

D-RAP

DIGITAL TWIN ECOSYSTEM OF STEEL PROCESSING

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Introduction

What do we mean by Digital Twins?

A verified digital representation of a physical, real-world production, test or in-service use case.

Key features

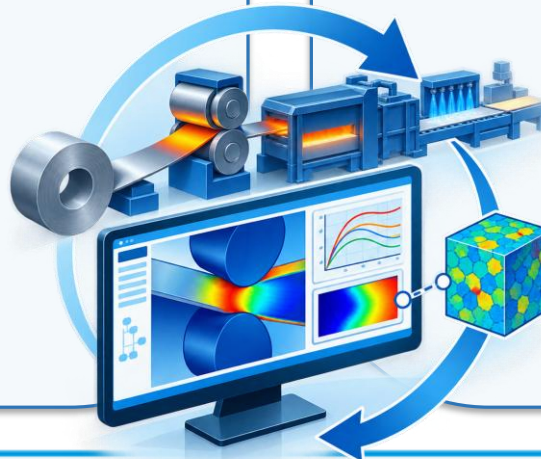
- **Multi-physics:** thermal, mechanical and electromagnetic
- **Microstructure:** phase changes, evolution and final properties
- **Optimization:** sensitivity studies and business cases

What are we trying to achieve?

An ecosystem to interact with WMG models, for fundamental metallurgical understanding and industrial applications

Key objectives

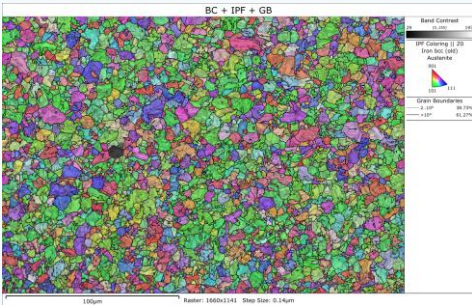
- **Capture and disseminate** modelling activity (open and confidential)
- **Educational platform**
- **Support lab facilities** with models and case studies



Example: Hot Rolling Digital Twin

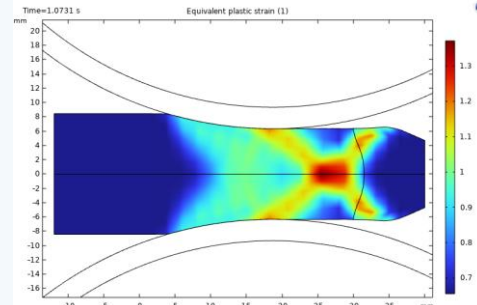
METALLURGICAL INPUT

Metallurgical input (e.g. grain size) defines the starting properties for hot rolling.



FINITE ELEMENT MODELLING

Finite element modelling provides the thermo-mechanical process history and spatial distribution of metallurgical properties.



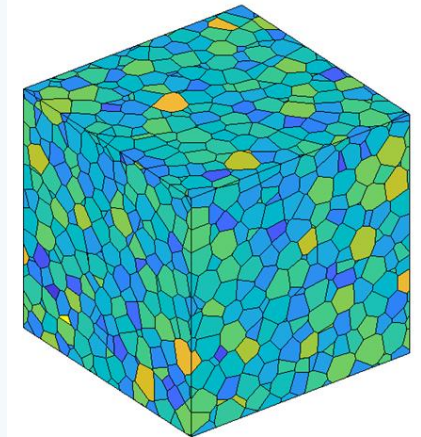
EMPIRICAL CORRELATION

The model is fitted for friction to reproduce strain and microstructure variations through thickness.



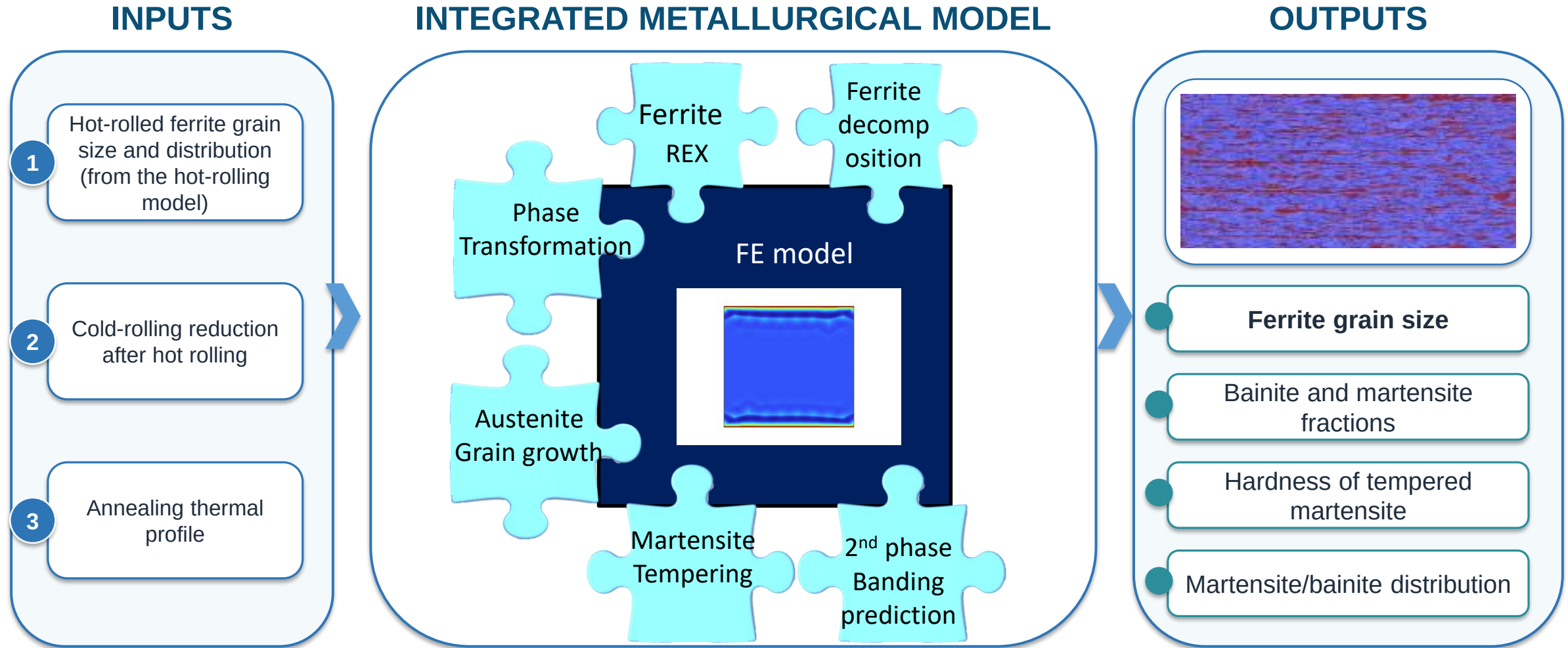
METALLURGICAL OUTPUTS

Metallurgical models predict recrystallisation and grain growth to determine the final grain size.



MODEL INTEGRATION • Provides initial conditions for downstream process twins: CAL (continuous annealing line) and ROT (run-out table).

Example: Continuous Annealing Digital Twin



The CAL Digital Twin links upstream processing history to phase evolution, microstructure and final material properties.

Results: the Digital Twins Suite

Physical facilities and process models are connected through a common digital-twin ecosystem.



HOT ROLLING



Hot
Rolling



RUN-OUT TABLE

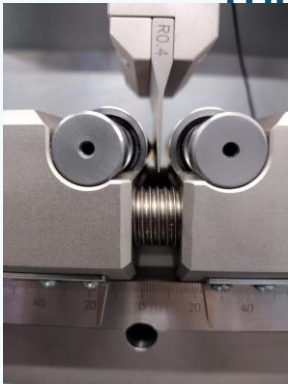


Run-out
Table

FEA + METALLURGY

Deformation • thermal cycles • phase transformation • grain size • recrystallisation

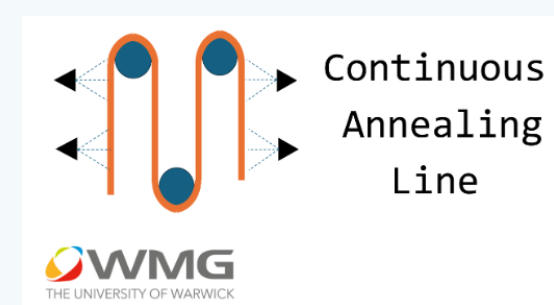
THREE-POINT BENDING



Three
Point
Bending



CONTINUOUS ANNEALING LINE



Continuous
Annealing
Line

Results: the COMSOL Server™

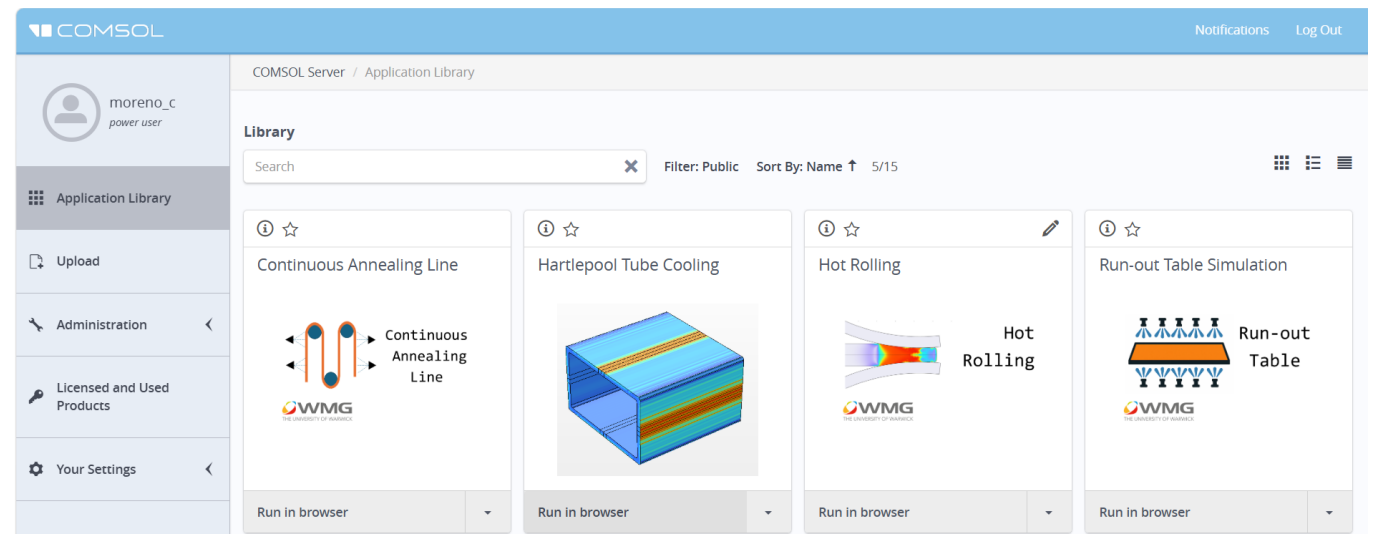
Applications are deployed through COMSOL Server™ as a secure environment for partner interaction.

Key features

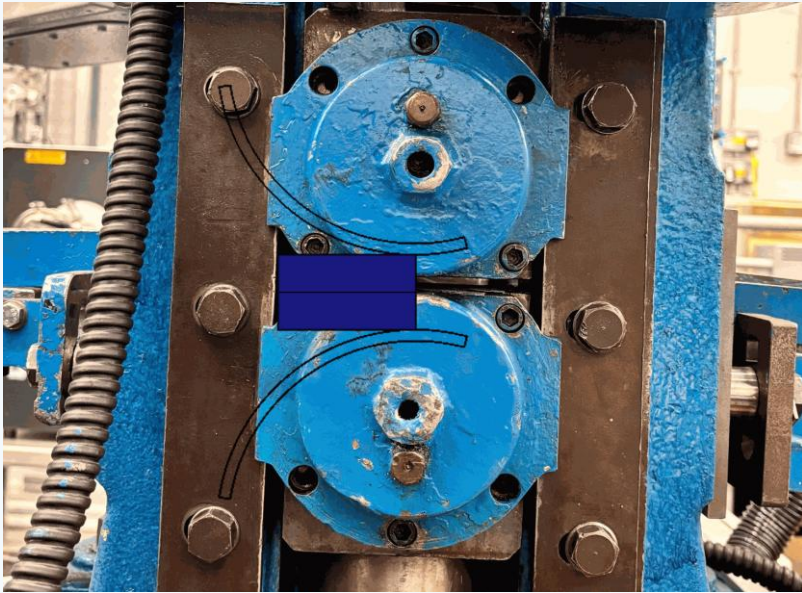
- No software licence required for end users.
- Strict version control and centralised updates.
- Customised interfaces tailored to partner needs.
- No FEA expertise or detailed knowledge of model development required.

Partners can use the ecosystem to:

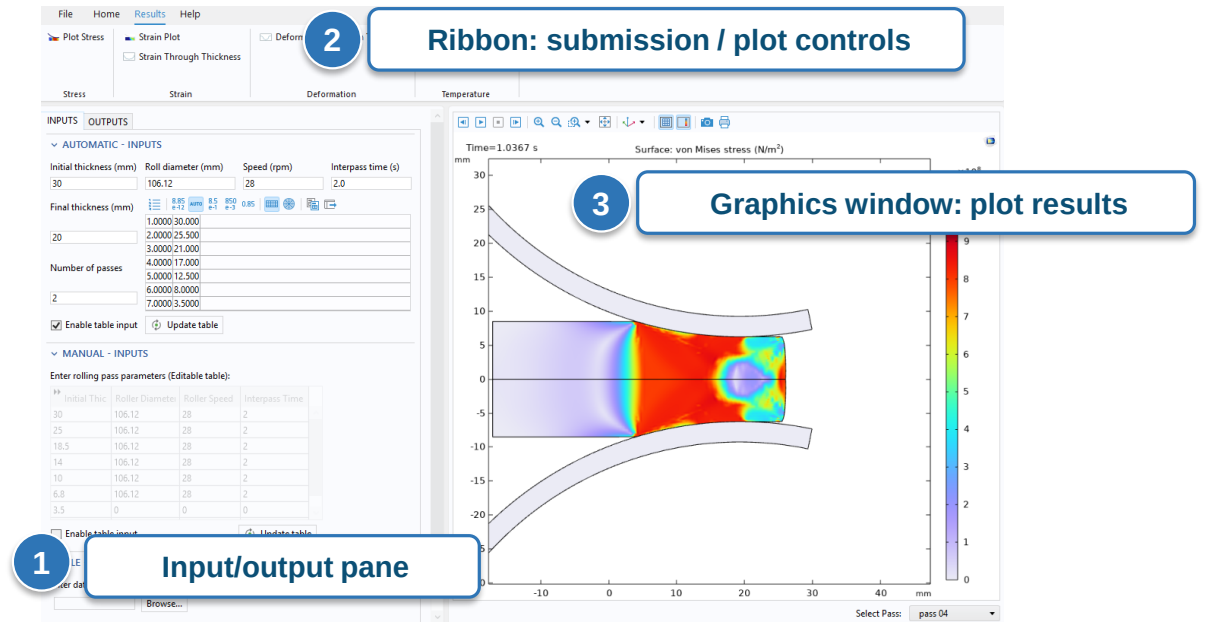
- Optimise process parameters for a defined output.
- Develop new products.
- De-risk the introduction of new products into an existing process.



Results: hot rolling Digital Twin



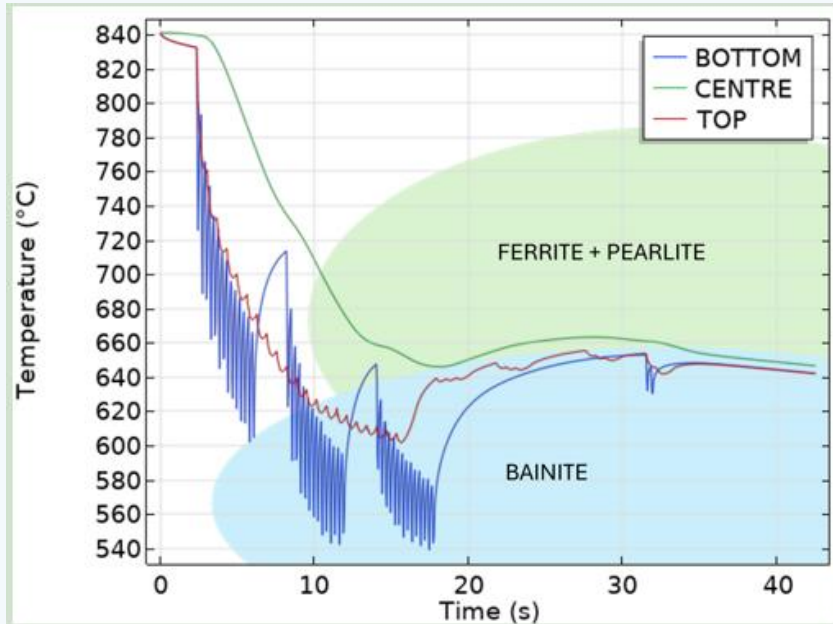
Physical rolling mill



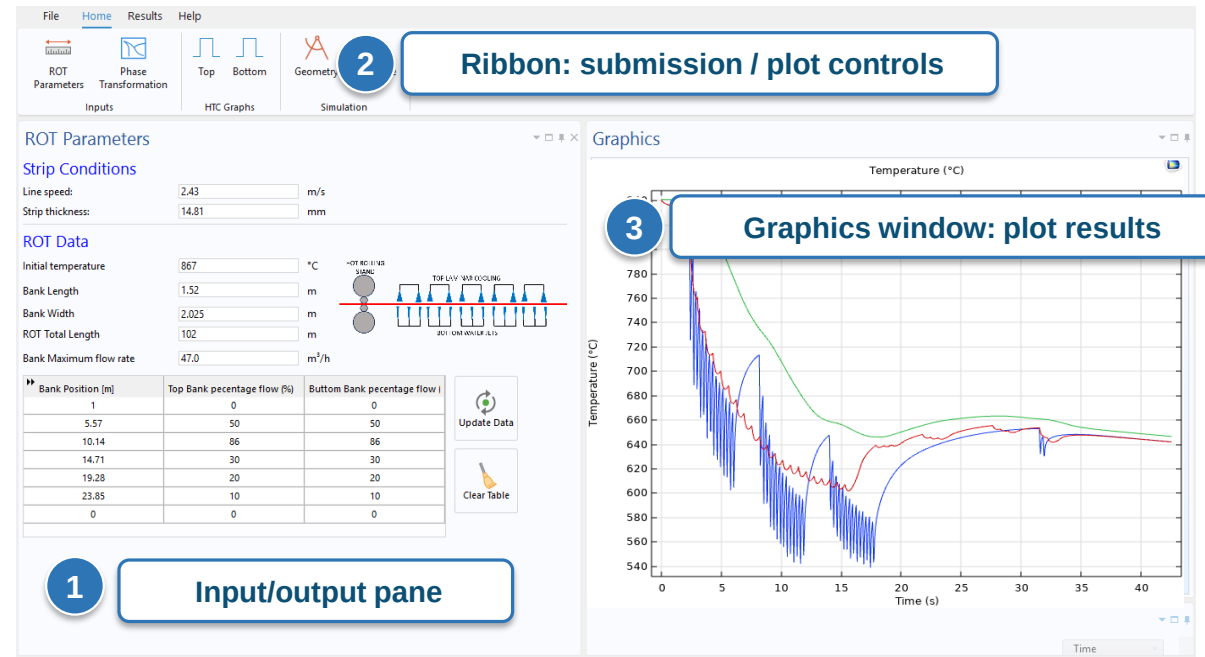
MODEL DEPLOYMENT

- Adaptable to different laboratory mills and industrial production rolling mills.
- Supports varying roll diameters, speeds, reduction schedules and thermal conditions.
- Enables process and material optimisation and sensitivity studies, including friction and reduction rate.
- Supports business cases that guide and de-risk physical trials.

Results: run-out table Digital Twin



Predicted through-thickness temperature history

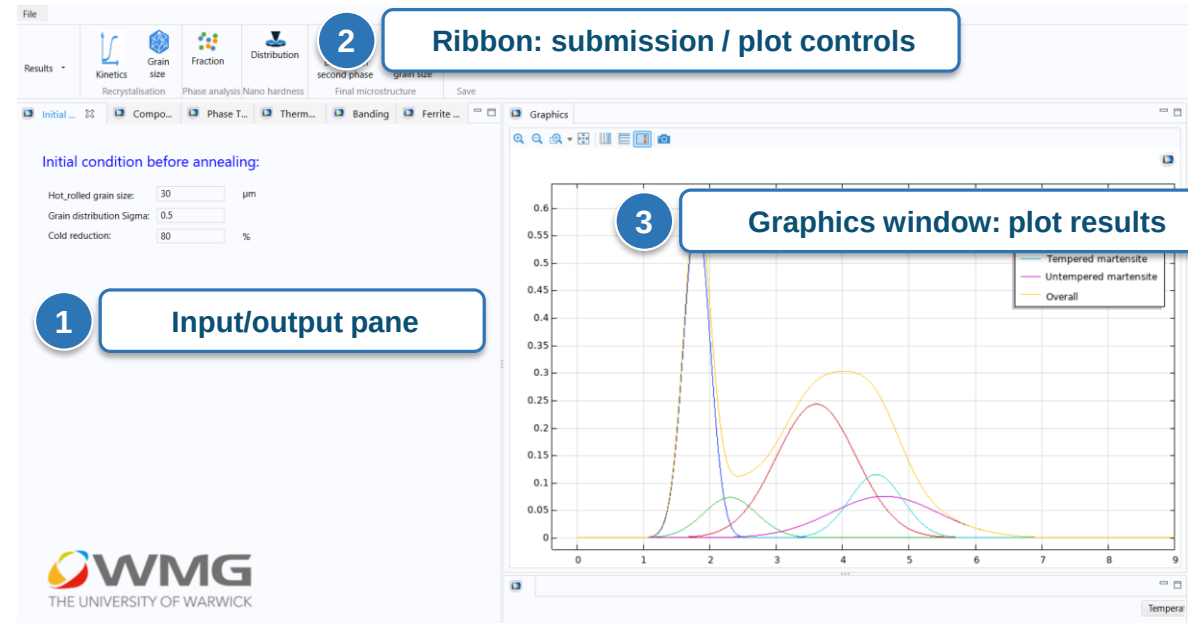
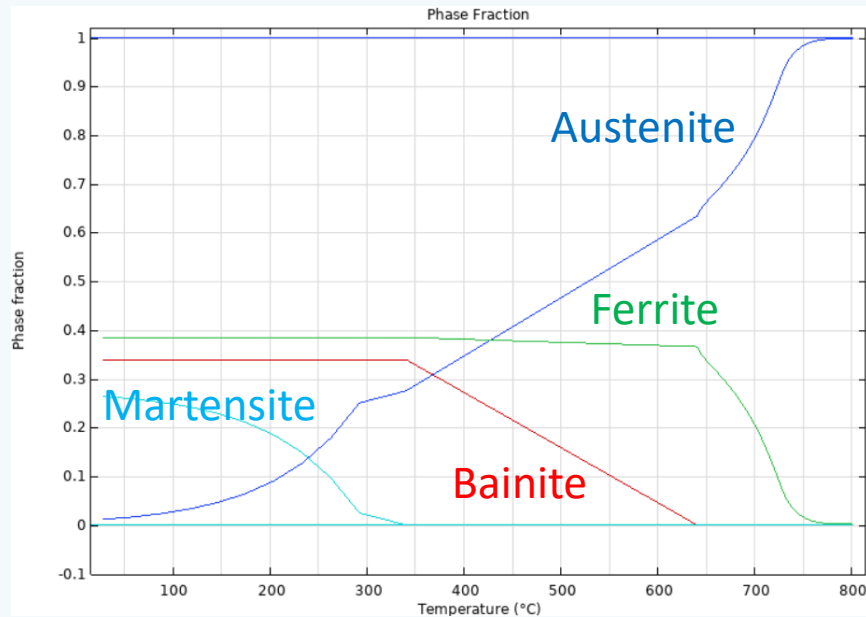


MODEL DEPLOYMENT

- Predicts temperature evolution along the run-out table where sensors are unreliable.
- Models through-thickness temperature and phase-transformation behaviour.
- Optimises cooling strategies for new steel compositions.
- Enables scenario testing and sensitivity studies without plant trials.

Results: continuous annealing Digital Twin

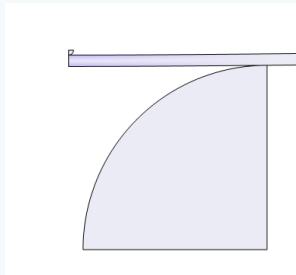
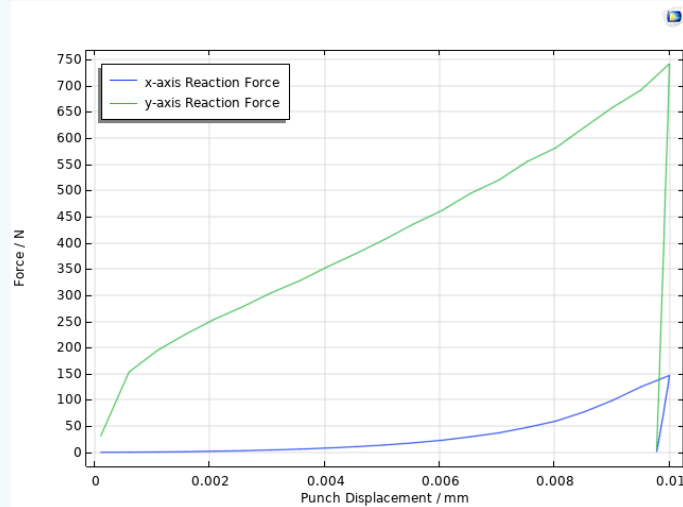
Phase transformation by temperature



MODEL DEPLOYMENT

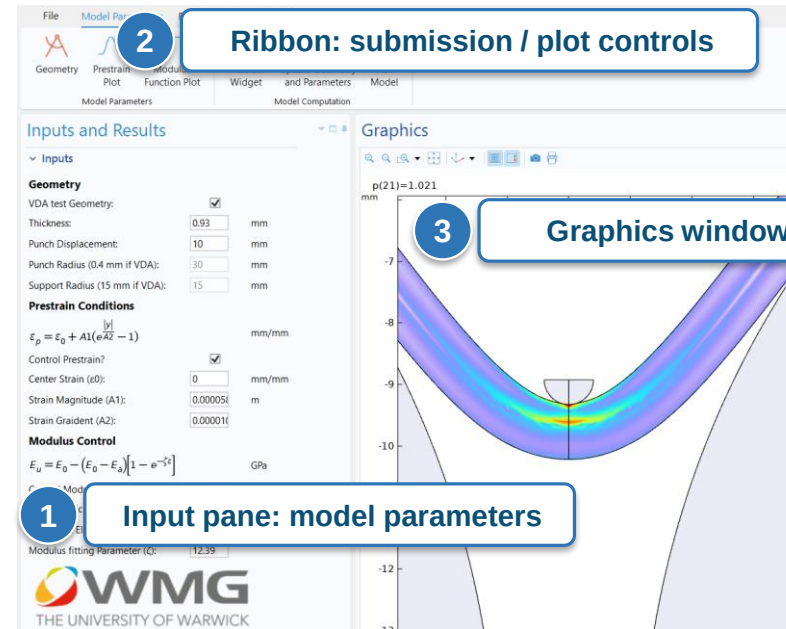
- Microstructural prediction for several steel grades.
- Sensitivity studies of plant process parameters and their effects on final microstructure.
- Optimisation of the thermal profile for a target microstructure and chemical composition.
- Prediction of final mechanical properties after continuous annealing.

Results: three-point bending Digital Twin



Springback		
Maximum Displacement (mm)	9.962	mm
Displacement After Springback (mm)	9.743	mm
Springback total (mm)	0.2193	
Maximum Angle °	53.64	°
Angle After Springback °	51.86	°
Springback Angle °	1.777	°

Force-displacement response and springback outputs



MODEL CAPABILITIES

- Simulates the VDA 238-100 tight-radius bend test and ISO 7438 bend-test geometries.
- Predicts stress, strain and springback, including the overbending required for a target geometry.
- Includes a decaying-modulus function based on the Yoshida–Uemori model.
- Allows prestrain from a cold-rolling finishing pass to be applied.

Conclusion

A common ecosystem connects process physics, microstructure and industrial deployment.

INTEGRATED MODELS

The suite links hot rolling, run-out-table cooling, continuous annealing and three-point bending within a common framework.

MULTI-PHYSICS + METALLURGY

Thermo-mechanical histories are combined with phase-transformation, recrystallisation and grain-growth models.

ACCESSIBLE DEPLOYMENT

COMSOL Server provides controlled partner access, tailored interfaces, centralised updates and no requirement for FEA expertise.

INDUSTRIAL VALUE

The parametric twins support optimisation, sensitivity studies, product development and the de-risking of physical trials.

Next step: continue validation with industrial data and expand the ecosystem with partner-facing applications.