TATA STEEL

TATA

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HPC at Tata Steel

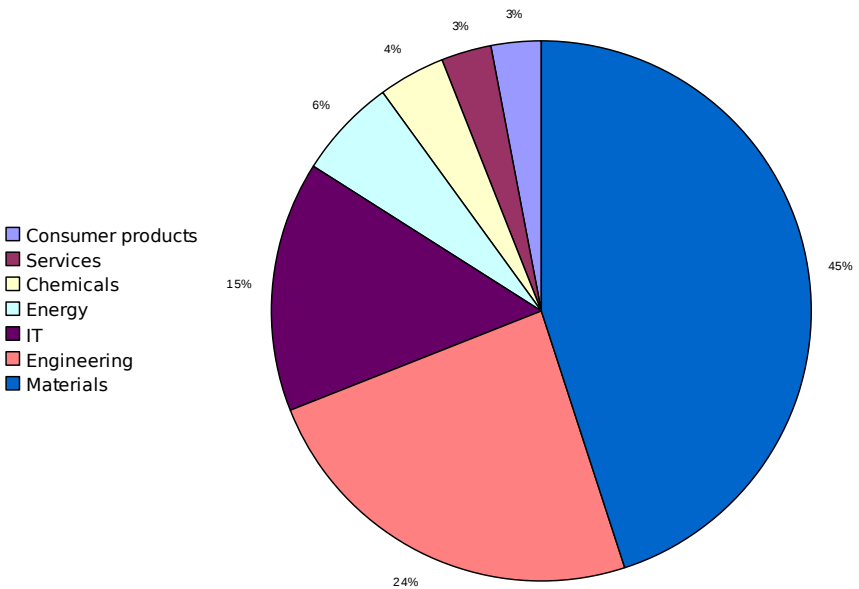
39th IDC HPC User Forum @ SARA
Amsterdam, October 12th, 2010

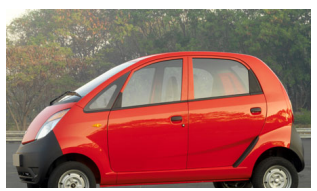
Tata Steel Europe RD&T
Process Modelling & Fluid Dynamics
IJmuiden, The Netherlands

Tata Group

- Indian industrial conglomerate founded in 1868 by Jamshetji Tata
- Active in more than 80 countries
- Combined turnover 2009: $ 70.8 bn
- Presence in 7 business sectors

JN Tata





Tata Steel

- 2007: Corus → Tata Steel Europe
- Now: top 10 global steelmaker
- Production capacity 28 Mt/a
- 80,000 employees globally (11,300 NL)
- Markets
  - Automotive
  - Packaging
  - Construction
- High quality steel → Emphasis on RD&T

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Aim Presentation: High Performance Computing at Tata Steel RD&T

- Why do we need it? Motivation
- What do we do with it ? Example

Contents of presentation

- Background & Aim
- Steelmaking in a nutshell
- Computational Fluid Dynamics at RD&T
  - What type of modelling work
  - New development: open-source CFD software OpenFOAM
- Example of CFD continuous caster
  - OpenFOAM
  - HPC
  - Results
- Conclusions

Steelmaking in a nutshell (1)

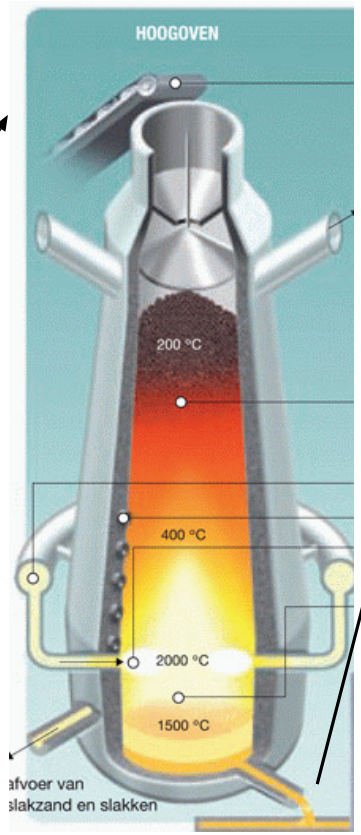
Blast furnace

Iron ore: Fe_2O_3

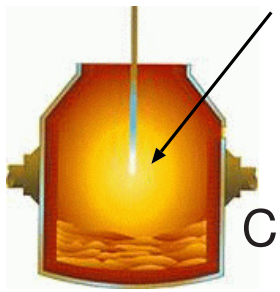
Cokes: C

Blast Furnace

$Fe_2O_3 + C \rightarrow Fe + C0_2$



Pig iron: $Fe + \approx 4\%C$



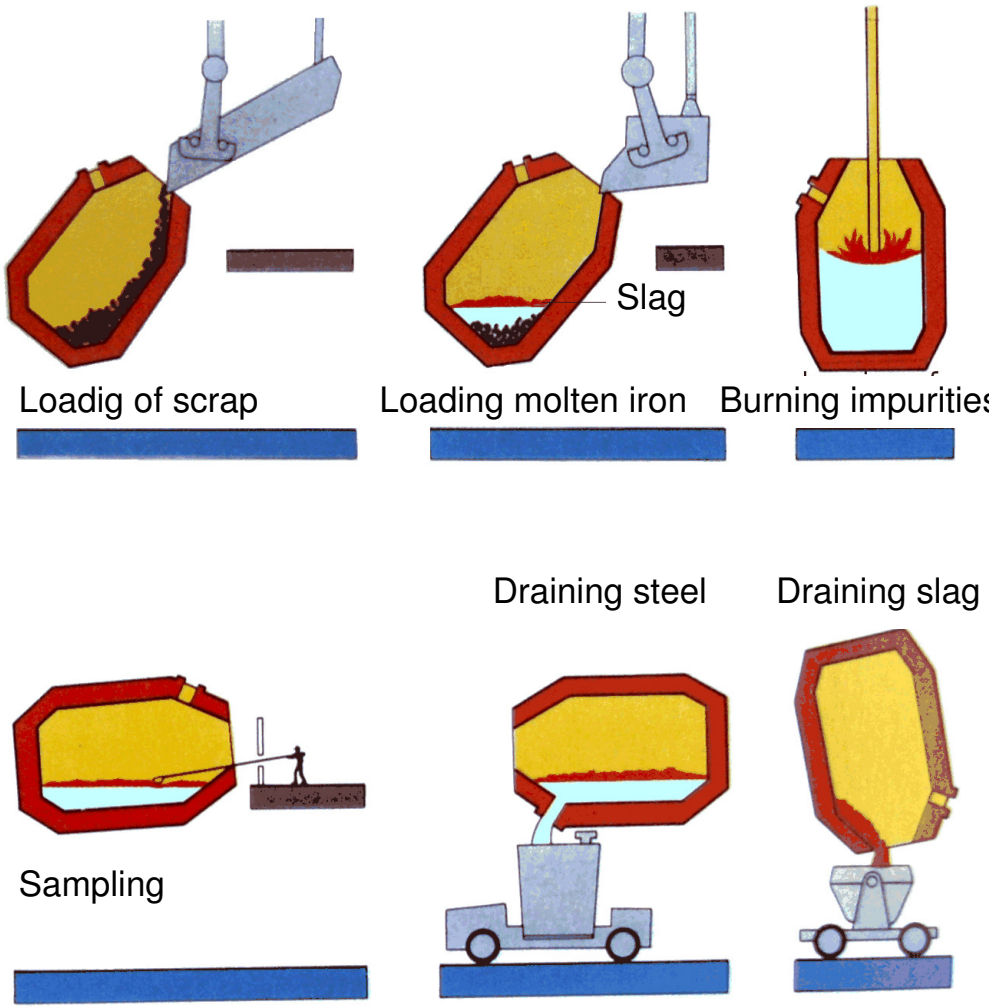
Converter

Steel: $Fe + < 1\%C + C0_2$

- High energy consumption
- Large $C0_2$ expell

Steelmaking in a nutshell (2)

Steelmaking in BOF



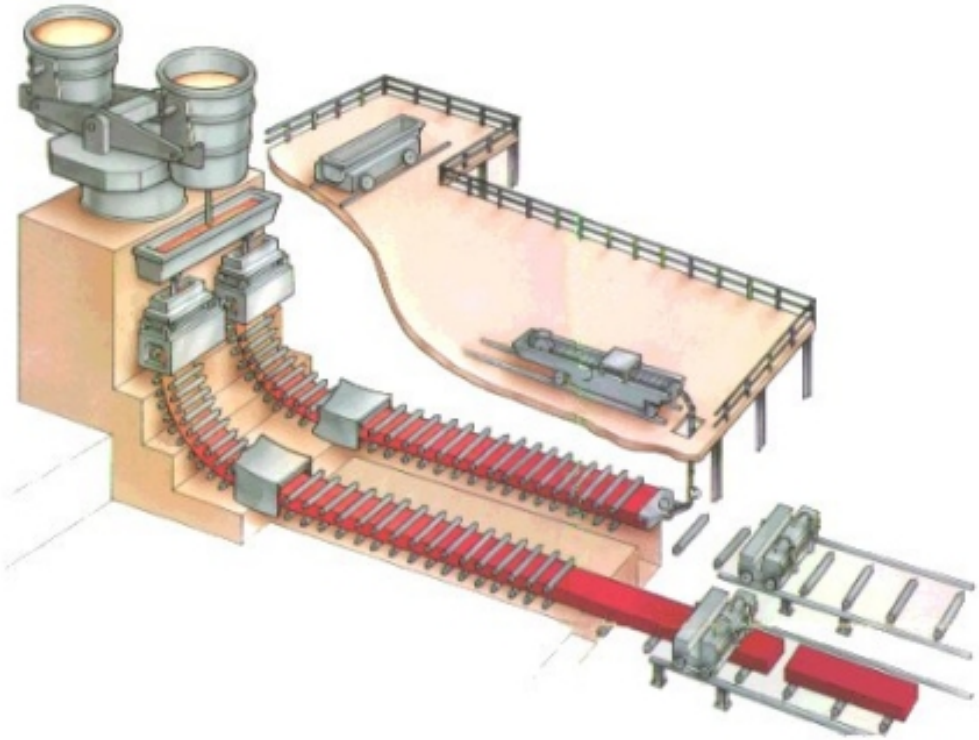
Process involves

- Gas/Liquid Fluid flow
- Kinetics
- Phase transisitions
- Magnetic fields, etc.

Steelmaking = Bulk Industry
Small improvements of the process → large costs savings

Steelmaking in a nutshell (3)

Casting process



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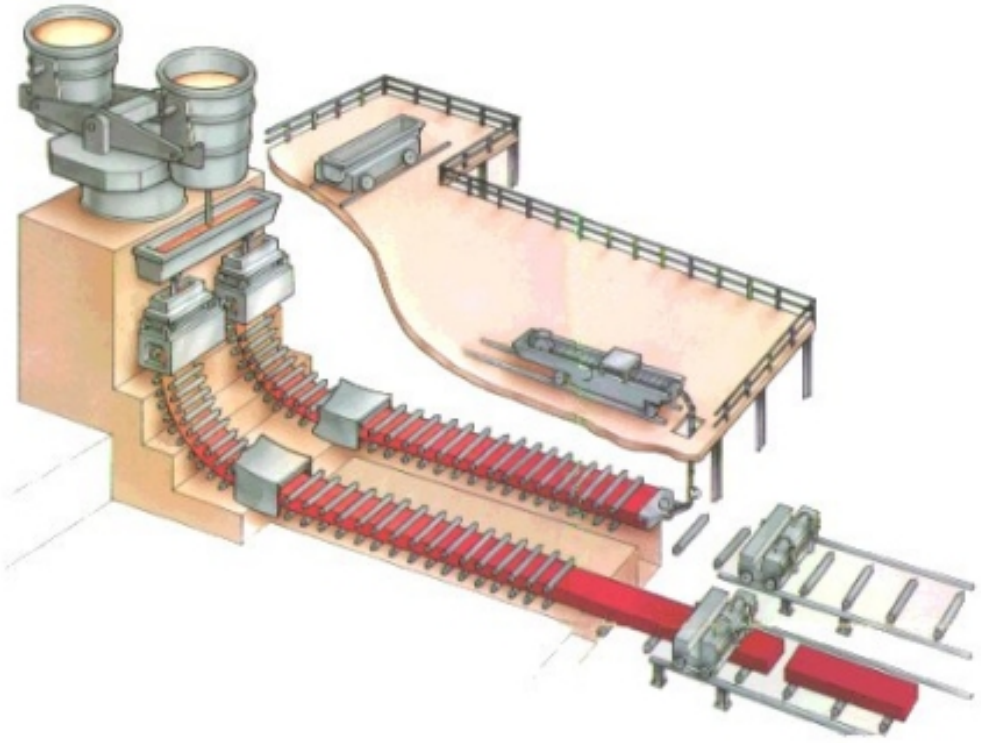
Steelmaking in a nutshell (4)

Computational Fluid Dynamics (CFD)



Harsh processing environment:
CFD is an important modelling tool for process optimisation

Process involves

- Gas/Liquid Fluid flow
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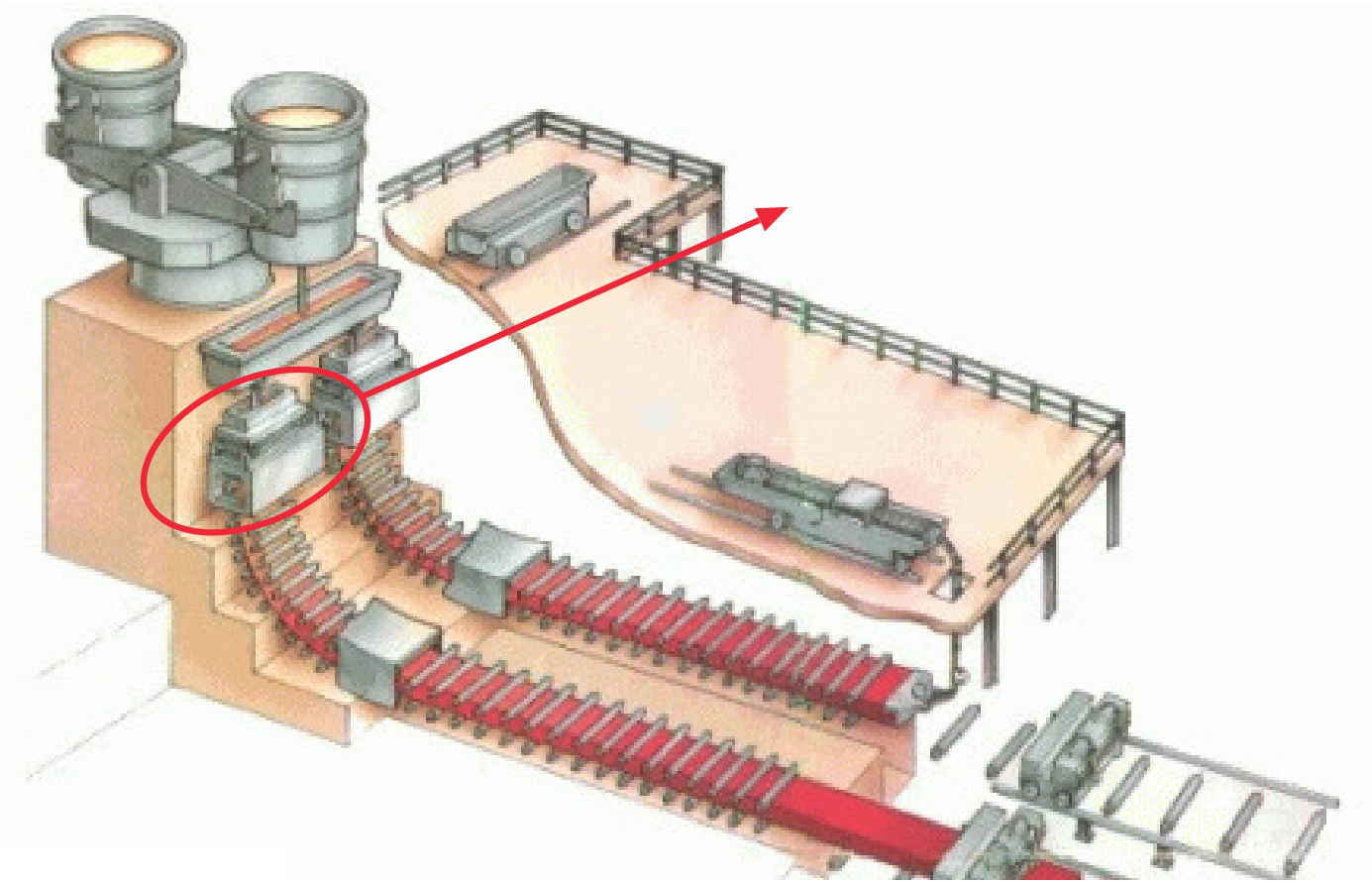
Small improvements of the process $\rightarrow$ large costs savings

An example of CFD: flow in the mould of a continuous caster



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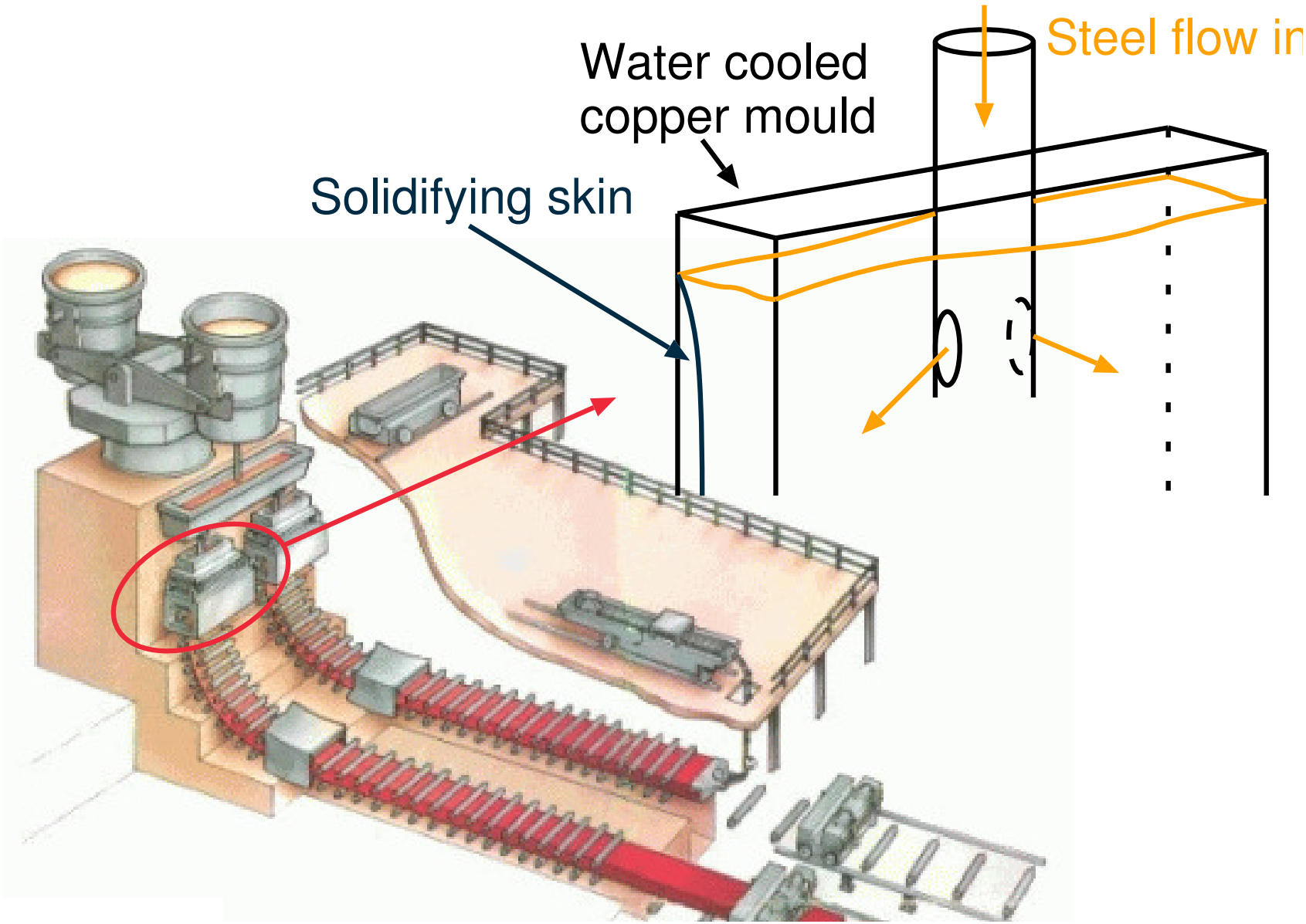

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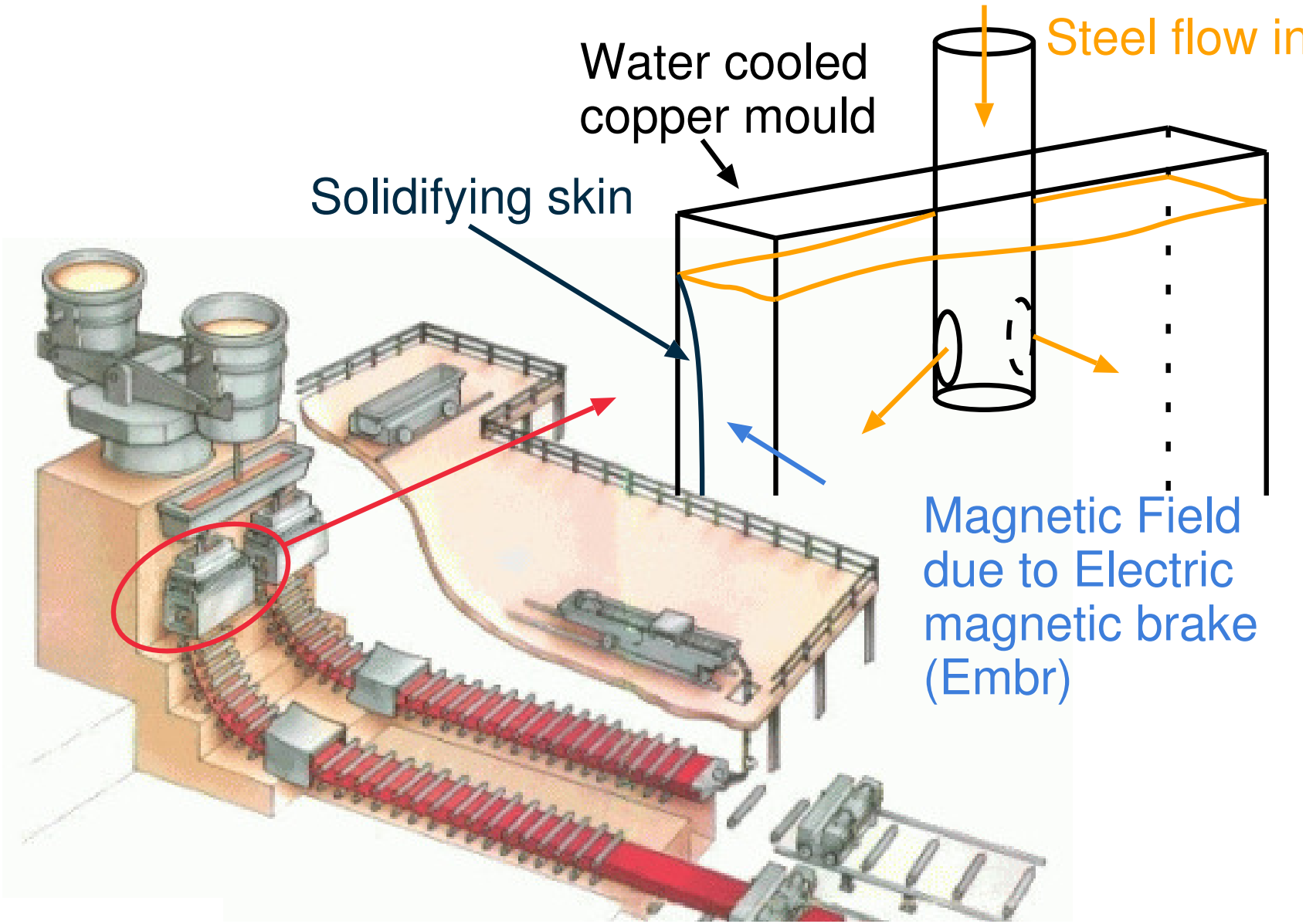


An example of CFD: flow in the mould of a continuous caster

Aim of the CFD model

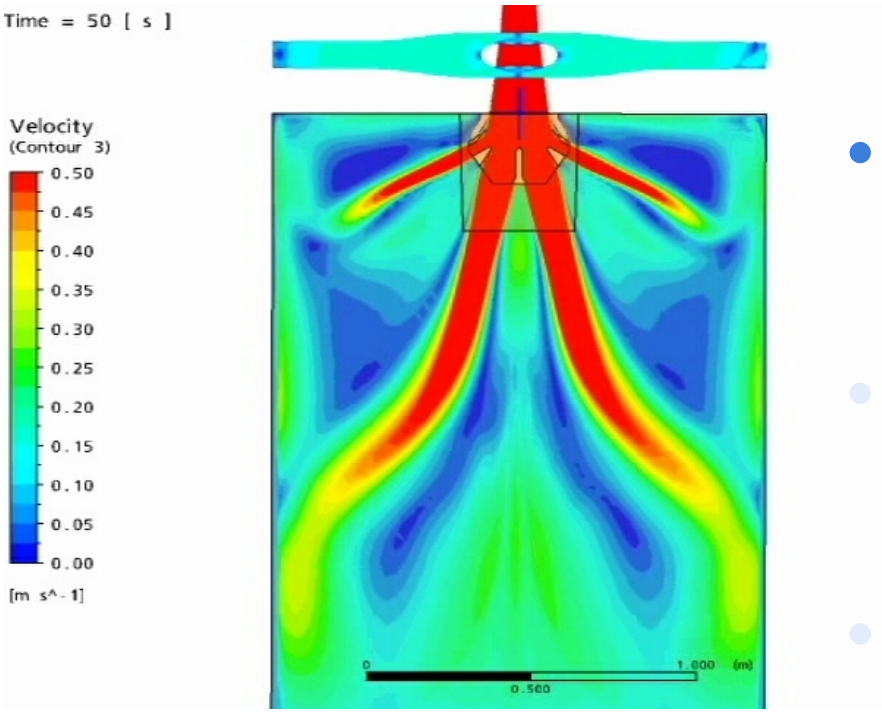
Find the effect of the EMBr settings on shell thickness in the mould.

Physics covered in the CFD model

- Incompressible mass, momentum, and enthalpy equations
- Solidification model:
  - Latent heat source term due to solidification
  - Momentum source forcing skin casting speed in solid skin
- Magnetichydrodynamics (MHD):
  - Magnetic field equation imposing Lorenz force on fluid
  - Turbulence model with dampening due to the magnetic field

Flow in the mould using CFX

No Embr; Velocity at start up



- CFX uses RANS turbulence models, leading to (over?) smoothing of the velocity field.
- Simulation time: 10 days at 8 CPU's of the Tata cluster for 100 seconds flow
- Without Embr, double roll flow pattern is found, corresponding to experimental observations. . .
- . . . however, with Embr, the flow reversal at meniscus that is found with experiments is not established by the CFD model.

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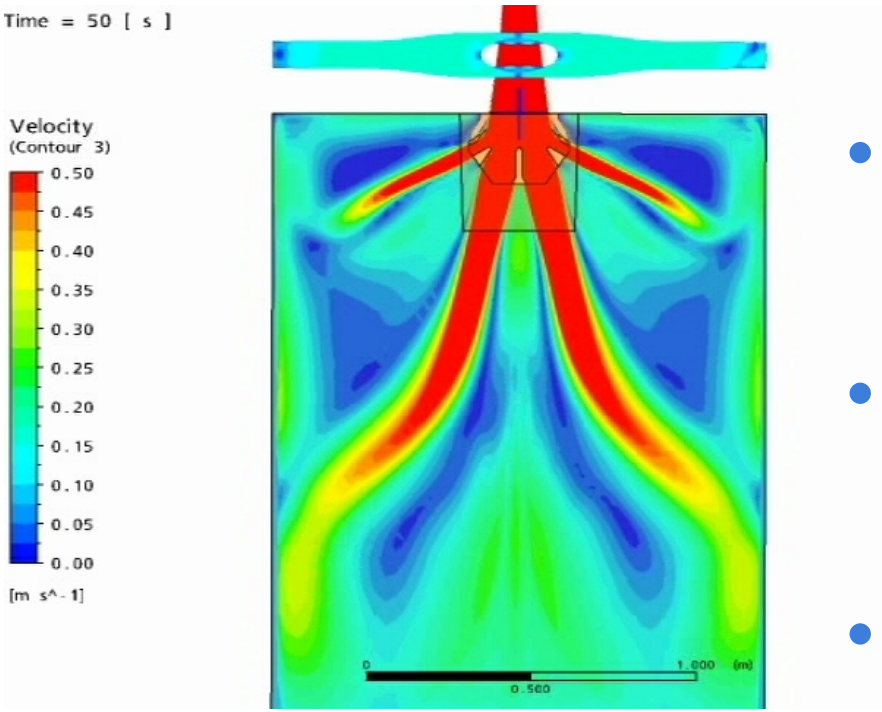

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Drawbacks of commercial CFD software

- Parallel CFD licenses are expensive and thus limited.
- The two commercial CFD packages used by Tata RD&T, Fluent & CFX, have recently merged, leading to an increase of license costs.
- A typical simulation requires to run 2 weeks on 8 CPU'S. Due to this, numerical expensive turbulence models can not be used, although this would often be required for obtaining better results.
- Specific steel-making models (e.g. solidification) can not be modified.

OpenFOAM®: a good alternative ?

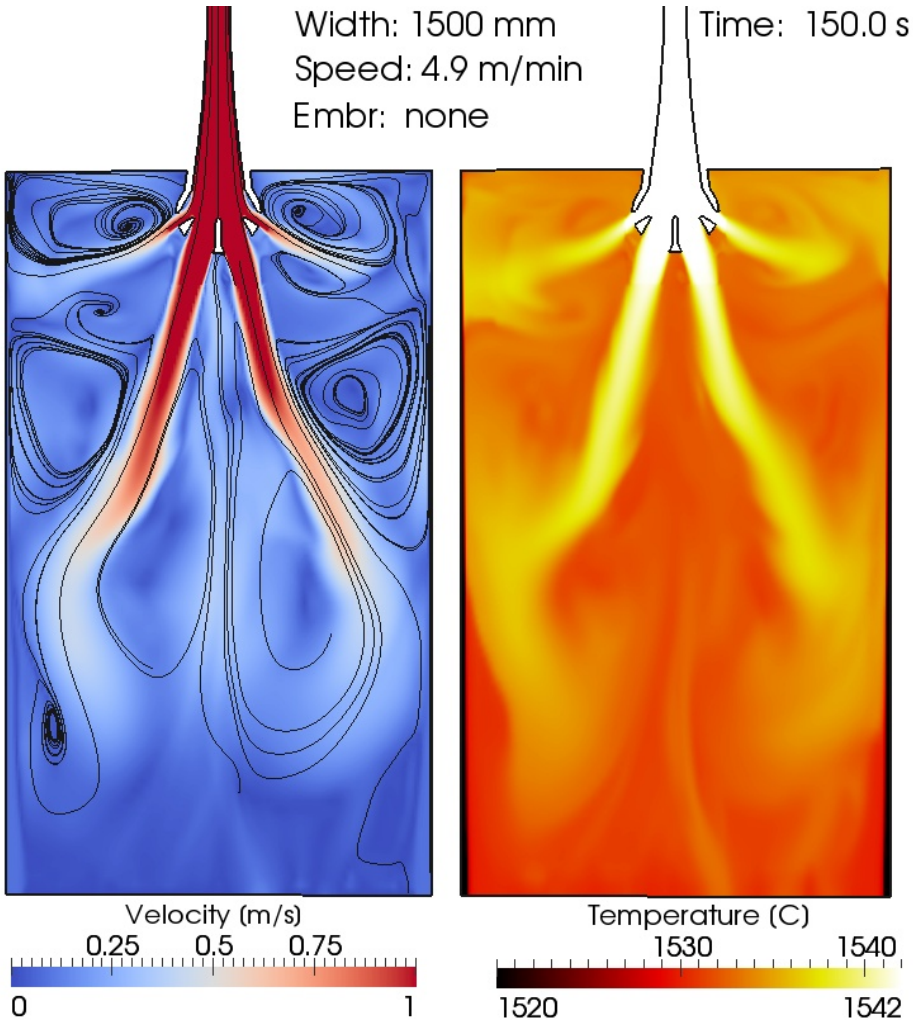
- OpenFOAM is a freely available open-source CFD toolbox.
- Benefits
  - No licence costs
  - Freely adjustable
  - Reduction of calculation time by using HPC at Sara
- Pitfalls
  - Steep learning-curve
  - More development time
  - Benchmarking required

OpenFOAM project at Tata RD&T

- A mould flow model including magnetic field and solidification has been developed
- The model has been tested on the Lisa.

Flow in the mould

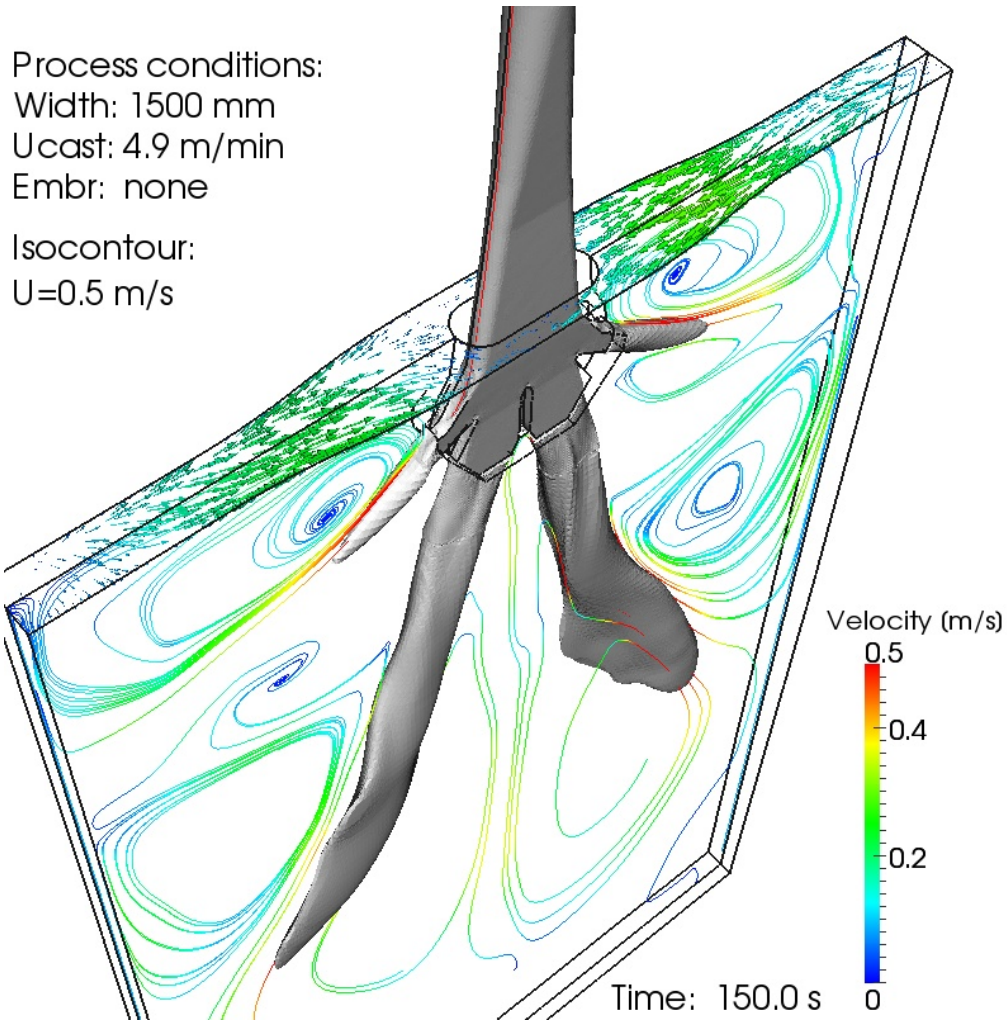
No Embr; Velocity and temperature over mid-plane



- Flow calculated on 4 cores8 of the Lisa
- One case runs in 24 hours
- Without magnetic fields good correspondence with our water model is obtained
- Heat accumulates around nozzle due to the Embr
- The reversal of the meniscus flow is also measured in the plant

Flow in the mould

No Embr; Meniscus speed



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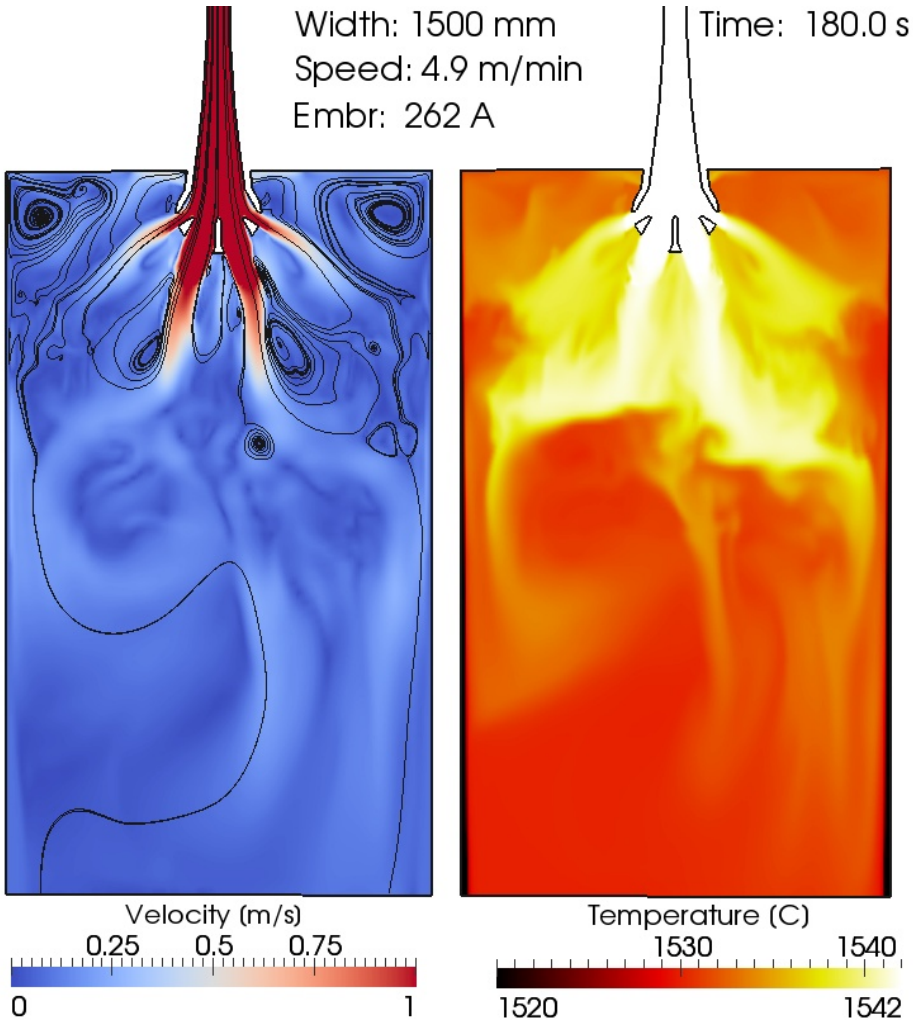
Flow in the mould

Embr 262 A; Velocity and temperature over mid-plane



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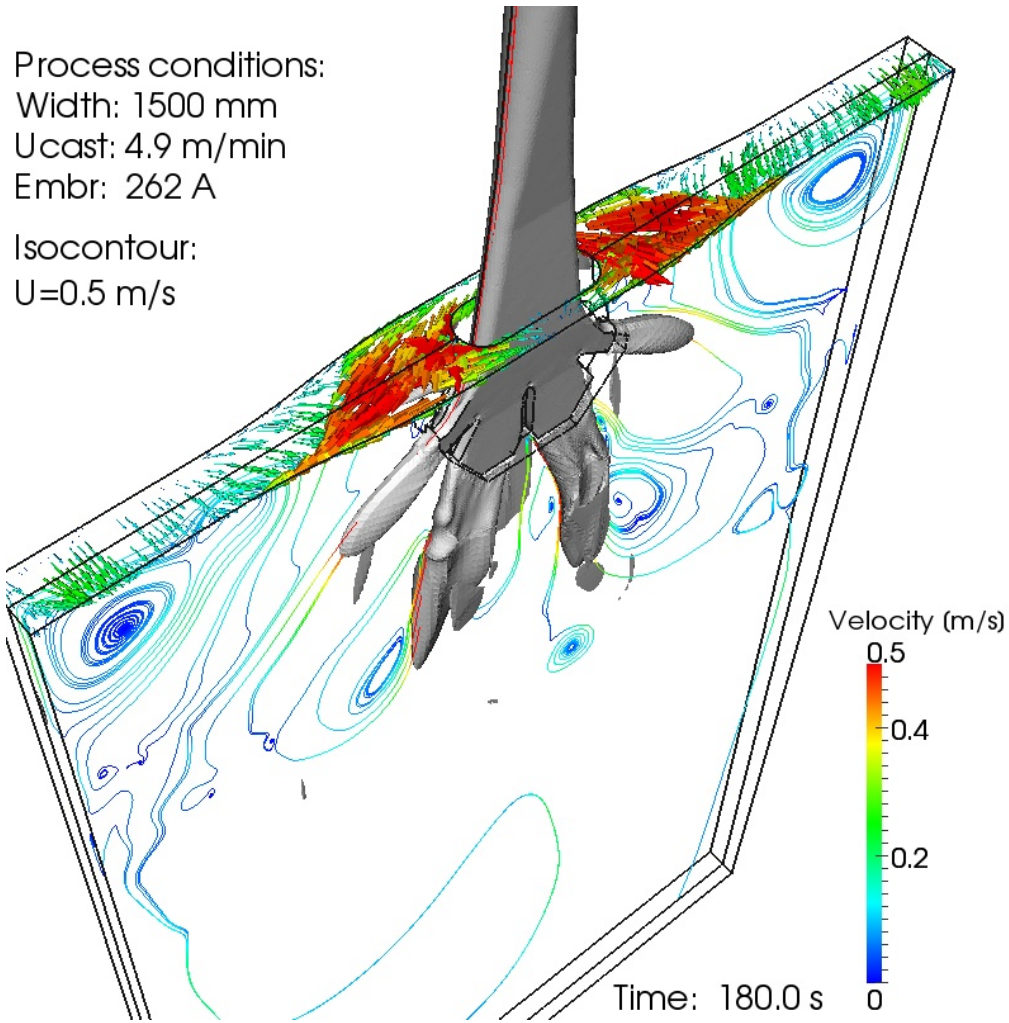
Flow in the mould

Embr 262 A; Meniscus speed



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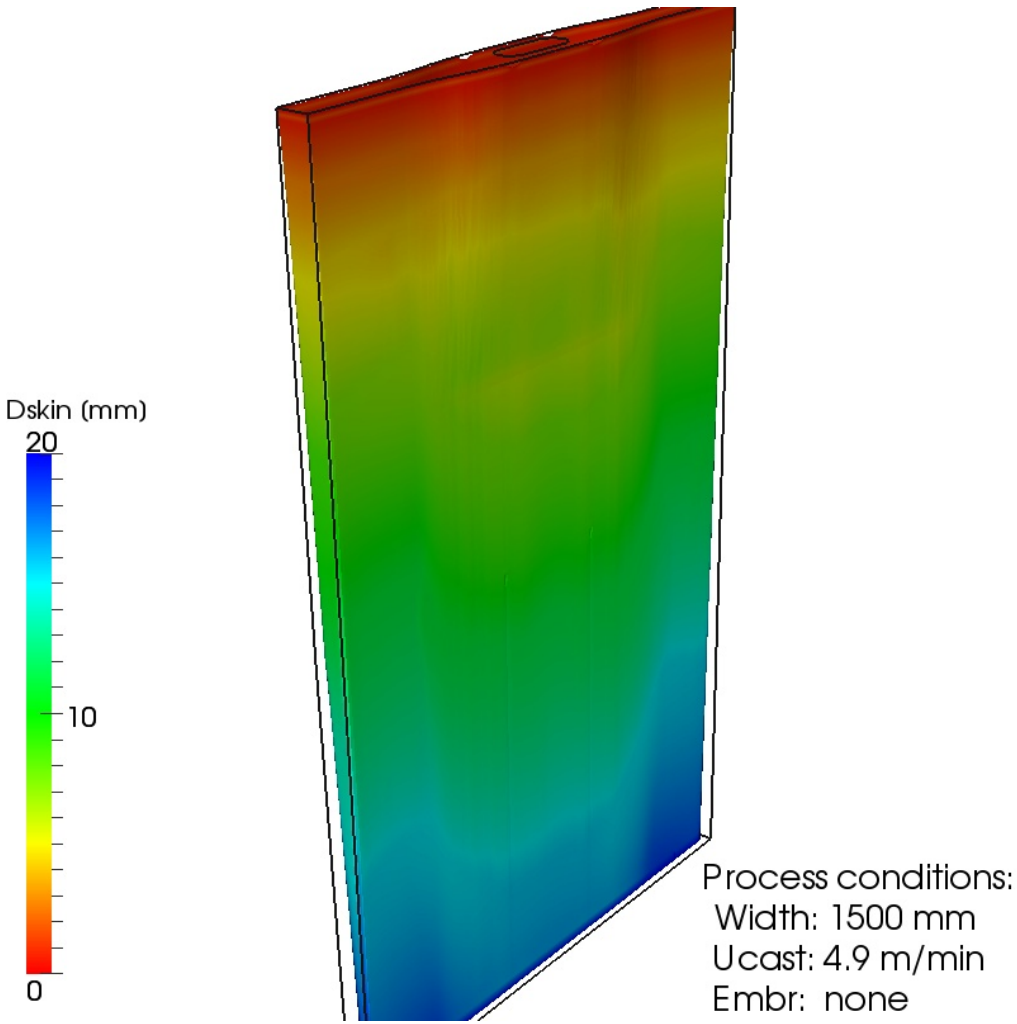
Skin thickness

EMBr switched off



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- EMBr results in slightly thinner skin in upper part mould

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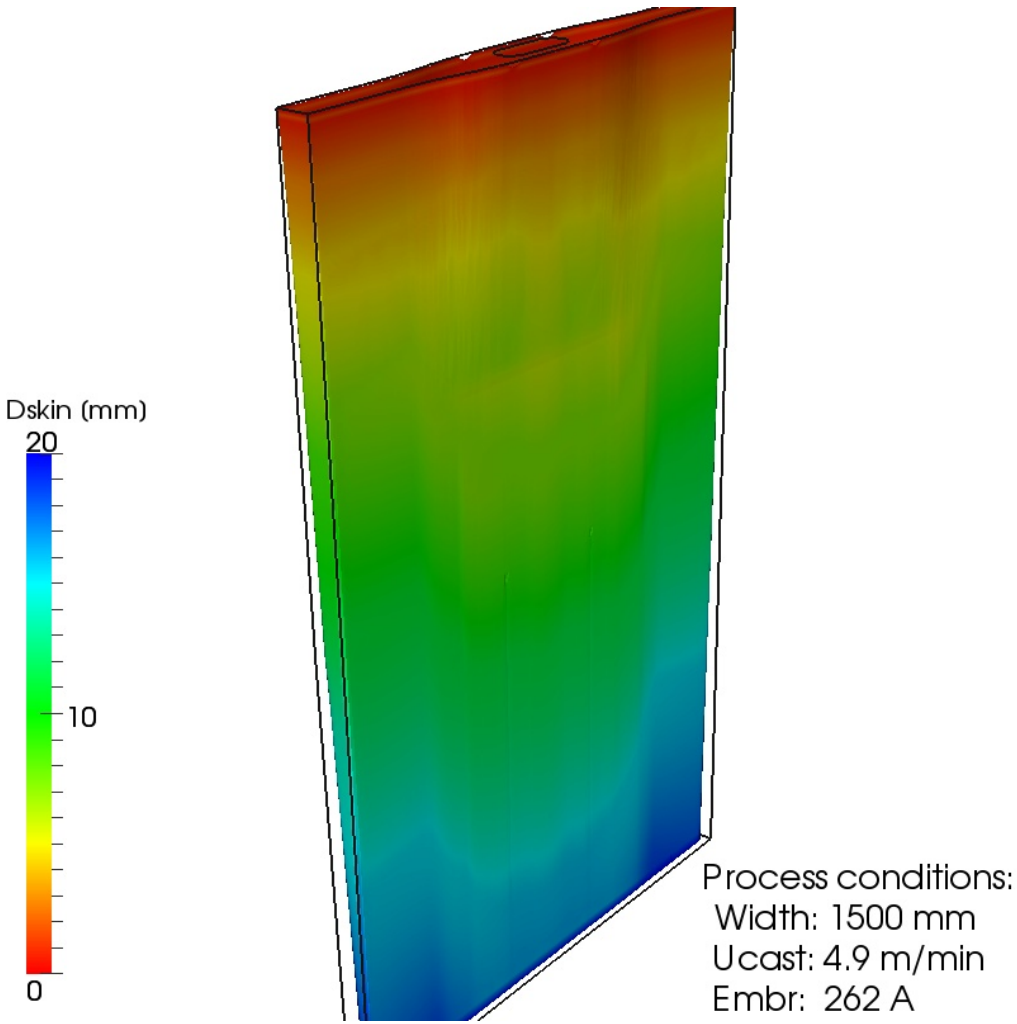

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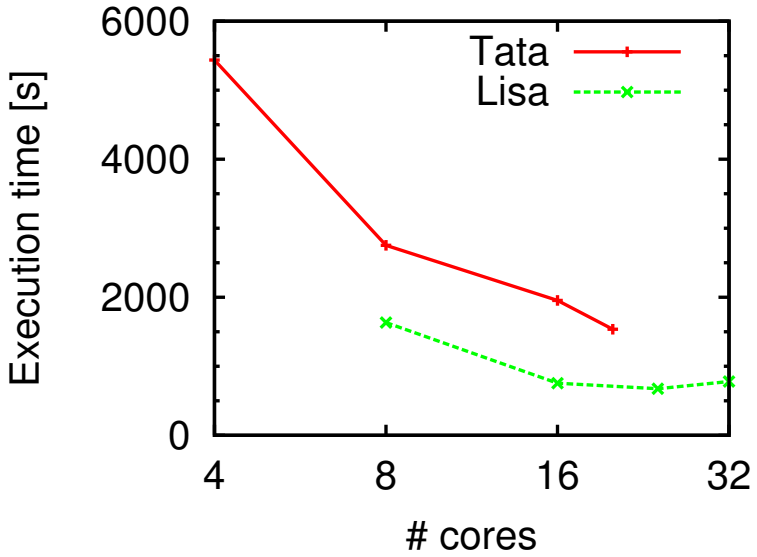
Comparing performance of the Lisa and in-house Tata cluster

- Execution time of identical OpenFOAM compared on Lisa and Tata cluster
- Speed-up at Tata cluster up-to 20 CPU's obtained
- However, even at 8 cores the Lisa is faster
- For 16 CPU's, Lisa is 2.6× faster than the Tata cluster.
- The OpenFOAM model is in its turn faster than the equivalent CFX model



Reduction simulation time

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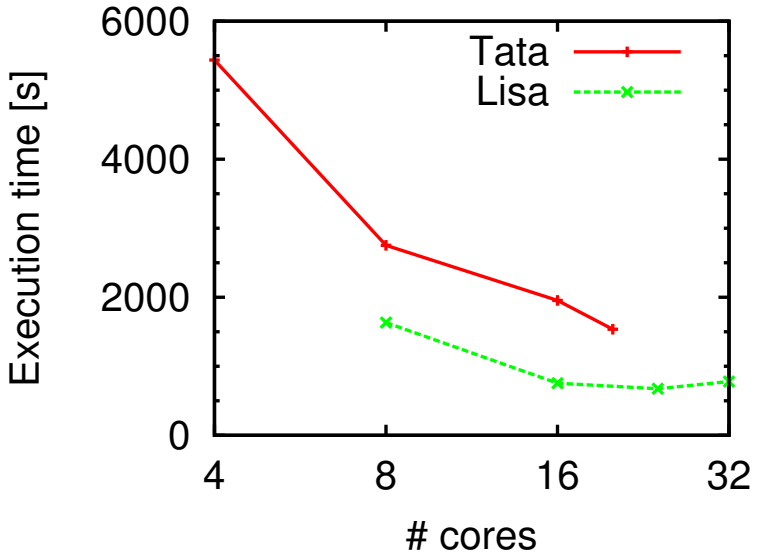

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Conclusions and next steps

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- Sara Computing & Networking Services was contacted, resulting an extra speed up of a factor 2.6 compared to our own cluster.
- *This pilot of HPC computing at Sara is considered very successful already and forms a good basis for further commercial usage of HPC in the future.*
- Benefits of HPC at Lisa are
  - Faster nodes and node-communication, leading to significantly shorter simulation times.
  - Peak loads of CPU-demand can be dealt with.
  - Professional support
- Potential pitfalls
  - Transfer of generated data may become difficult.
  - Queueing time not always predictable.

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Next steps...

- Data post-processing (rendering complex scenes) now becomes the bottle neck
- Paraview, (post-processor for OpenFOAM data), is now used on single workstations, however, can be used in parallel on a cluster as well.
- Question: Can Sara be of help setting up parallel off-screen data rendering with Paraview?