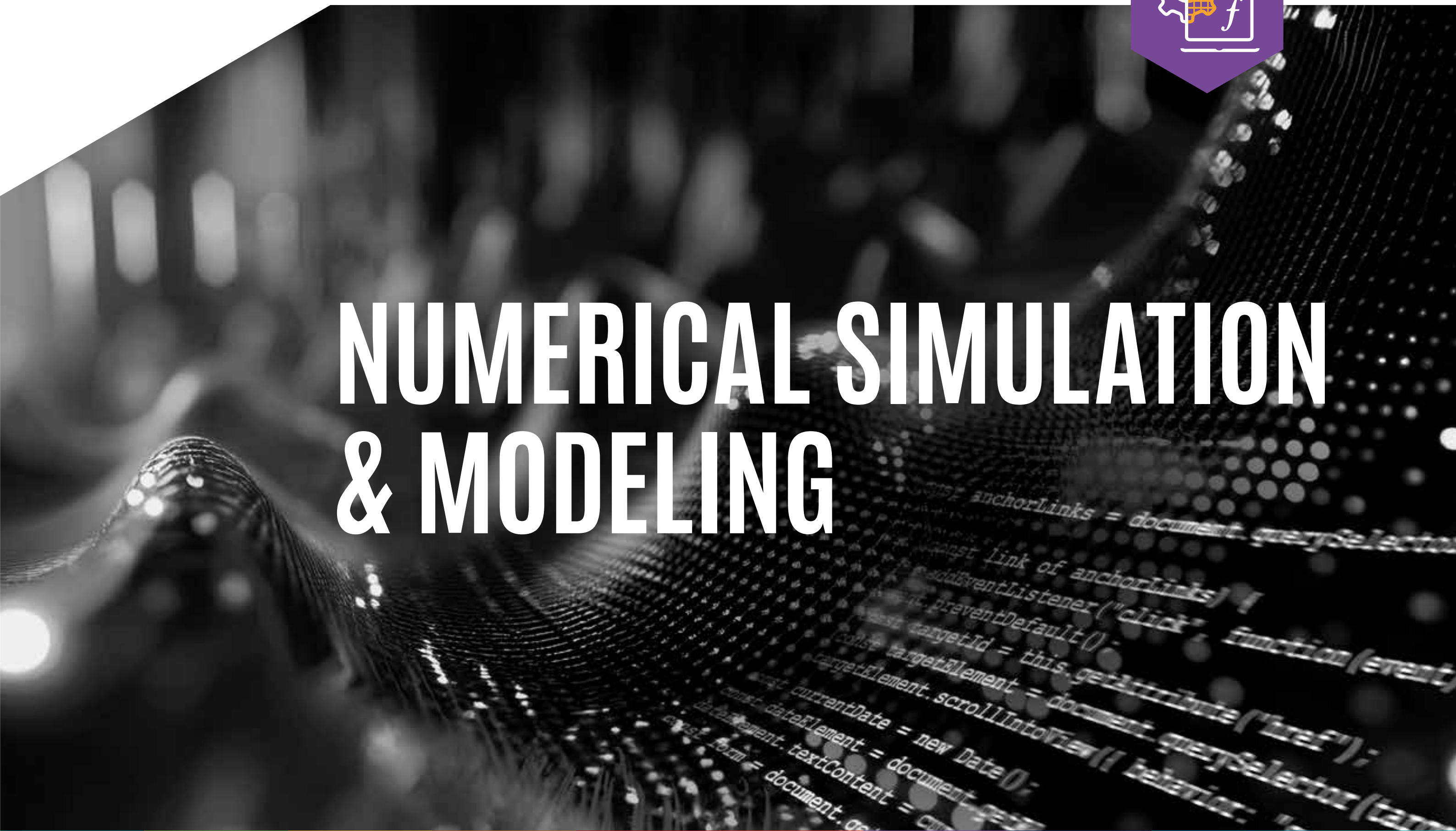
IRT M2P

Institut de Recherche Technologique
Matériaux Métallurgie et Procédés



# NUMERICAL SIMULATION & MODELING

**Analysis of multiphysical phenomena using a series of calculations and a mathematical model to optimize and enhance the efficiency of industrial processes**

At the crossroads of metallurgy, materials physics and numerical technologies, the materials and industrial processes modeling has become an indispensable tool for improving the durability and efficiency of structures, integrating new technologies and driving innovation.

## APPLICATIONS

**Our work in numerical simulation and modeling covers all our fields of activity, enabling us to provide comprehensive solutions to our academic and industrial: metal powders & advanced foundry, heat, thermochemical & surface treatments, composite materials & joining.**

This scientific methodology now plays a key role in Industry 4.0 and strategic sectors (automotive, aeronautics, energy, etc.), for which its ability to optimize structural design and accelerate development processes is more valuable than ever. By enabling analysis and anticipation of the impact of various factors on real situations, numerical simulation and modeling offer crucial competitive advantages for industry:

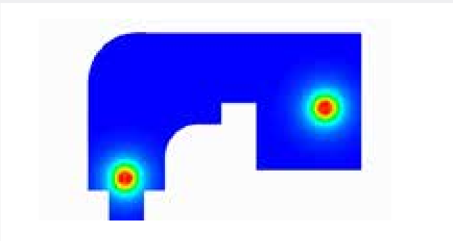
- **Process control**
- **Improving product quality**
- **Risk reduction**
- **Performance optimization**
- **Cost and time-to-market reduction**
- **Innovation and development of new products**
- **Simulation and prediction of behaviors**

At IRT M2P, our simulation and modeling experts focus on understanding multiphysical process phenomena, or those occurring during process operation, whether mechanical, chemical, thermal or dynamic phenomena.
They use various approaches and methods (numerical tools, mathematical models and calculations, bibliographical studies, experimental trials and data analysis, etc.), enabling them to develop high-performance tools.

### METAL POWDERS & ADVANCED FOUNDRY

**Numerical simulation and modeling of atomization processes for metal powder production:** Analysis of gas and metal flows and their interaction to optimize operating parameters, predict particle size distribution, improve fine powder yields, and reduce gas consumption and costs.

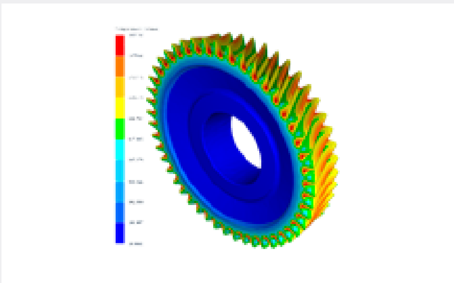
**Simulation and modeling of the PAM-CHR (Plasma Arc Melter - Cold Hearth Refiner) foundry process:** Optimization of metal flow, interaction with plasma torches and inclusion management to ensure alloy purity, adapt operating parameters, and determine melt thickness for each alloy.



**Modeling of the induction melting furnace process:** Analysis of heating, electromagnetic stirring and thermal and fluid flows in a crucible, in order to optimize energy efficiency, control the temperature, reduce metallurgical defects, and adapt parameters to different alloys.

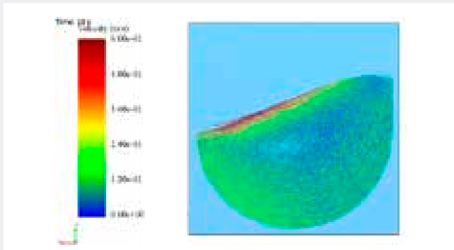
### HEAT, THERMOCHEMICAL & SURFACE TREATMENTS

**Numerical modeling of the induction hardening process:** Analysis of heating, thermal phenomena, phase transformations and mechanical deformations in order to optimize the material's microstructural and mechanical properties, while adapting the parameters for the geometries and alloys used.



**Numerical simulation of the air quenching process:** Study of air flow, heat exchange and thermal cycles to optimize operating parameters and nozzle configuration, thus ensuring efficient cooling and the mechanical performance of the parts.

**Numerical modeling of the tribofinishing process:** Analysis of granular flow and energy distribution in a vibratory tank to optimize operating parameters, sample position and choice of media for appropriate and efficient treatment.

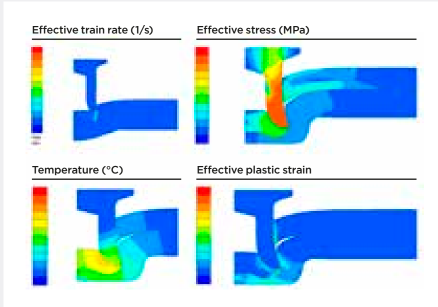


**Modeling of thermodynamics and phase diffusion in cementation and nitriding furnaces:** Prediction of alloying element effects, optimization of process parameters, and calculation of concentration profiles to improve surface hardening.

**Steel phase prediction using Machine Learning:** Using EBSD data to train models capable of distinguishing steel phases on EBSD maps, offering a more accurate analysis than metallographic images.

### COMPOSITE MATERIALS & JOINING

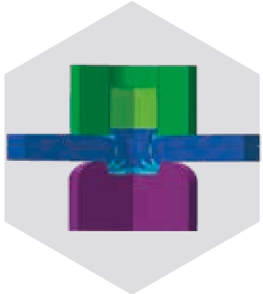
**Simulation of material joining processes:** Study of deformation, heating and material interactions in order to predict heat-affected zones, optimize process parameters and provide joint behavior models to design offices.



# EXPERTISE & SERVICES

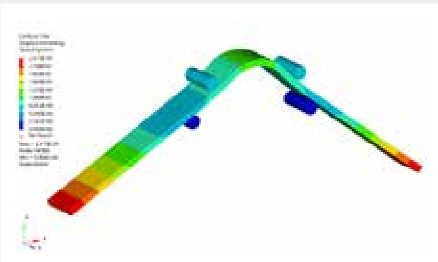
**Our team offers in-depth expertise and personalized services in the following areas:**

**Finite Element and Computational Fluid Dynamics numerical simulations**
We carry out advanced numerical simulations in Finite Elements (FE) and Computational Fluid Dynamics (CFD) to model and analyze complex processes, thereby optimizing performance and reducing development costs.



**Data management / Machine Learning / AI**
Thanks to our expertise in data management, we integrate Machine Learning and Artificial Intelligence (AI) solutions to analyze and optimally exploit the vast quantities of data generated, thus fostering innovation, automation and continuous process improvement.

**Numerical simulation and modeling of the mechanical design of composite materials:** Analysis of the mechanical behavior of materials, for example in non-linear static and non-linear dynamics, prediction of displacements, stresses and deformations, comparison of materials and correlation of results with experimental testing.



**Simulation and numerical modelling of dry textile preforming:** Analysis of the mechanical behaviour of dry textiles (shear, tensile, bending), prediction of stresses and deformations (folds, overtensions, tearing), definition of preforming strategies (one shot, sequential + definition of boundary conditions (release of plies, blocking of fibres)) and correlation of results with tests.

**Optimizing the mechanical design of composite materials:** Numerical modeling, topological and parametric optimization to improve the geometry, mass and mechanical performance of parts, thus reducing costs and development time compared to trial-and-error methods. Predicitve modeling with data science surrogate models which runs faster.

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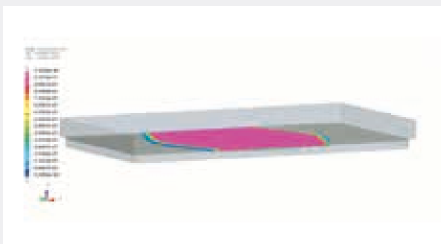
**Numerical simulation and modeling of the RTM (Resin Transfer Molding) composite materials process:** Optimization of resin injection conditions in fiber reinforcement by determining the injected volume, speed, pressures and predicting resin front closures in order to minimize porosity and improve the process.

**Numerical simulation and modeling of the C-RTM (Compression Resin Transfer Molding) process:** Analysis of resin flow, mechanical compaction and composite properties to optimize injection and compaction conditions, and predict defects such as porosity to improve process efficiency.



**Simulation and numerical modelling of composite distortions induced by curing:** Thermochemical calculations during curing, calculations of residual stress, distortions after curing, after demolding, after trimming, mold compensation.

**Further information on our activities www.irt-m2p.fr**

## RESOURCES @M2P

### METHODS

- Computer-Aided Design (CAD)
- Technical Drafting
- Mechanical Design
- Composite Design
- Finite Volume Method
- Finite Element Method
- Discrete Element Method
- Inverse Method
- Machine Learning
- Deep Learning
- Artificial Intelligence
- Computational Fluid Dynamics (CFD)
- Thermal Analysis
- Electromagnetic Analysis
- Mechanical Deformation Analysis
- Thermodynamic Analysis
- Mechanical Assembly Analysis
- Linear and Non-Linear Static Mechanical Analysis
- Composite Material Calculation
- Sensitivity Analysis
- Topological Optimization
- Parametric Optimization
- Programming
- Surrogate models

### SOFTWARE

- SOLIDWORKS
- Abaqus
- ALTAIR: Hypermesh, Optistruct, Radioss, Hyperstudy, Edem
- Ansys Fluent
- COMSOL multiphysics
- OpenFoam
- FORGE NTX
- Qobeo
- ESI PAM-COMPOSITES: PAM FORM, PAM-RTM, PAM-DISTORTION
- Thermo-Calc : Dictra, Prisma
- Minitab
- Matlab
- Scilab
- Python
- P-EXPAANS

# RELATED ACTIVITIES

- METAL POWDERS
- HEAT & THERMOCHEMICAL TREATMENT
- ADVANCED FOUNDRY
- COMPOSITE MATERIALS
- SURFACE TREATMENT & COATINGS
- MULTIMATERIALS JOINING
- MECHANICAL SURFACE TREATMENT

### About IRT M2P

The Institute of Research and Technology for Materials, Metallurgy & Processes (IRT M2P) is your partner for developing innovative products and processes to accelerate your company's growth.

We bring our expertise, a wide array of state-of-the-art semi-industrial technological platforms and a network of academic labs to the R&D projects we carry out with our more than 120 industrial partners.

Contact us to discover our 10 areas of technological expertise:

> Advanced Foundry
> Life Cycle Assessment & Recycling
> Metal Powders
> Surface Treatment & Coatings
> Mechanical Surface Treatment
> Heat & Thermochemical Treatment
> Composite Materials
> Multimaterials Joining
> Analysis & Characterization
> Numerical Simulation & Modeling

### Working together

- Multi-partner research projects with private/public co-funding
- Private research studies, tailor-made services
- Small series & prototype production
- Training

IRT M2P

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Matériaux Métallurgie et Procédés

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