VALCRA – Roadmap
Process optimization features

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European Commission

Research Fund for Coal & Steel

Process optimization

What means Process Optimization?

" definition of strategies such as tailoring operating practices and actions aimed to reduce the occurrence of defects in the final product, without detrimental impacts on productivity and safety conditions"

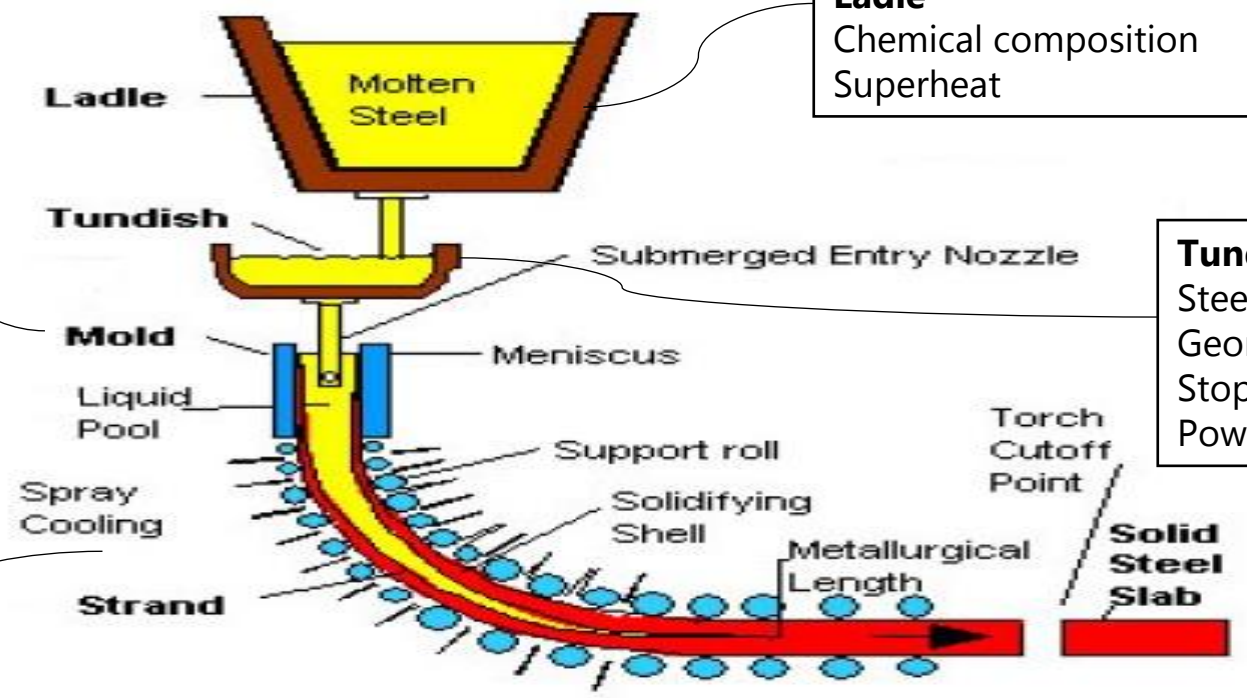
Process optimization

Process parameters

Many parameters can influence the occurrence of defects in CC.

Mould
Heat flux, water ΔT
Casting speed
Mould oscillation
Mould taper
Powder properties
SEN design
Level control
Electric Mould Stirring (EMS)

Secondary cooling
Design (ex. nozzle position, distance, size, etc)
Water flowrate distribution
T trend along the strand



Ladle
Chemical composition
Superheat

Tundish
Steel protection
Geometry (dams, baffles)
Stopper Ar flowrate
Powder selection

Process optimization

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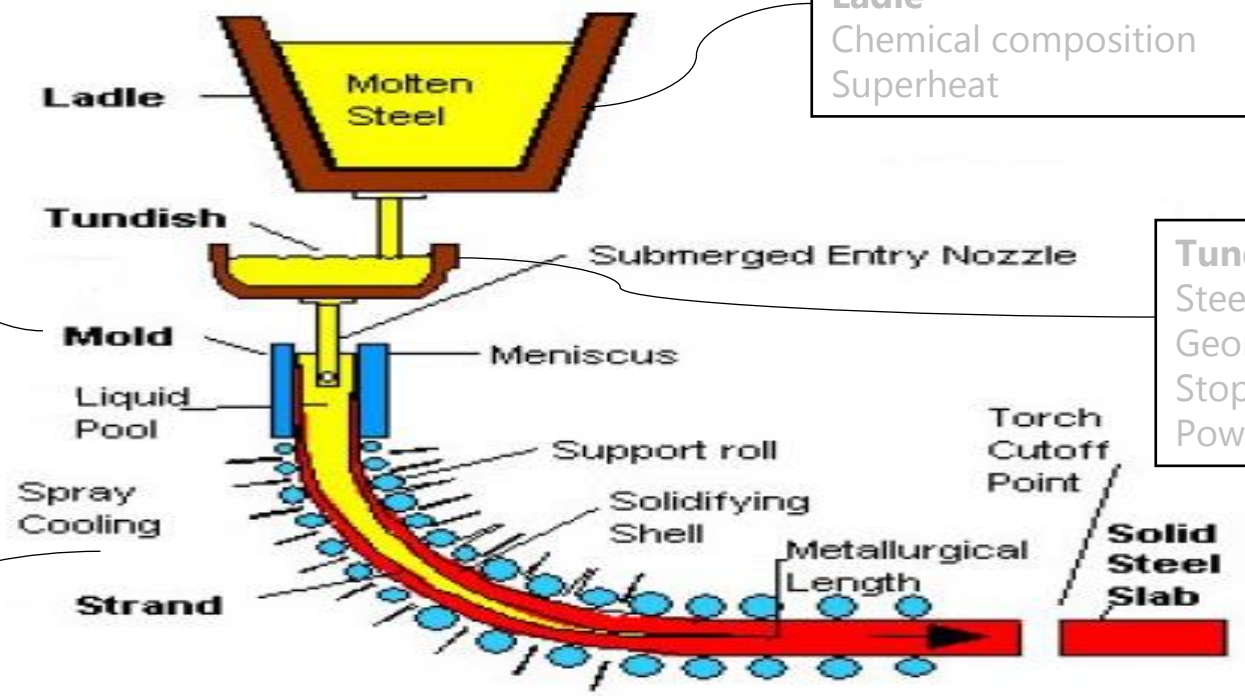

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The quality of slab/billet is strongly affected by several parameters, often interconnected each other

Process optimization

EU research

Layout design

Modification to the caster definition to reduce cracks formation

Operating conditions

Definition of operating windows to reduce cracks occurrence. Definition of rules for downgrading due to potential crack generation

It emerged **4 main sub-topics** concerning **process optimization** in CC

Improved steel compositions

Optimization of steel chemical composition for improving castability and to reduce defect occurrence

Injection techniques

Identification of specific techniques for inoculant addition to liquid steel to modify solidification

Process optimization

EU research

First milestone of VALCRA project is the publishing of D3.1.
The main results of process optimization are highlighted.

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Process optimization

EU research

The scope of RFCS projects is to minimize the **presence of defects.**

Different strategies have been applied, and all solutions are customized in function of steel-grade, plant conditions, production needs, new implemented tools

Process optimization

EU research

QUESTION 1.

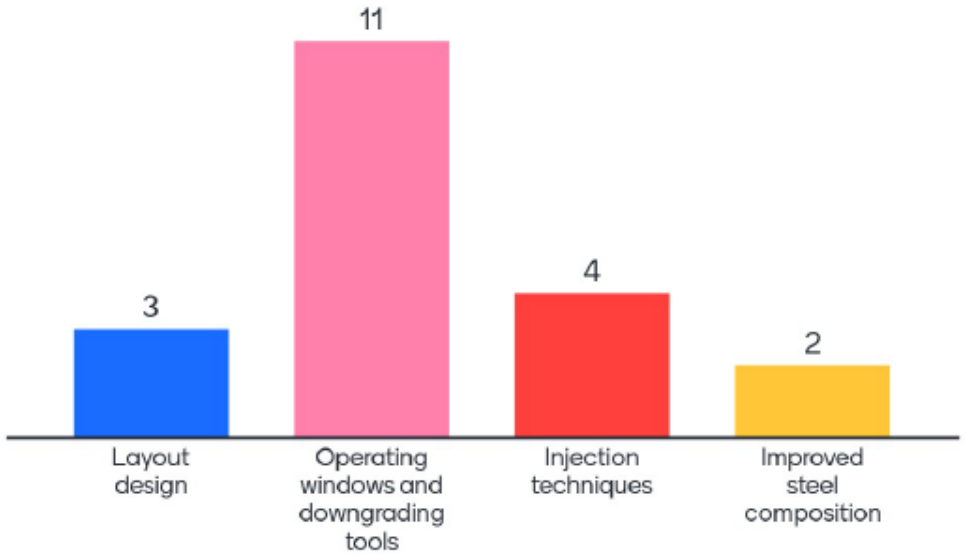
In short-medium term, which of these sub-topics is more performing to optimize casting process (based on your own experience)?

A. Layout design

B. Operating windows and downgrading tools

C. Injection techniques

D. Improved steel composition



Process optimization

Layout design

"Modification to the caster definition to reduce cracks formation"

Project	Main topic	Product	Type of defects
DDT	SEN wear and tundish positioning	Slab	Trasversal crack and longitudinal crack
CASTEDEMON	Modification of end plate distortion	Slab	Off corner depression
SOLIMOULD	The influence of mould taper was studied in connection with casting speed and steel chemistry.	Billet	Control of heat flux / Reduction of disturbance level
Control of the dendritic structure of the initial frozen shell in continuous casting,	Variation of mould geometry to prevent detachment of solidifying shell	Billet	Corner defects
CASTEDEMON	Variation of taper at the top of the mould, variation of mould taper at meniscus	Billet	Longitudinal cracks

- **Few projects about this sub-topic**
- **Trials campaign performed gives good results**

Process optimization

Layout design

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Question 2.

Considering layout modification (mould taper, caster design, tundish configuration), which could be the main difficulties in a fully application of such solutions in CC process?

A. Lack of data and reliable models to relate new solutions and to face defects
B. Choice of alternative ways to reduce the incidence of defects easier than layout modification
C. Lack of knowledge and studies on this topic
D. Too high financial investment costs
E. Layout modification cannot solve the problem since tuning and setting operation can generate loss of production and risks of product quality problems

Process optimization

Layout design

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Process optimization

Layout design

Question 3.

In short-medium term, considering possible benefits of layout modifications, for which product could be more effective a modification of casting layout?

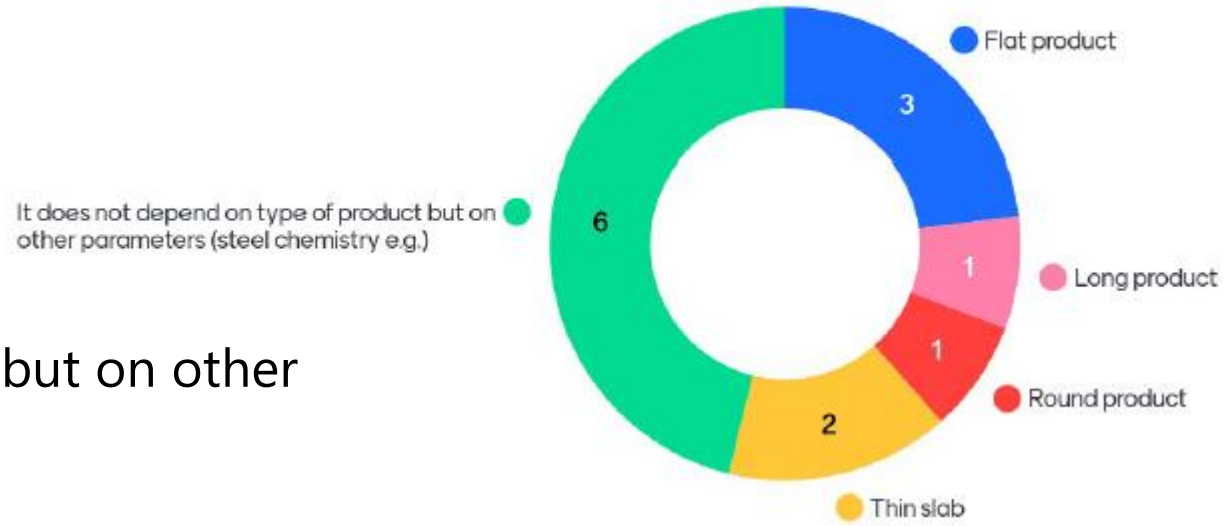
A. Flat product

B. Long product

C. Round product

D. Thin slab

E. It does not depend on type of product but on other parameters (steel chemistry e.g.)



Process optimization

Operating conditions

"Definition of operating windows to reduce cracks occurrence. Definition of rules for downgrading due to potential crack generation"

- Operating windows changing is always supported by numerical and physical modelling
- It is implemented when the incidence of defects must be reduced, or new tools are introduced
- The selection of suitable operating window is mainly based on mould thermal exchange and chemical composition of steel.

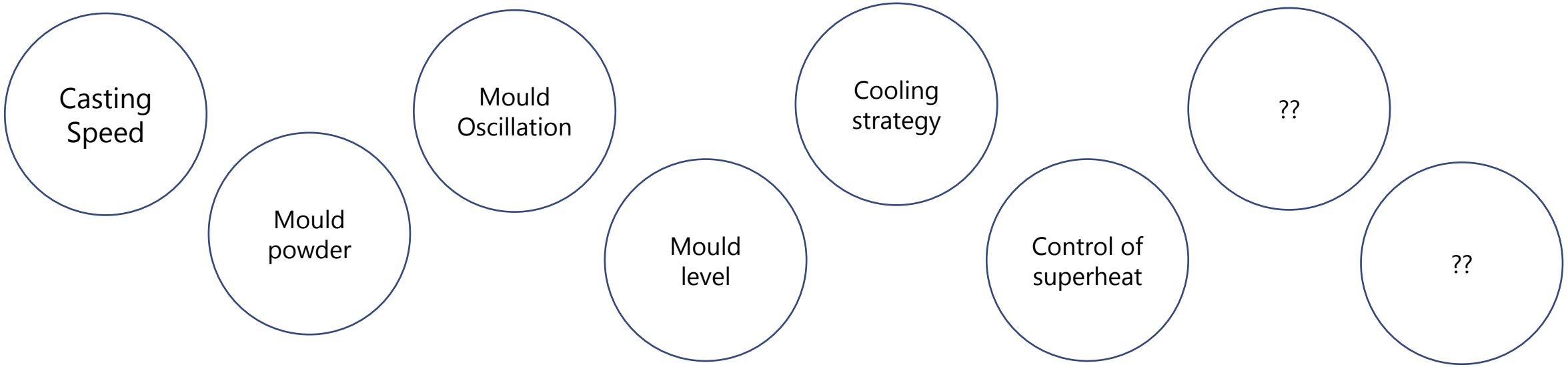
Process optimization

Operating conditions

CASTABILITY	**Faster cooling** to prevent Ti and Ti-Nb precipitation	Slab	Segregation Cracks
PRECIPITATION	Ti and Nb precipitate at grain edges. New **soft cooling** to keep Temperature of slag >900°C during bending	Slab	Off corner and transversal cracks
DEFREE	Mould coated with nickel + **control of superheat and casting speed**. Reduction of defects also connected with roller settings	Slab	Trasversal and star cracks / Centreline segregation
SUSPYCC	**Control of level of oscillation and control of CCM motors**		System of alarm to prevent breakouts and downgrading rules
CASTDEMON	**Downgrading thought the use of digital tool**		
SLAGFILMOWLD	Steel susceptible of crack in SEN region due to lack of molten slag**. Proposed soft cooling + Increased superheat + Lower oscillation amplitude**	Stainless steel slab	Deep longitudinal cracks
PRECIPITATION	For microalloyed steel, **Changing in water distribution** to uniform heat transfer in secondary cooling	Billet	Off corner cracks
ICCRACK	**Hard-cooling has been balanced with spray nozzles**	Billet	Transversal cracks
SUSPYCC	Definition of empirical surface **quality index and relationship with casting speed**	Billet	Transversal cracks

Process optimization

Operating conditions



- Difficulties emerged in the RFCS projects are the interconnection between all these parameters, that makes hard the prediction and transferability of results.
- It is important to have reliable measuring systems and mathematical models

Process optimization

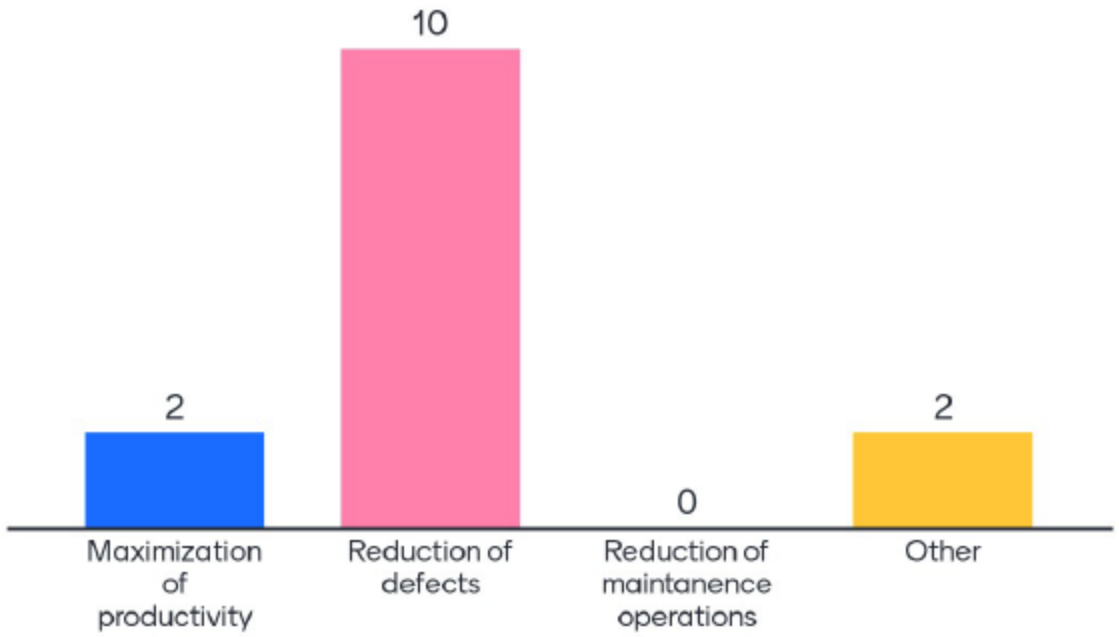
Operating conditions

QUESTION 4.

In selecting operating windows, and the necessary supporting tools, definition of strategy is fundamental.

In your opinion, which is the strategy that should be applied?

A. Maximization of productivity
B. Reduction of defects
C. Reduction of maintenance operations
D. Other



Process optimization

Operating conditions

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QUESTION 5.

Modifications of operating conditions can be considered the most useful route to rapidly move from a defect to an almost zero-defect conditions. However, as it emerged in RFCS project analysis, operating condition modification is an attempt road, where continuous solution need to be tested.

According to you, which is the main concern/s regarding modifications of operating conditions and so where research should be addressed?

A. Lack of reliable and suitable predictions models
B. Lack of right measuring and sensoring systems
C. Necessity of too many experimental trials before implementing a new solutions
D. Lack of technical and scientific knowledge
E. Difficulty to easily transfer results from one application to another
F. Other

Process optimization

Operating conditions

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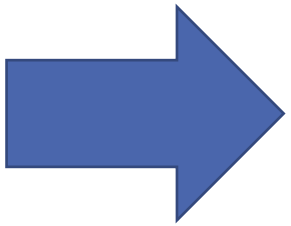
Process optimization

Injection techniques

"Identification of specific techniques for inoculant addition to liquid steel to modify solidification"

***GRAINCONT is the only project about this subtopic**:*

- Ti-Ce and Ti-Zr con Fe-Cr 20%. ZrN precipites and works as nucleation of ferrite with grain size refinement
- Fe-TiO2/TiN and CeAlS influence
- Study of injection system, upgrading the "Hollow Jet Nozzle"



The goal is to have sulfide and oxide particles to refine grain

Process optimization

Injection techniques

QUESTION 6.

Use of inoculant is a possible route to manage the solidification inside the steel, but not industrial application have been studied in RFCS project.

Which further studies are necessary to bring this solution to industrial scale?

A. Identification of a wide range of inoculants, customized on different steel-grades
B. Promotion of technical solutions to easily integrate the system in a standard CC process
C. Definition of a countermeasures set if the process presents some anomalies
D. I think that is not a promising solution since the risk to generate defective products is still too high

Process optimization

Improved steel composition

"Optimization of steel chemical composition for improving castability and to reduce defect occurrence"

CASTABILITY AND SURFACE [...]	Addition of Nb for preferential precipitation of Nb(C,N). Rule for Ti/Nb content	Slab and Thin Slab	Surface cracks
DETERMINATION OF HIGH [...]	study of depth of oscillation that leads to segregated cracks. Good results with the use of Ti	Slab and Thin Slab	Segragated cracks
PRECIPITATION	V/Nb with new softer cooling to improve quality	Slab with Nb	Segregation and trasverse cracking
PMAP	B-steel, sulphur enhances detrimental effect of Boron. Modification of composition is not enough	Billet	Off-Corner
DEFREE	C-Mn-Ti steel and AlN precipitates on grain boundaries. Avoidance of formation along gamma grain	Billet	
CASTABILITY AND SURFACE [...]	Inclusion and castability. Study on Ti Steels	Billet	

- The most studied steelgrades are steel containing V, Nb , Ti and Boron.

Process optimization

Improved steel compostion

"Optimization of steel chemical composition for improving castability and to reduce defect occurrence"

- **During research phase**, modification of steel composition is the main solution to be applied. All the projects highlight that modifications of steel composition have to be correlated to suitable operating windows

- The approach followed in RFCS project is to vary and monitor the ratio between Susceptible elements (**Nb, Ti, V**) in correlation with **C, N and S.**

Advantage

- Easiness of preliminary studies thanks to knowledge and IT tools already developed
- I can ideally remove the element/s that cause/s the defects

- I cannot change arbitrarily steel composition.
- Characterization of new steel composition in term of mechanical characteristics is not always easy
- I can have castability problems

Disadvatnge

Process optimization

Improved steel composition

QUESTION 7

OPEN QUESTION

RFCS have been focused on only few elements that have been changed: Nb, Ti, V, B,(Al,Mn), typically of microalloyed steels.
Which are the other elements that can be studied and that can influence CC process?

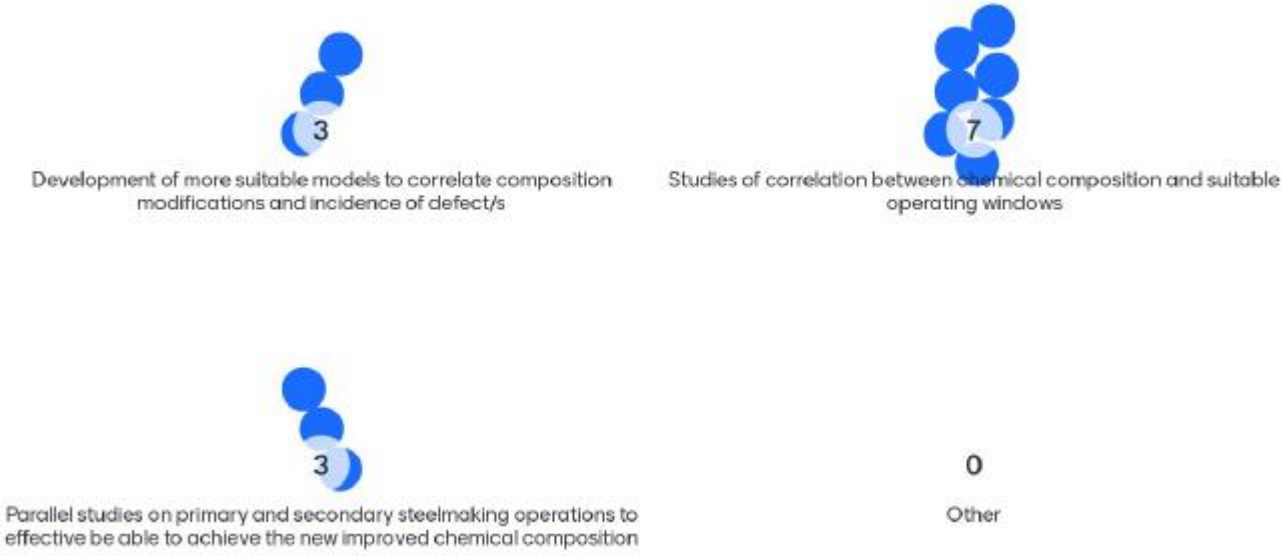
Cu	Ca and S causing clogging	S, Cu, Sn
Si	CuS influence on steel hot ductility	Cu, Sn, Mo, N, high Si, high Al
Cu, Mn/S ratio, Carbon equivalent, system: Al-Ti-B-N	Nitrogen	Mo, high Al >1%

Process optimization

Improved steel composition

QUESTION 8
About improvement of steel composition, which other study field must be explored in the next future?

A. Development of more suitable models to correlate composition modifications and incidence of defect/s
B. Studies of correlation between chemical composition and suitable operating windows
C. Parallel studies on primary and secondary steelmaking operations to effective be able to achieve the new improved chemical composition



Process optimization

Conclusion

Future needs: last two questions

- ✓ *Process optimization is faced in the RFCS projects as a feature to reduce the incidence of defects or when new tools is implemented. Optimization studies can be correlated to other aspects of the process?*

- ✓ *Environmental issues. They are still missing. The only strategy adopted is the goal of zero-defects policy. "**I optimize the process to reduce the incidence of defects**". We have to move also to "**I optimize the process to reduce the environmental impact of CC process and in turn reducing defects**".*

Process optimization

Conclusion

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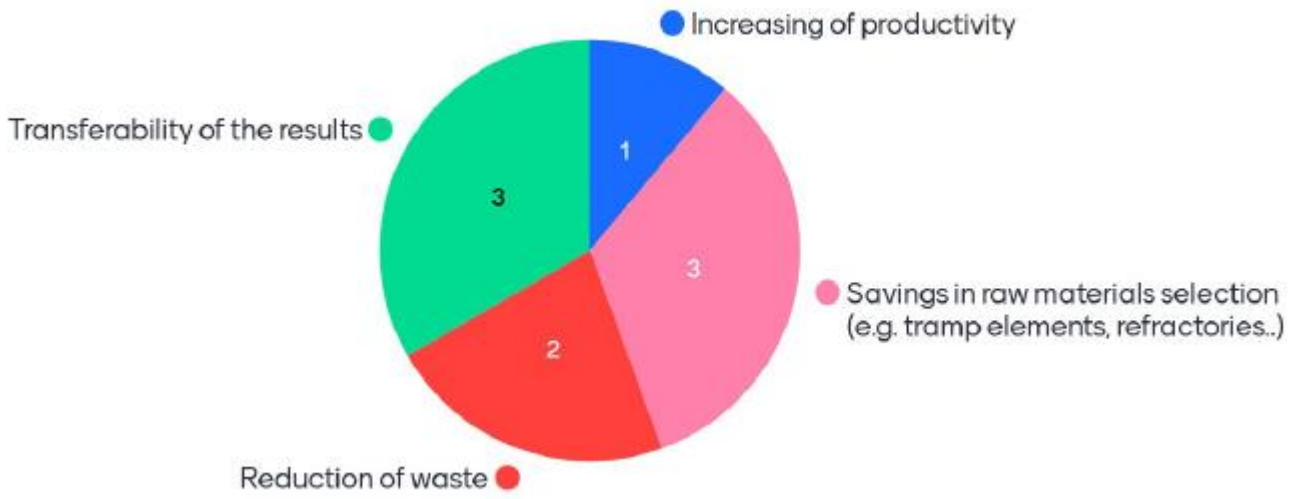
QUESTION 9

Process optimization is mainly addressed to defect incidence reduction. Which other aspect should be studied in term of optimization?

A. Increasing of productivity
B. Savings in raw materials selection (e.g. tramp elements, refractories..)
C. Reduction of waste
D. Easiness of solution implementation
E. Transferability of the results



Process optimization

Conclusion

QUESTION 10 – OPEN QUESTION

Research about defect reduction leads to a benefit in terms of environmental aspects due to product yield improvements. Do you think that there are other topics that can be studied to reduce the environmental impact in CC plants?

Fluorine mould powder reduction

Improved refractory lifetime so less waste

cast steel with higher Cu content would allow to use EAF cycle reducing CO2 emission.

the reused of waste

Thanks for the attention!

Stay informed

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