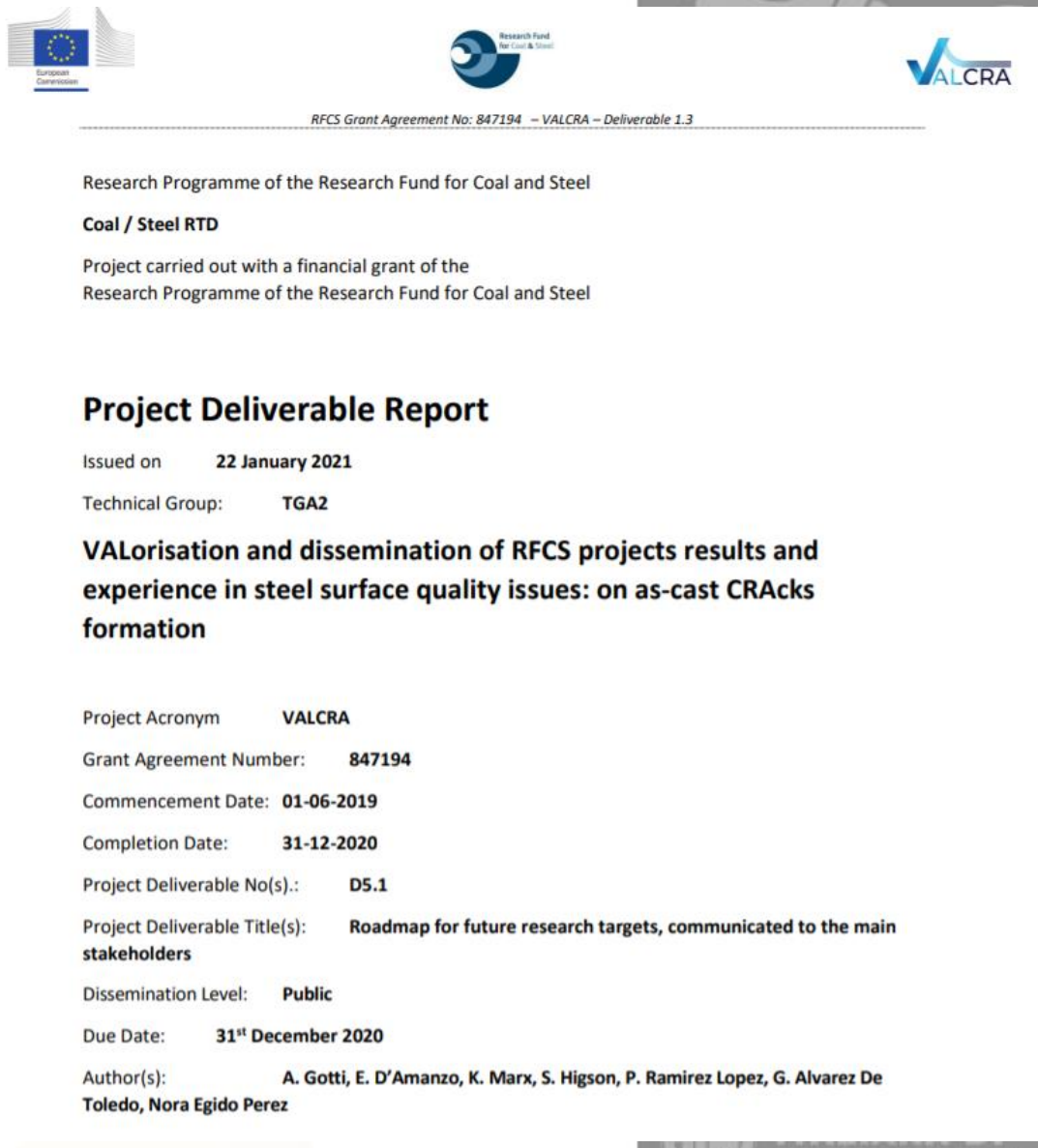
Further general items

- **Aging plants and equipment in EU**
  - ✓ *Extend the effective life*
  - ✓ *Adapt older casters to produce new steels with increasingly higher specifications*
- **Residual and alternative elements to be studied**
  - ✓ *Ce, Cu, Sn, etc.*
- **Integrated process control**
- **Increased staff skills, training, relevant role of R&D**
- **Resources and energy saving**
  - ✓ *Also with respect to the overall aim of 'carbon neutral' steel production → Green Deal*
- **Near-Net-Shape Casting:** *do further improvements in sensor, modelling and early detection of defects allow the near-net-shape savings to be realised?*

Cracks in continuous casting

ROADMAP for future research actions

VALCRA final deliverable, openly available at:
https://valcra.eu/wp-content/uploads/2021/03/D5.1-VALCRA-Roadmap-for-future-research-targets-communicated-to-the-main-stakeholders.pdf



RFCS Grant Agreement No: 847194 – VALCRA – Deliverable 1.3

Research Programme of the Research Fund for Coal and Steel

Coal / Steel RTD

Project carried out with a financial grant of the
Research Programme of the Research Fund for Coal and Steel

Project Deliverable Report

Issued on **22 January 2021**

Technical Group: **TGA2**

VALorisation and dissemination of RFCS projects results and experience in steel surface quality issues: on as-cast CRAcks formation

Project Acronym **VALCRA**

Grant Agreement Number: **847194**

Commencement Date: **01-06-2019**

Completion Date: **31-12-2020**

Project Deliverable No(s).: **D5.1**

Project Deliverable Title(s): **Roadmap for future research targets, communicated to the main stakeholders**

Dissemination Level: **Public**

Due Date: **31st December 2020**

Author(s): **A. Gotti, E. D'Amanzo, K. Marx, S. Higson, P. Ramirez Lopez, G. Alvarez De Toledo, Nora Egido Perez**

Cracks in continuous casting

ROADMAP for future research actions

Ageing plants

- **DRIVER**: European plants are ageing
- **SUGGESTIONS**:
  - Improve efficiency to extend working life
  - Produce high value added grades on existing production unitis with limited investment

Validation of numerical models

- **DRIVER:** Modelling and other Digital platforms (e.g. Virtual Reality, Artificial Intelligence, Internet of Things, etc.) are key technologies. They need **real plant data, experimental validation and adequate data inputs**
- **SUGGESTIONS:**
  - Research on Digital twins, online metallurgical models, multivariate analysis for correlation with process conditions and Big Data analysis.
  - Enhance availability of thermophysical and chemical properties, open-access databases and product quality data accessible to all steelmakers.

Modelling knowledge transfer

- **DRIVER:** Numerical modelling knowledge needs transferring across a broader platform other than stakeholders in RFCS projects
- **SUGGESTIONS:**
  - Removing barriers to full exploitation of modelling: e.g. complexity, software/hardware availability, licensing costs, skills gap and online implementation.
  - Dissemination actions and education

Cracks in continuous casting

ROADMAP for future research actions

Mould Powders

- **DRIVER:** development of casting powders is pushed by production of higher performance steels
- **SUGGESTIONS**:
  - Generate fundamental knowledge on the physiochemical properties of new combinations of flux materials
  - Study interaction between these and new steels.
  - Further develop models
  - Alternative techniques to allow application of standard powders in more demanding applications

Intelligent sensors

- **DRIVER:** Tangible savings in yield or improved quality can be achieved through automated monitoring and inspection of casting conditions/outputs and product quality
- **SUGGESTIONS:**
  - Develop sensors capable of **process control** and **product monitoring** and/or coupling to **digital technologies** to suggest corrective actions to cracking and process problems based on machine status and product quality

Alternative alloying elements

- **DRIVER:** The use of **cheaper or more readily available** alternative alloying elements can imply production problems, e.g.: mould powder pick up, clogging and negative modification of flux properties
- **SUGGESTIONS:**
  - Study the effect of alternative alloying elements for new generation steels from more economical and sustainable sources

Thanks for your attention!

Questions are welcome

Stay informed

http://valcra.eu/

https://www.linkedin.com/company/european-continuous-casting-network

VALCRA linkedin group (linkedin.com/groups/13794289/)