Project VMAPanalytics – Furnace modelling

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Swerim AB

Agenda

- Swerim in short
- VMAPanalytics project
- Furnace modelling aproach
- Data modelling aproach
- Conclusions

SWERIM

Swerim conducts needs-based industrial research and development concerning metals and their route from raw material to finished product.

Our vision is a fossil-free and circular industry.

SWERIM

Swerim in short

- Independent research institute
- Unique pilot, test and demonstration facilities (Customized experimental equipment)
- Customers from all over the world
- Long-term strategic partner
- Three research councils with industry representatives
- 190 employees
- Turnover approximately SEK 250 million

Long tradition – the oldest part established in 1921 (Metallografiska institutet) and MEFOS (1963)

VMAPanalytics - Project outline

Project partners

Prevas

gemit Solutions

SWERIM

GRÄNGES INNOVATIVE ALUMINIUM ENGINEERING

Morgårdshammar part of the DANIELI group

Fraunhofer SCAI

OVAKO

Industrial advisory board

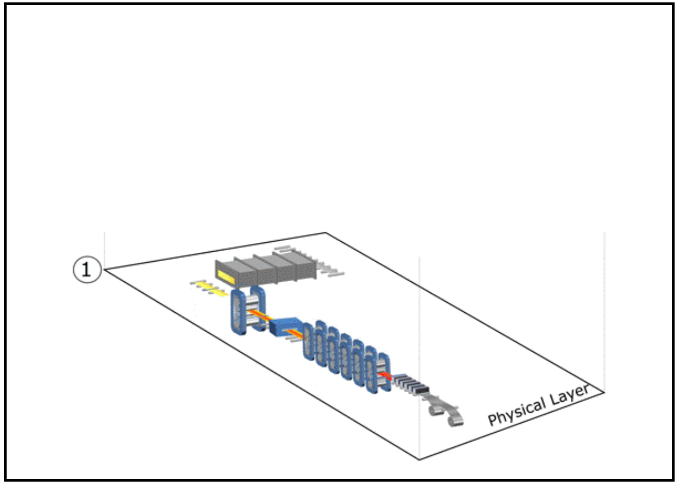
TO 60

Jernkontoret

Supported by

VINNOVA Sveriges innovationsmyndighet

ITEA 3

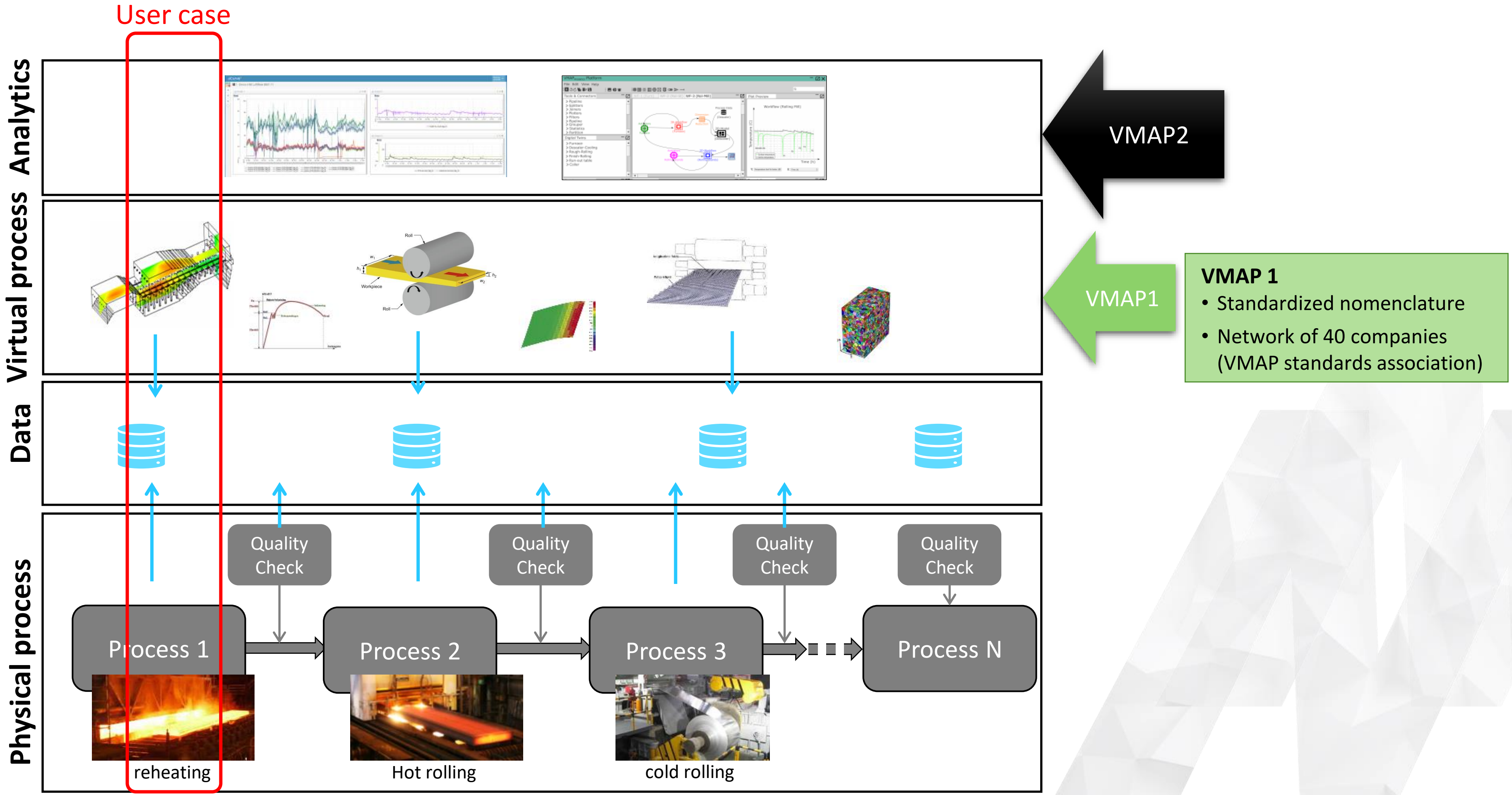


- Improved product quality
- Process robustness
- Condition monitoring of the mill
- Visualization of the state of the process.

VMAP

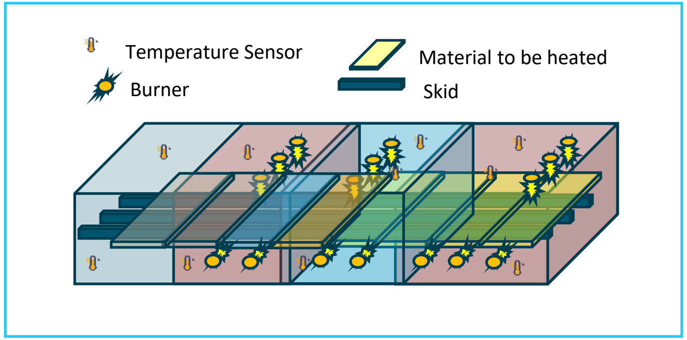
*https://www.vmap.eu.com/vmap-release/

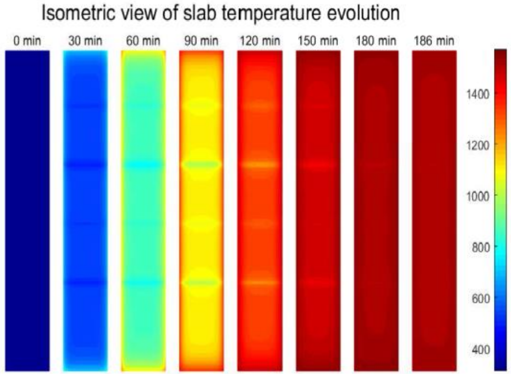
VMAP Concept



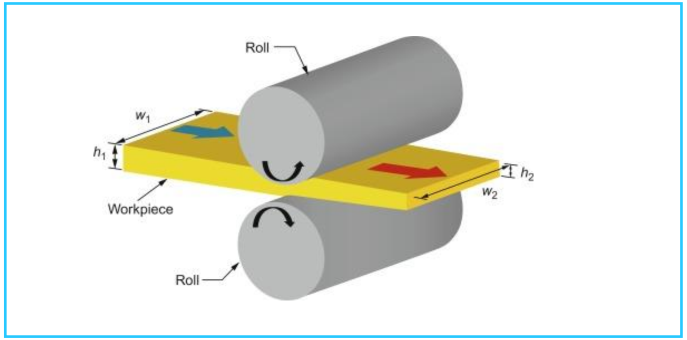
VMAP analytics – furnace model

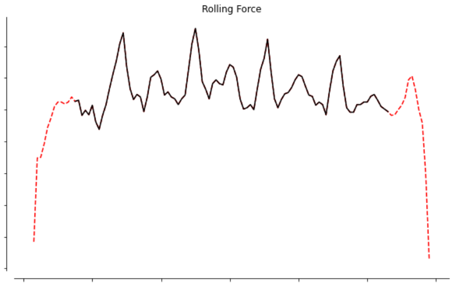
Walking beam reheating furnace





Hot rolling





Modeling strategy

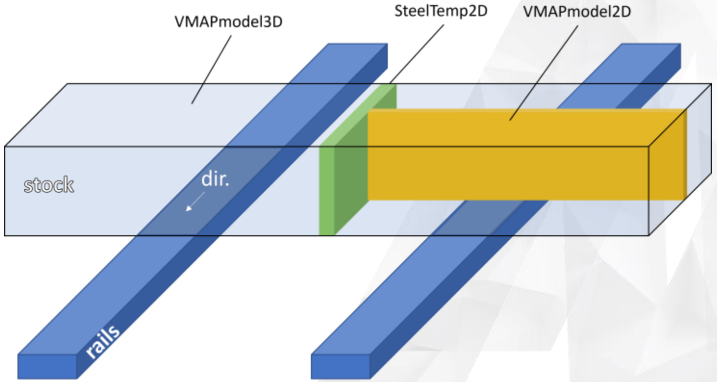
Resultant heat flux boundary conditions, spatial distribution similar as in SteelTemp

- Radiative heating (view factor, combustion gas interaction)
- Convection
- Furnace & stock configuration

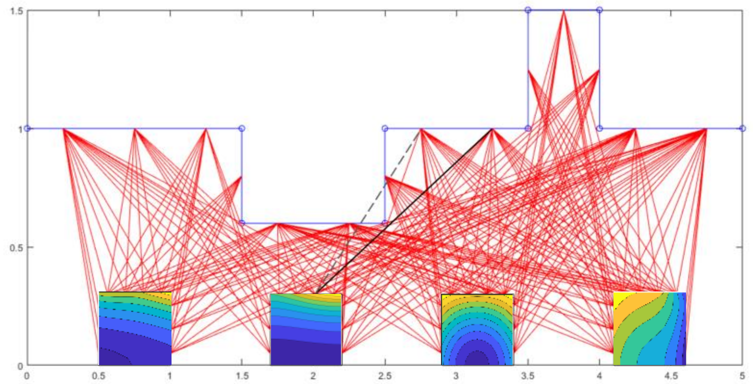
Iterative solution
Non-linear FEA

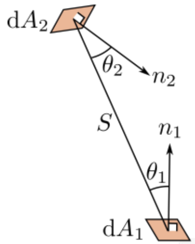
Heat conduction in stock

- Non-linear thermal problem
- Heat conduction through contact
- *Latent heat of transformation

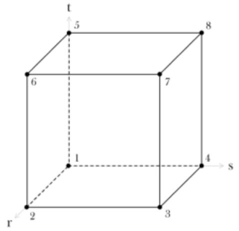


3D thermal FE-model





- ✓ Transient thermal FEA in 3D
- ✓ Includes view factor for radiative heating
- ✓ Includes walking beams for skid mark analysis
- ✓ Can be coupled to hot rolling simulation



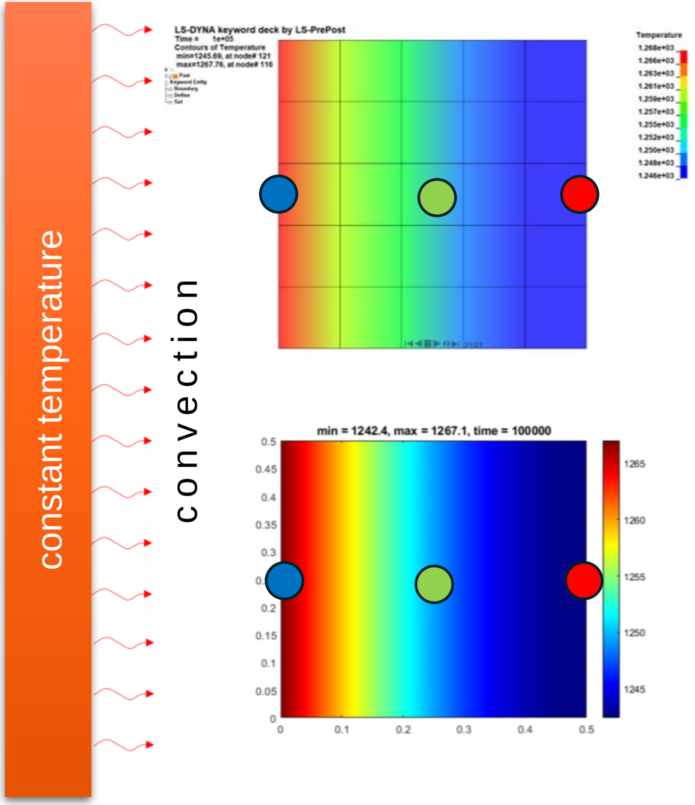
Transient heat conduction

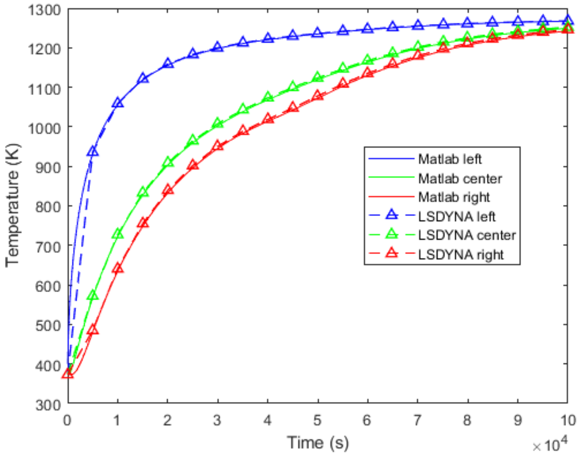
$$\rho c_p \frac{\partial T}{\partial t} - \nabla \left(k \nabla T \right) = \dot{q}_v$$

$$\mathbf{M}\frac{d\mathbf{T}}{dt} + \mathbf{K}\mathbf{T} = \mathbf{f}$$

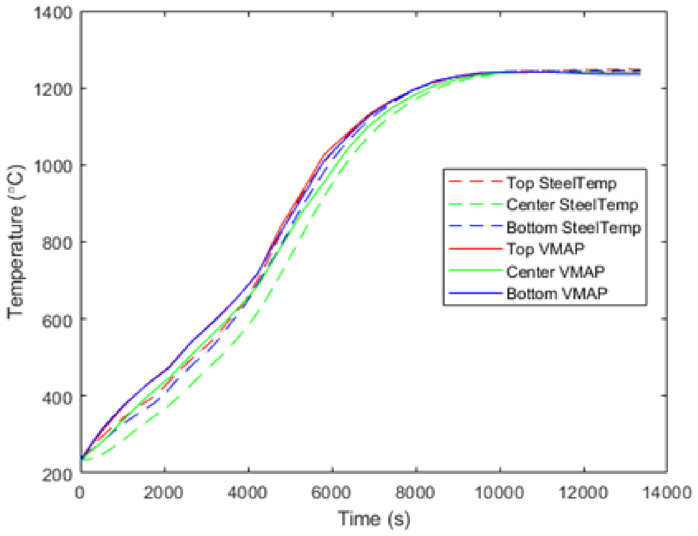
boundary conditions

Benchmark with LS-Dyna

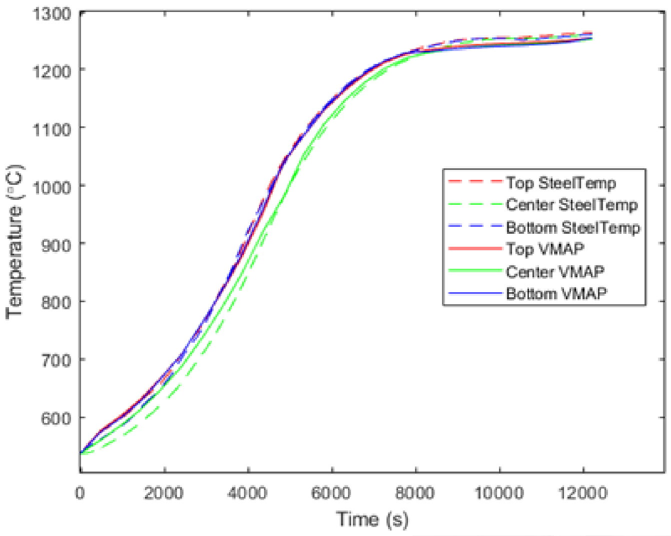




Comparison with FOCS data

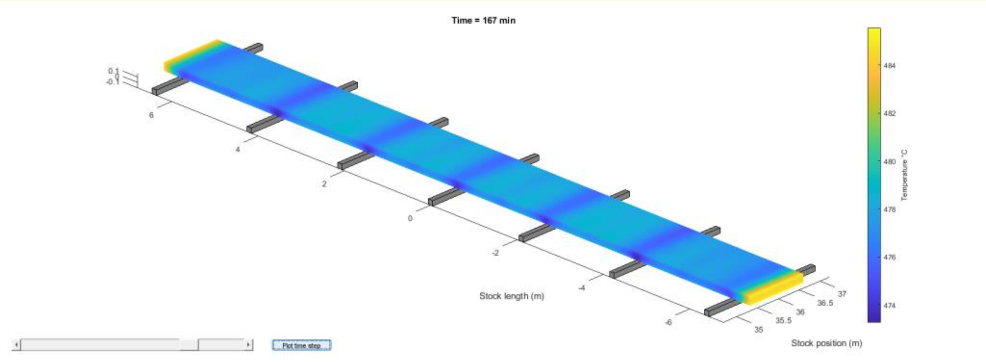


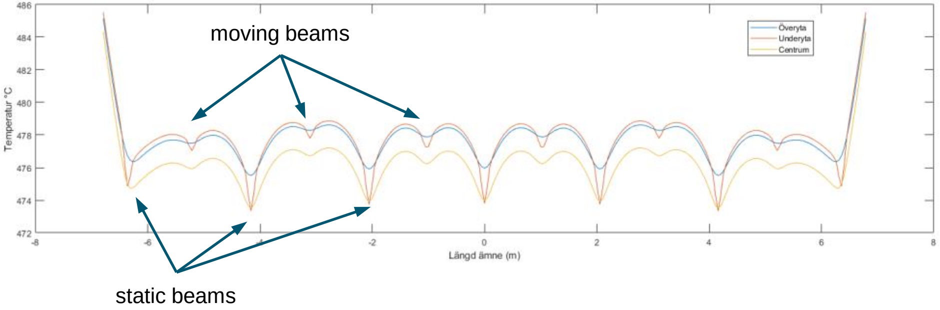
Charged at 234°C

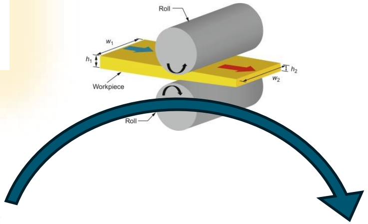


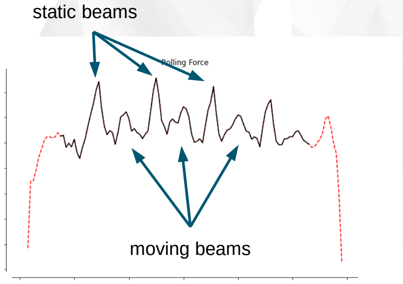
Charged at 537°C

Simulation results – 3D









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Data modelling approach

Find the best function in the family w.r.t. the performance metric

Some performance metric

$$\arg\min_{f \in \mathcal{F}} \|d(f(x), y)\|$$

$$\arg\min_{f \in \mathcal{F}} (f(x) - y)^2$$

A family of functions, e.g. functions of the form f(x)=ax+b

$$\arg\min_{f \in \hat{\mathcal{F}}} \|d(f(x), y)\|$$

$$\arg\min_{f \in \hat{\mathcal{F}}} (f(x) - y)^2$$

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From signal to model input variables

Time	Signal A
12:00	1.3
12:01	0.8
12:02	0.6
12:03	1.0
12:04	0.8
12:05	1.1
12:06	1.2
12:07	1.3
12:08	1.1
12:09	1.4
12:10	1.1
12:11	1.1
12:12	1.3
12:13	1.0
12:14	0.7
12:15	1.1
12:16	0.9

Slab 1

Slab 2

Slab 3

Pivot on time windows for each slab

Relative time	Signal A Slab 1	Signal A Slab 2	Signal A Slab 3
00:01	1.3	1.0	1.3
00:02	0.8	0.8	1.1
00:03	0.6	1.1	1.4
00:04	1.0	1.2	1.1
00:05		1.3	1.1
00:06			1.3

Calculate statistics

	Signal A, mean
Slab 1	0.9
Slab 2	1.1
Slab 3	1.2
...	...

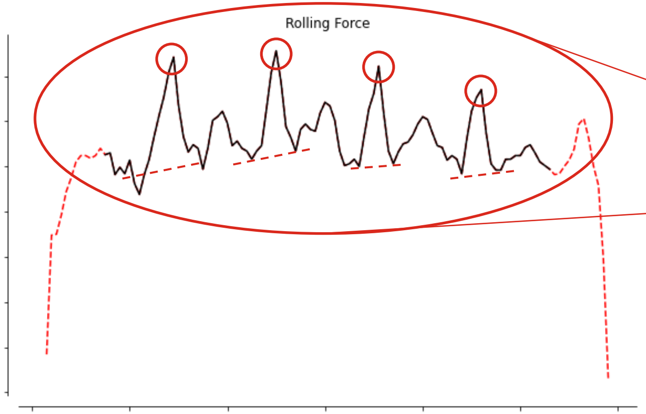
dmlc XGBoost

	Signal B, mean
Slab 1	1.9
Slab 2	2.4
Slab 3	2.1
...	...

Combine multiple signals and statistics

	Signal A, mean	Signal A, sum	Signal B, mean	...
Slab 1	0.9	3.7	1.9	...
Slab 2	1.1	5.4	2.4	...
Slab 3	1.2	7.3	2.1	...
...	...	...	...	...

From signal to model target variable



	Avg. peak height
Slab 1	0.10
Slab 2	0.07
…	…

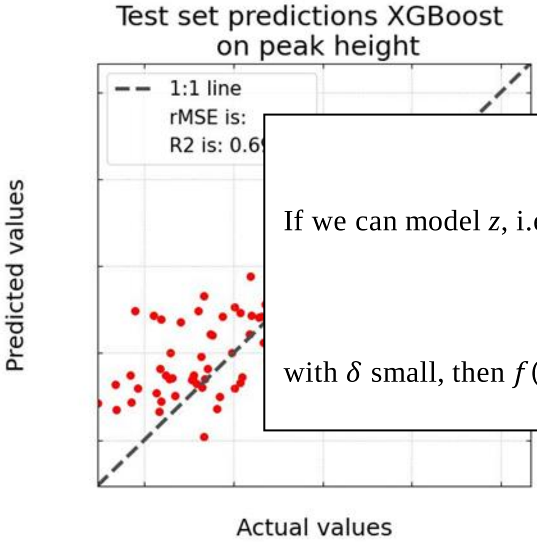
Machine learning in practice

	Signal A, mean	Signal A, sum	Signal B, mean	...
Slab 1	0.9	3.7	1.9	...
Slab 2	1.1	5.4	2.4	...
Slab 3	1.2	7.3	2.1	...
...	...	...	...	...

	Avg. peak height
Slab 1	0.10
Slab 2	0.07
...	...

$$\arg\min_{f \in \mathcal{F}} \|d(f(x), y)\|$$

Mediator variable

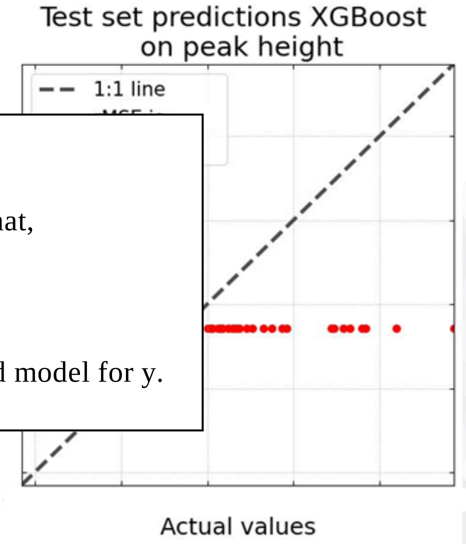


$$y = \alpha z + \epsilon.$$

If we can model z, i.e., find a function $g(X)$ such that,

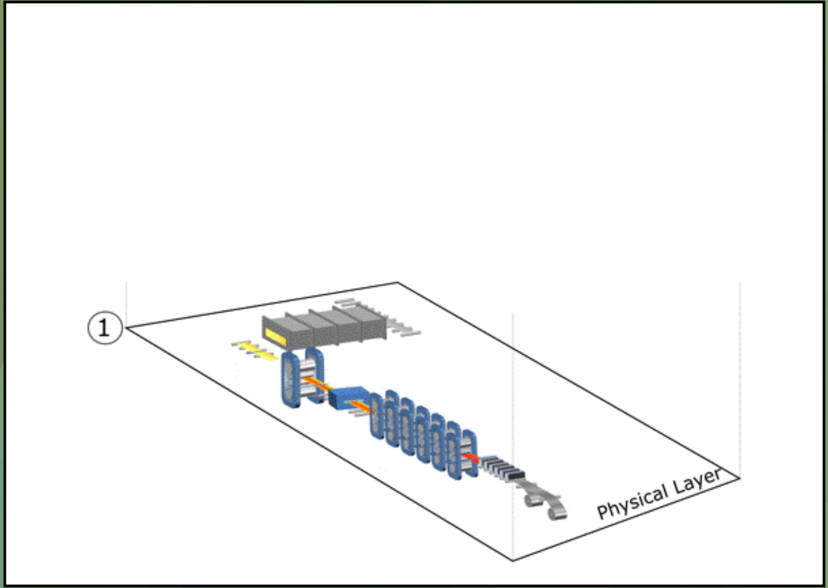
$$z = g(X) + \delta,$$

with δ small, then $f(X) := \alpha g(X)$ would be a good model for y.



Conclusions

- 3D model that predicts skid marks well
- Results can be transferred to next processing step, e.g. hot-rolling
- Data handling takes time
- Issues with AI models – opaque, extrapolation



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We create benefit for industry