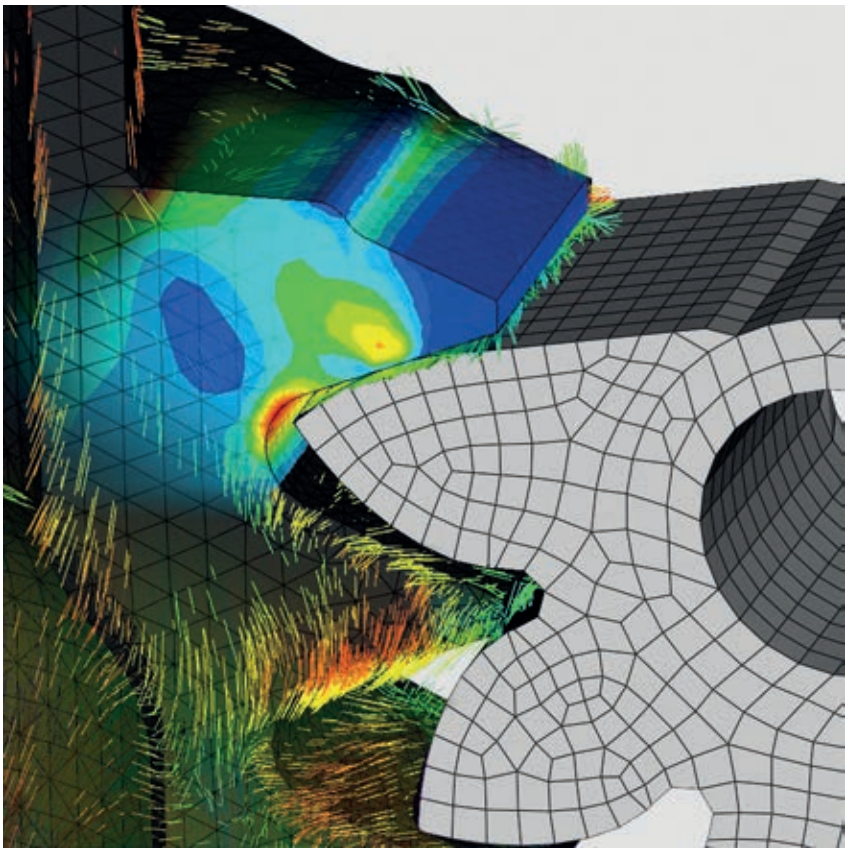
HIGH PERFORMANCE POLYMERS



Simulate. Collaborate. Innovate.

engineering
service

RADICI GROUP

The best way to predict the future is to simulate it.

Customized technical support fuelling the success of innovative projects, including metal replacement, realized using our broad range of engineering materials.
This is what RadiciGroup High Performance Polymers can offer customers, thanks to its state-of-the-art computer-aided engineering (CAE) virtual simulation tools and the experience of its technical specialists.

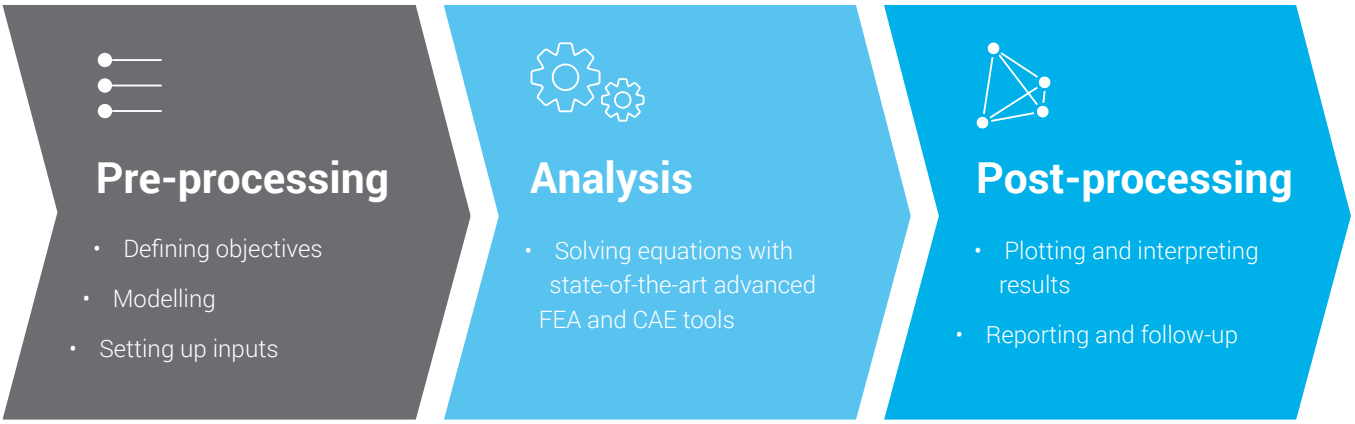
Virtual simulations for real solutions.

Designing with engineering polymer materials to achieve demanding **performance**, **lightweighting** and **sustainability** targets becomes much more accessible, timely and cost-effective by using reliable computer-aided simulation tools for the prediction of processing behaviour as well as real-world capabilities.

For studying the complex behaviour of fibre-reinforced composite materials, an **advanced material modelling approach** is crucial to make accurate predictions using integrated simulation technology, which couples the process-induced properties (such as fibre orientation, weld line location, etc.) with the macroscopic material behaviour.

RadiciGroup High Performance Polymers Engineering Service makes all this available for customers and partners by performing in-house studies to support the development of challenging applications involving our special thermoplastic compounds. Moreover, our service provides access to reliable simulation data and material cards for the most widespread software tools on the market.

Doing things “first-time right”.



- Complete specialized technical support along the entire CAE **workflow** process.
- Selection of the best model, method and software to obtain the right **answers** to the questions coming from our customers’ product development teams.
- Support for **innovation** challenges and **metal replacement** project workflows, including preliminary comparative **cost analysis**.
- Follow-up with **shape optimization**, **co-design**, and transition to the prototype phase.

Why choose RadiciGroup Engineering Service.

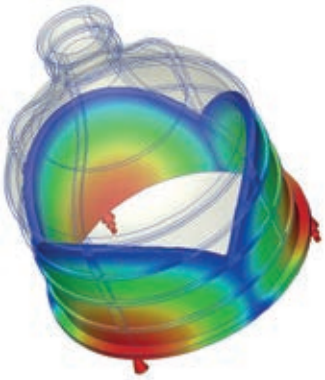
A professional support such as the one provided by the Group, making use of advanced CAE tools, can deliver many benefits for the development of demanding projects:

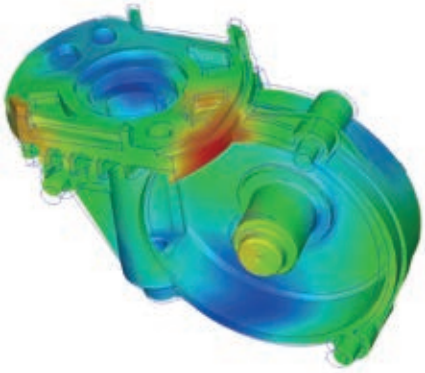
- **Minimizing trial and error** and the use of physical prototypes, thanks to reliable CAE simulations.
- **Detecting and correcting any feasibility obstacles** in virtual environment, when the cost of making changes is still relatively low.
- **Performing an accurate material selection**, choosing the best grade in our outstanding product range to meet the project requirements.
- **Relying on updated, precise and specific material data** to perform technical calculations and simulations internally.
- **Implementing ecodesign principles**, on the path to creating more sustainable products together with our costumers.
- **Keeping costs under control**, exploring and comparing alternative solutions to choose the best option.
- **Troubleshooting unexpected issues** during prototyping or early production stages.

A whole set of simulations for all your needs.

Process simulation: injection moulding and more.

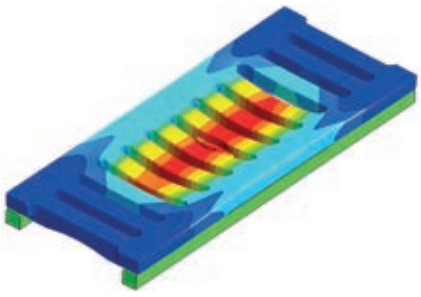
- Use of the most well-known CAE tools on the market for simulating **injection moulding** and related technologies.
- Predicting the **filling**, **packing** and **cooling** behaviour and estimating moulding **warpage.**
- Assessing optimal process parameters, suggesting injection type and locations, predicting process-related defects, etc.
- Making use of cutting-edge software modules to closely reproduce the viscoelastic material response, crystallization rate, fibre-flow interactions, core-shift effects on inserts, and more.
- Simulation of other processes, such as **3D printing** and **extrusion,** is under investigation.

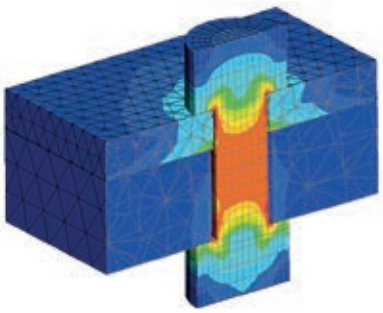


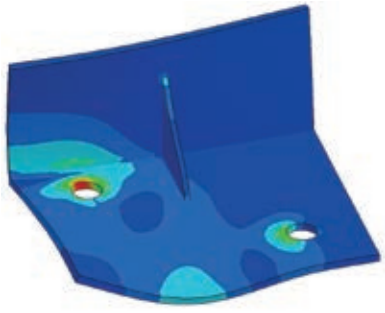


Structural simulation: static, dynamic and multiphysics.

- Evaluation of **static** stiffness and strength evaluation of parts against **design and abuse loads**.
- **Non-linear** structural simulation and multi-body **contact** modelling to simulate small assemblies.
- Modal and harmonic analysis to assess frequency response to **vibrations**.
- Modelling of high-speed **impact** and **crash** phenomena can be modelled with implicit and explicit FEM codes, keeping in consideration the **strain rate dependency** of material properties.
- **Thermal** and **thermo-mechanical** effects on the model's structural behaviour can be considered.

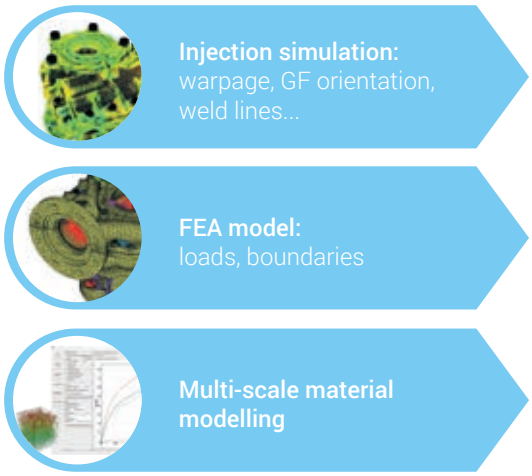






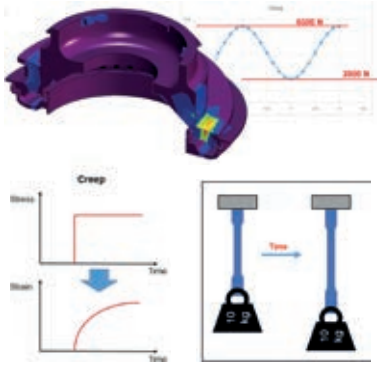
Integrated simulation: linking process to structure.

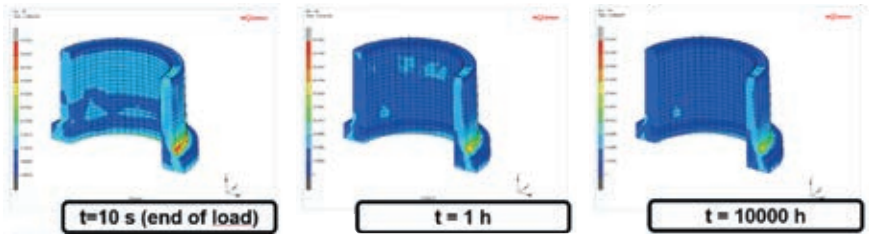
- Integrated simulation can take into account material **anisotropy**, induced by **glass-fibre orientation** during injection moulding or by local TPC reinforcement.
- **Weld line** locations, residual stress, **warpage** effects can be considered as well.
- These advantages are made possible by **multi-scale material modelling** technology, supported by specialized software.
- An integrated analysis provides higher **accuracy** and **reliability**, thanks to a more in-depth understanding of material characteristics, and thus reduces over-engineering and the need for prototype testing.



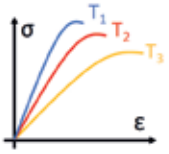
Long-term behaviour: fatigue, creep and ageing.

- Thermoplastic materials show peculiar phenomena that are important to consider for improving performance in the long run.
- Subjecting materials to cyclic loading for a great number of cycles results in fatigue damage, which may lead to premature failure.
- The constant application of a steady stress for a long time can cause materials to “flow”, changing their apparent stiffness and ultimately, possibly, causing them to fail – this is the **creep** phenomenon.
- The exposure of thermoplastics to heat or chemical substances for a prolonged time (**ageing**) may damage or otherwise affect their properties, changing their response to external loads.
- Our **CAE software and procedures** provide us with specific workflows and tools to deal with these kinds of aspects and accurately predict the long-term capabilities of a part.

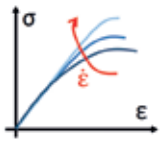




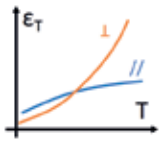
Characterization, modelling and material card construction.



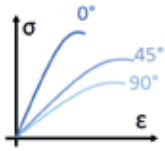
Tensile properties
at various T, RH



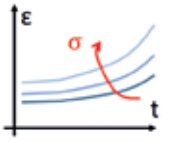
High speed tensile properties
at various strain rates



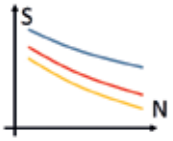
CLTE
Longitudinal and transvere



Anisotropic
Multi-scale material models



Creep properties
Strain vs time



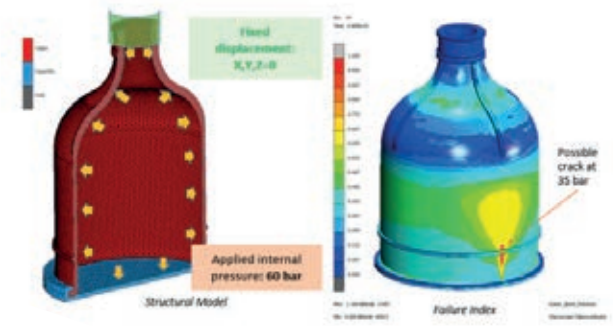
Fatigue properties
Wöhler S-N curves

Process simulation
Comprehensive material cards

... and more!
Based on specific needs of each project

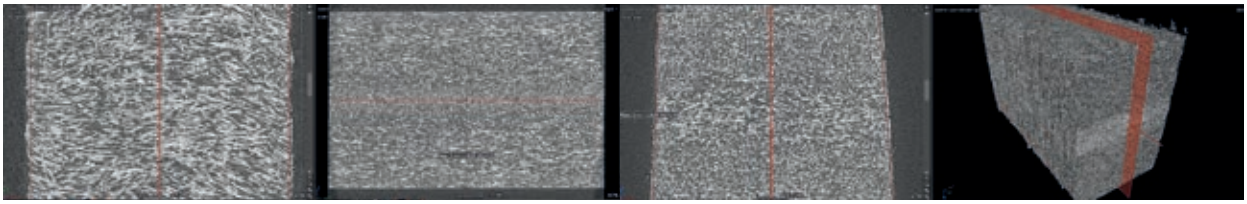
- **Reverse-engineering** and advanced material modelling for the **Digimat®** platform internally performed.
- Use of **micro-computed tomography** to inspect and validate fibre-orientation predictions with extreme accuracy.
- Material cards checked and **validated** independently, with comparison of FEM and testing on standard specimens or demonstrator parts.
- Many of the **mechanical** and **physical** data necessary to simulate material performance are organized in internal data management systems and available from our technical support team.
- **Specific** on-demand characterizations can be requested by customers for dedicated collaboration projects and applications.

Integrated structural simulation



Real part validation

- Burst pressure
- Pulsating pressure (fatigue)
- Creep
- Others



The microstructure of the specimens used for anisotropic material calibration is inspected using advanced micro-computed tomography (µCT) techniques.

Computer-Aided Engineering services drive improvements in sustainability and ecodesign. Here's how.

- **About 80%*** of product-related environmental impacts are determined during the design phase.
- Ecodesign is a methodology that guides the designer in **considering the ecological impact** of products during their developmental phase.
- A set of **technical tools** and rules are available for designers, which should be complemented with material selection expertise, design know-how and CAE skills to become really effective.
- **Lightweighting - achievable through the redesign, rethinking and optimization** of products - can lead to significant environmental benefits, especially in the automotive and transportation sectors.
- Recyclability is facilitated by following the principles of **Design For Disassembly,** which make the recovery of end-of-life products easier and more affordable.
- Sustainable materials, such as RadiciGroup's portfolio of **recycled or bio-based thermoplastic compounds**, can be successfully employed in technical applications, by a careful and detailed evaluation of material performance and variability in computer-aided simulations.
- Certified, third-party verified, **LCA and EPD® system data** are available for all RadiciGroup engineering polymers to assess the real and measurable environmental performance of the different solutions.

* EU Commission - EU Science Hub - Sustainable Product Policy 23/4/2020

Simulations for every kind of application.

RadiciGroup High Performance Polymers Engineering Service is the ideal solution for countless applications in all those sectors where creativity, high performance and flexibility are required. It has countless applications in:

Automotive | E-mobility | Electrical/ Electronic | Consumer goods | Furniture | Sports accessories | Water management

RadiciGroup High Performance Polymers Engineering Service is available to our customers and strategic partners, in support of demanding projects made with our engineering thermoplastics. **Our understanding of materials science and competence in accurately predicting real-world performance really makes a difference**.

Get in touch with your local RadiciGroup Sales Representative to learn more about the opportunity for us to collaborate on your projects through our Engineering Service.

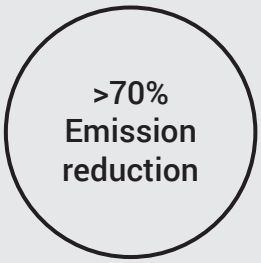
RadiciGroup.
Inside your world.

RadiciGroup is one of the world's leading producers of a wide range of chemical intermediates, polyamide polymers, high performance engineering polymers and advanced textile solutions, including nylon yarn, polyester yarn, yarn made from recovered and bio-source materials, nonwovens and personal protective equipment for the industrial and healthcare fields. These products are the result of the Group's outstanding chemical expertise and vertically integrated polyamide production chain and have been developed for use in a variety of industrial sectors, such as: automotive, electrical and electronics, household appliances, consumer and industrial goods, apparel, furnishing, construction and sports. The basis of the Group's strategy is a strong focus on innovation, quality, customer satisfaction and social and environmental sustainability.

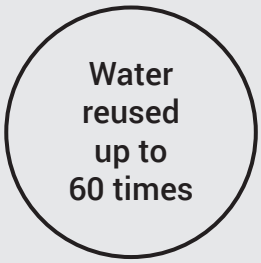
Sustainability

Every day at RadiciGroup, we work to make circularity our business model. We optimize the use of materials while fine-tuning our processes, eliminating waste and promoting recyclability from the earliest product design phases. We are always looking for low-impact solutions in terms of natural resources and energy. We rely on certified management systems for Quality, Health and Safety, Environment and Energy to keep our companies in line with the highest sustainability standards.

GRI, third-party certified **Sustainability Report** covering all RadiciGroup companies worldwide.



Since 2011, in RadiciGroup plants.



Water reused in RadiciGroup production plants.

Data Source: RadiciGroup Sustainability Reports

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