Mould Powders - Roadmap

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Introduction

European Funded Projects involving Mould Powders

Acronym	Title	Year	Report Number
7210-PR/273	Mould powder consumption, melting and lubrication and their effects on mould heat transfer and subsequent surface quality of continuously cast slab	2005	EUR 21907
FOMTM,	Application of fibre optical thermal monitoring at CC billet mould for improved product quality, Report number,	2007	EUR 28466
FLUXFLOW	Enhanced steel product quality & productivity by improved flux performance in the mould through optimising in the multiphase flow conditions & special regard to melting & entrapment	2008	EUR 23182
PRECIPITATION	Precipitation behaviour of micro-alloyed steels during solidification and cooling,	2010	EUR 24024
SLAGFILMOWL	Optimising slag film properties and determination of operational windows for lubrification, mould heat transfer and shell formation	2011	EUR 24988
LSSEMIQUAL,	Reduction in surface cracking in as cast low sulphur and calcium treated steels, Report number,	2013	EUR 25885
LUBRIMOULD,	Identification of optimal mould lubrification conditions through an innovative hot and cold simulation method, Report number,	2013	EUR 26173
TRANSIENT,	Effect of transients on quality of continuously cast product, Report Number,	2014	EUR 26399
INNOSOLID	Investigation of innovative methods for solidification control of liquid steel in the mould	2019	EUR 29549
NNEWFLUX	Non-Newtonian mould fluxes - a smart viscosity response to enhancing production flexibility of steel grades prone to entrapment	Ongoing	Ongoing
OPTILOCALHT	Optimisation of Local Heat Transfer in the CC Mould for Casting Challenging and Innovative Steel Grades	Ongoing	Ongoing
RealTimeCastSupport	Embedded real-time analysis of continuous casting for machine-supported quality optimisation	Ongoing	Ongoing

Surface defects

Examples of Surface Defects

Longitudinal cracking - Slab

Steels in the peritectic range are particularly susceptible due to the peritectic transition which cause significant shrinkage of the solidifying shell.

Reduce cracking by minimising shrinkage early in solidification where the strand is most vulnerable. Use mould powders that form a thick crystalline slag layer.

Other contributing factors to Longitudinal cracking include: Poor mould level control and uneven flow distribution in the mould.

Longitudinal corner cracking – Slab

In the corners heat is extracted in 2 directions, there is more cooling and shrinkage than in the centre of the mould. Initial overcooling thicker shell which pulls away from the mould creating an air gap reducing heat transfer locally leads to melting back and thinning the shell at a point just away from the corners. The shell deforms forming a depression (or gutter). Cracks are formed in the root of the depression.

Reduce the heat flux to create a thinner more uniform shell which generates less stress and strain. Use mould powders that form a thick crystalline slag layer.

Other methods can include reducing cooling at the mould corners or rounding off the corners.

Other contributing factors to Longitudinal corner cracking include: Excessive taper on the narrow face

Surface defects

Examples of Surface Defects

Transverse and corner cracking

Formed due to longitudinal stresses in the strand and can occur for many reasons.

In the mould: Poor lubrication, Incorrect mould taper

Below the mould: Deformation during bending and straightening, Base of oscillation marks

Can be connected to composition where carbon content and alloys (e.g. Cr,V,Nb) as well as nitrogen increase the cracking risk.

This can be reduced by the use of an appropriate mould powder with a high break temperature promoting lower heat transfer through high crystallinity.

Star cracking

Tends to occur low down in the mould. Formed during periods of fluctuating heat flux which can be linked to a lack of lubrication due to insufficient liquid flux or fracturing of the solid flux layer. The fluctuation causes local stresses in the solidifying shell which can lead to small cracks radiating in a star pattern.

Poor mould powder and slag pool depth leads to poor heat transfer and lack of lubrication. Poor mould powder feed control.

A thick crystalline slag will reduce heat transfer increase shell thickness and produce a thicker liquid slag layer which will ensure that the mould is fully lubricated.

Summary of Crack Related Powder Practice

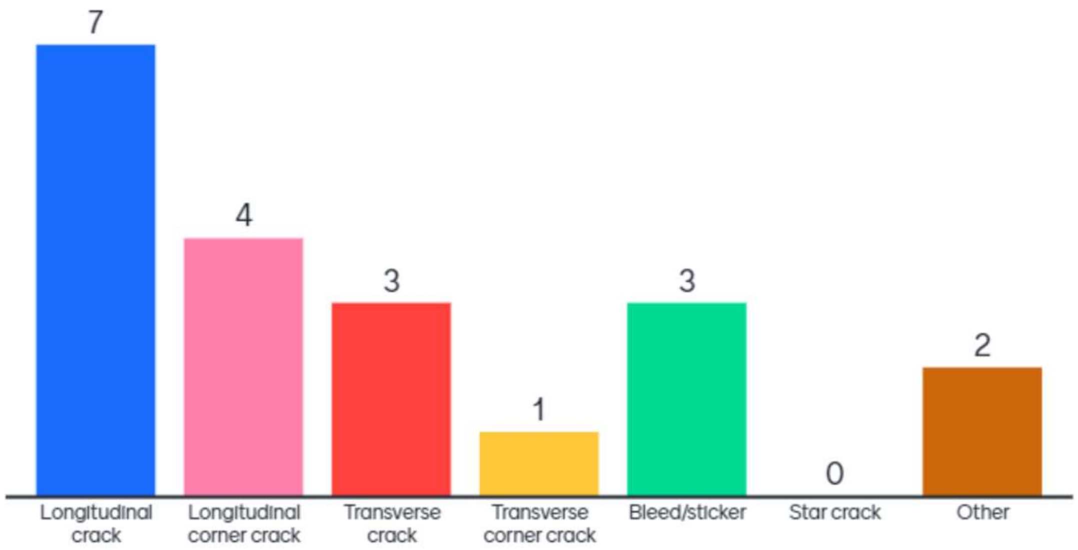
Many types of surface defects can be linked in full or in part to mould powders.

Crack Type	Susceptible grades	Best Powder Practice
Longitudinal cracking	Medium-Carbon Peritectics	High thermal resistance, thick crystalline slag layer
Longitudinal corner cracking	Medium-Carbon Peritectics	High thermal resistance, thick crystalline slag layer
Sticker Breakouts	High Carbon	Low viscosity glassy slag
Oscillation Marks	In general	Thick crystalline slag will help but oscillation practice is much more critical
Transverse and Corner Cracking	Peritectic, Micro-alloyed, Low-Carbon	High thermal resistance, thick crystalline slag layer
Star Cracking	Peritectics	High thermal resistance, thick crystalline slag layer

Question 1

Defects

Which type of surface defects are the most significant issue related to mould powders?



Results from on-line Mentimeter poll

Powder Feeding

The performance of mould powders as designed and predicted can only be achieved if the powder is applied correctly and consistently.

The layers within the mould powder need to be stable and under control.

Best practice for consistency of application either by applying the powder ‘little and often’ or automated continuous feed.

Modelling

New and more powerful tools for powder selection have developed using numerical and computational modelling. Over time, as would be expected with developing digital technologies and techniques this has become complex.

Models developed have included:

- Prediction of flux properties from powder composition including crystallisation and melting temperatures
- Evolution of the slag composition due to contact with liquid steel which potentially will lead to a change in flux properties
- Formation of liquid flux layers
- Flux layer thickness
- Flux flow in moulds
- Flux consumption
- Heat transfer through different flux layers
- Liquid fraction in the mould
- Stresses in the solidified shell and crack formation

These models can be used in the specification of fluxes for specific plants and grades or to ascertain whether a standard commercial powder is suitable for a particular application.

Question 2

Modelling

What is most important element of powder modelling?

Results from on-line Mentimeter poll

Modelling

Going Forward

Comprehensive model to predict the behaviour of a new powder relative to steel compositions:

- How composition and properties changes during casting
- Predict flux layer thicknesses
- Predict flux consumption
- Heat transfer from liquid steel through the flux to the copper and the cooling water
- Link with solidification models to include prediction of defect formation
- Use to specify composition of mould powder and ideal casting parameters for defect free steel

Novel Techniques

In order to address specific issues new and novel mould powders and techniques for controlling heat flux in the mould have been developed or are being developed as part of ongoing projects.

Novel/Specialised Mould fluxes

Carbon and Fluorine Free

Carbon-Free

Low carbon mould powders help prevent pickup of carbon in ultra-low carbon steel grades which can lead to surface defects issues. However, without enough carbon in the mould powder, the melting rate becomes too high and can cause slag rim issues.

Fluorine-Free

The use of fluorides in mould powders has significant negative aspects such as hydrogen fluoride gas is a health and safety issues for operators in the immediate area and environmental issues on the larger scale. Other by product such as hydrofluoric acid lead to issues with corrosion in the casting machine.

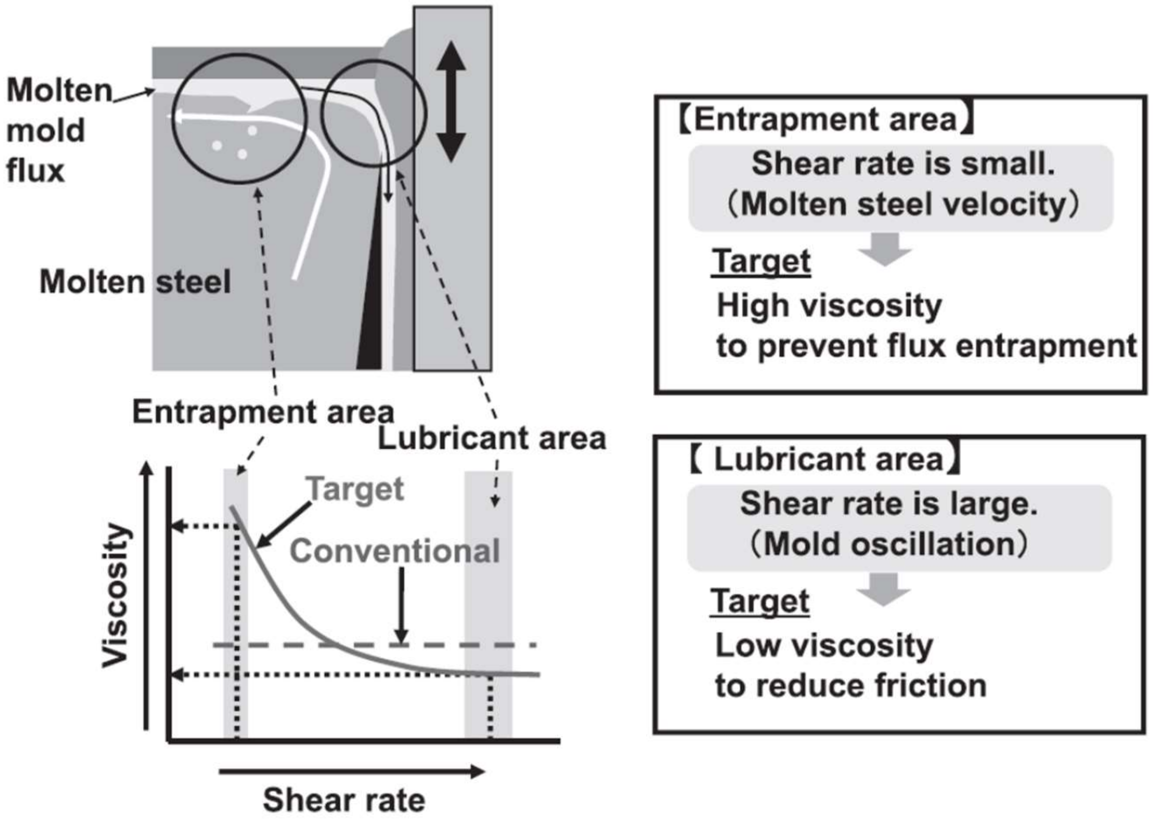
There are ongoing projects looking at the selection of suitable low fluorine or fluorine-free powders. The main thrust is the replacement of the fluorine bearing elements with an alternative such as Na2O or B2O3.

Novel/Specialised Mould fluxes

NNEWFLUX - Non-Newtonian mould fluxes

Non-Newtonian mould fluxes a smart viscosity response to reduce slag entrapment in steel grades prone to entrapment.

Where shear rate is low, at the surface, viscosity is high reducing entrapment. Where shear rate is high, at the slag rim and down the strand, viscosity is low enhancing lubrication.

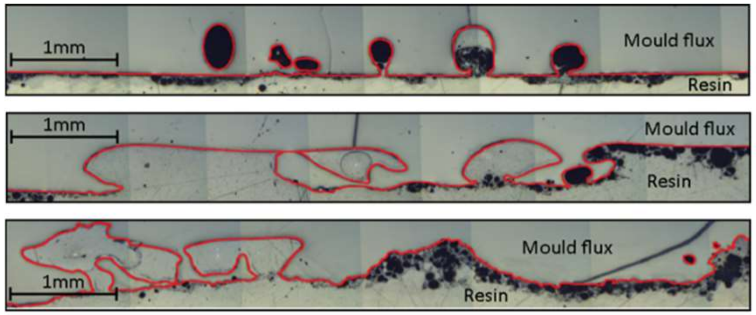


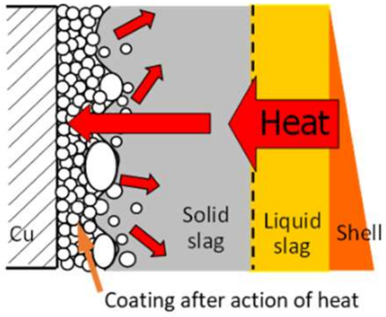
Techniques to Control Heat Transfer Locally

OPTILOCALHT

Optimisation of Local Heat Transfer in the CC Mould for Casting Challenging and Innovative Steel Grades. Use of novel techniques to control heat transfer locally such as:

Intumescent Coatings



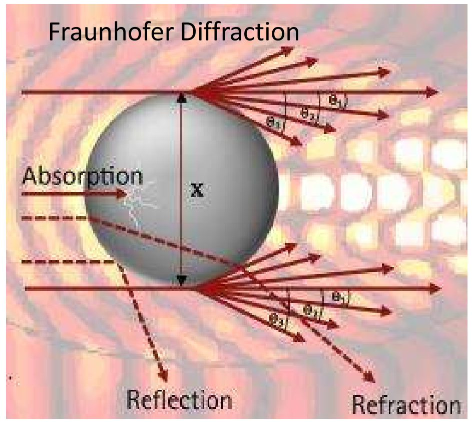


Hunt, PhD Thesis 2017

Porosity and scattering effects

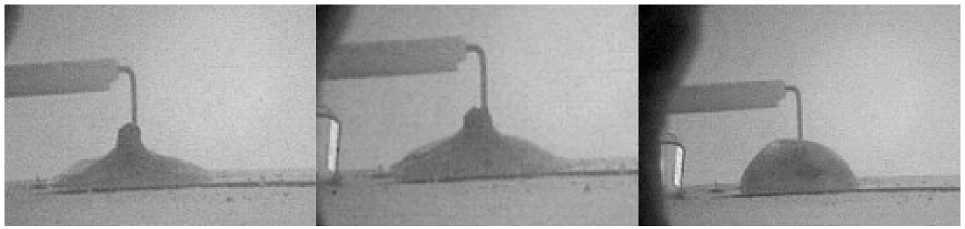
Stewart, Scholes & Hunt, Patent 2016

Mie scattering



Slag electrification & electropulsing

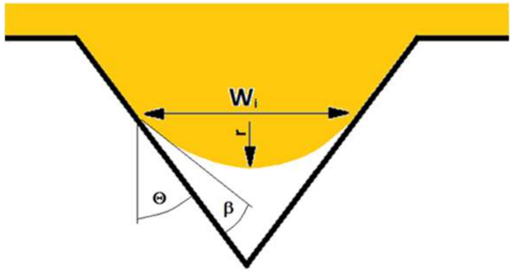
Mills & Riaz, Unpublished results, 2001 *Qin, 1998*



Techniques to Control Heat Transfer Locally

INNOSOLID

A surface profile was applied to the mould copper surface. The profile allows the solidified slag layer to thicken locally increasing the thermal resistance in the grooved area.



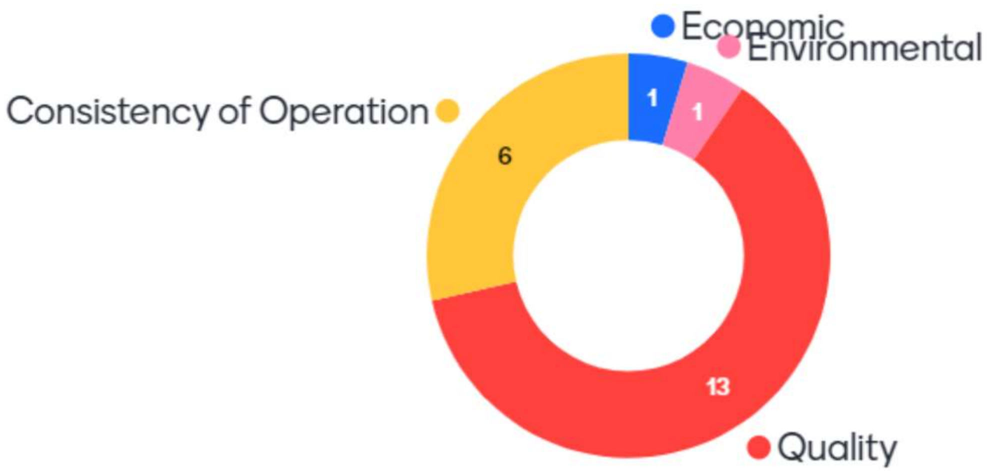
Trials were carried out on the mould of a pilot caster. There was a clear improvement of surface quality linked with the mould surface profiling for peritectic grade casts.

It was not possible during the timescale of the project to move to industrial trials.

Question 3

Driving Forces

What do you see as the main driving forces for mould powder development?



Results from on-line Mentimeter poll

Feedback outcome: future of casting powders

Map of future needs

Viscosity optimisation	Advanced high strength steel grades	New steel grades	High alumina steel (HSLA) and ultra low carbon steel	F free	Without fluorine and carbon	New steel grades
•To prevent entrapment	•Need to control heat transfer					
Lithium-free powders	Use of ESP caster	New steel grades	More flexible operative window (e.g. Casting speed range)	High strength grades	Speed of casting increase	
•Due to possible price increase of Lithium			•Solve mould solidification problems			
F free	Improve quality	Improving the loop control of powder level in mold	New steel grades	Reduce deviation in powder property and performance	Towards 0 defects	
•Requirement for environment	•Also by adapting process conditions					

Feedback outcome: future of casting powders

Map of future needs

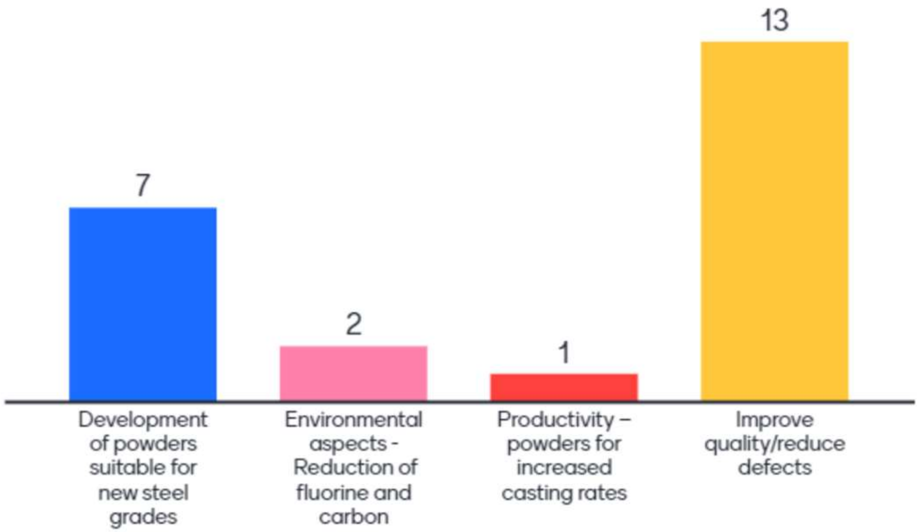
These can be grouped into categories:

- Development of powders suitable for new steel grades
- Environmental aspects - Reduction of fluorine and carbon
- Productivity – powders for increased casting rates
- Improve quality/reduce defects

Question 4

Map of future needs

Mould Powder modelling - Which topic is of most interest to you for future development?



Results from on-line Mentimeter poll

Going Forward

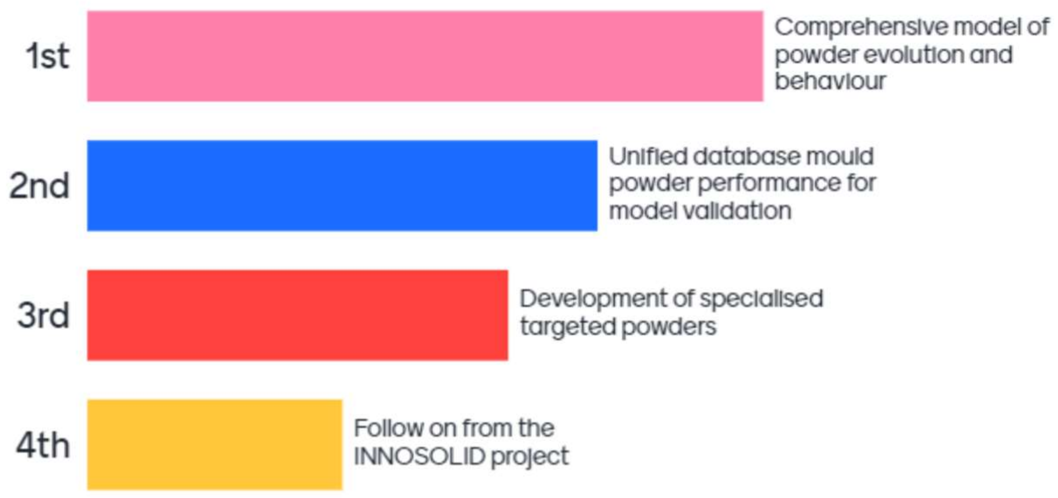
Ongoing Projects
NNEWFLUX, OPTILOCALHT, RealTimeCastSupport

Potential for future work

- Creation of a unified database for performance of mould powders for validation of models
- Project to compare and contrast techniques used in mould powder modelling and suggest a method for the production of a unified comprehensive model of powder evolution and behaviour
- Development of specialised targeted powders
- Carrying on from the INNOSOLID project – The two techniques developed for local control of heat flux at the meniscus have potential for future development.

Question 5

Rank suggested future actions in order of preference.



Results from on-line Mentimeter poll

Thank you for your attention.

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