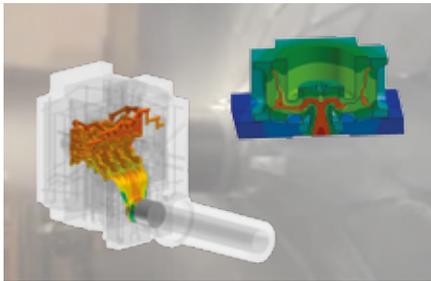
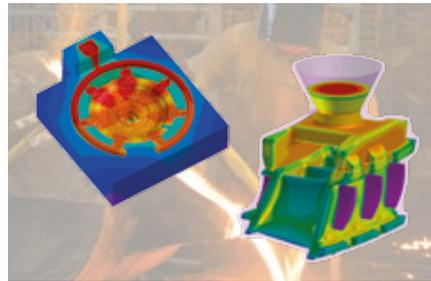


# ProCAST

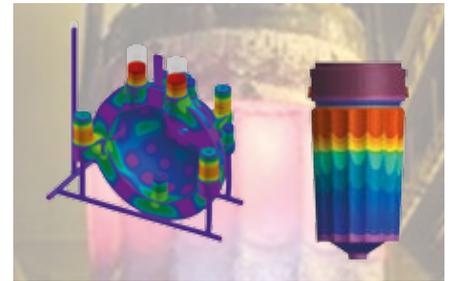
## CASTING SIMULATION SUITE



High & Low Pressure  
Die Castings



Gravity Die & Investment  
Castings



Steel & Ingot  
Castings

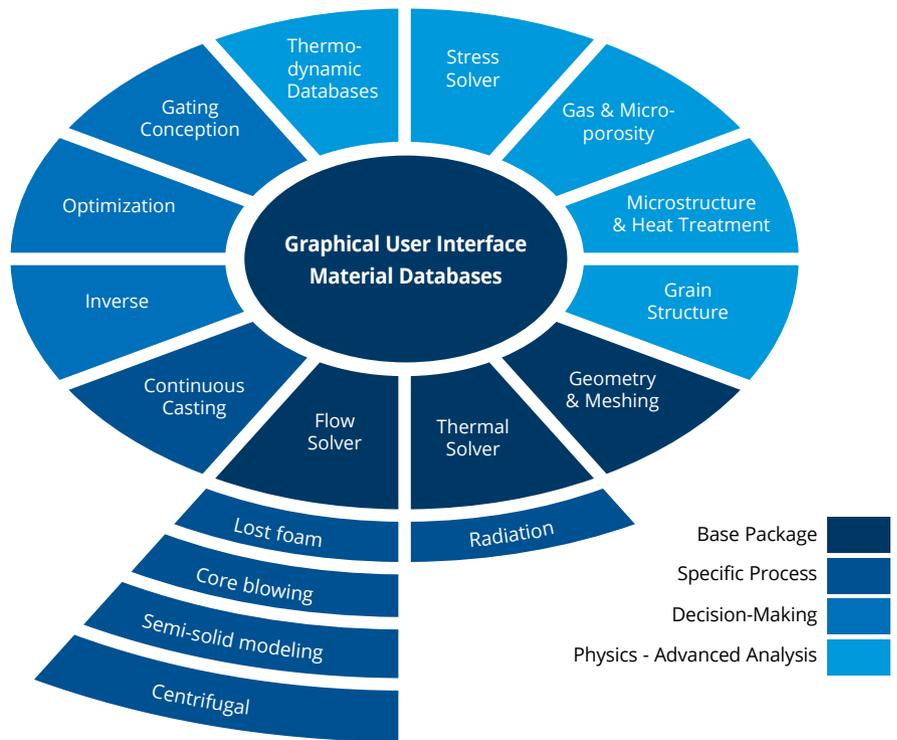
# ESI's Casting Simulation Suite: ProCAST

With our casting solutions you can Get it Right the first time and enhance your productivity & profitability

ESI's Casting Simulation Suite, ProCAST, provides a complete set of solutions for the foundry industry. An advanced tool which is the result of more than **25 years of collaboration** with major industrial partners and academic institutions across the world, ProCAST offers an **extensive suite of modules and foundry tools** to meet today's challenging industrial requirements. Based on the powerful Finite Element Technology, ProCAST enables predictive evaluations of the entire casting process, including filling and solidification defects, mechanical properties and complex part distortion. It enables rapid visualization of effects of design changes and provides a basis for correct decision-making, from the earliest stages of the manufacturing process. ProCAST enables the modeling of all casting processes for all castable alloys, and also addresses other foundry relevant manufacturing process like core blowing & heat treatment.

**QuikCAST** solvers, **fast and efficient** solutions to address the basic of any casting process - filling, solidification, porosity prediction - are available in the ProCAST environment. **Optimization Solvers & Die Design Tools** complete the ProCAST suite and are all offered under one single graphical user interface, Visual-Environment, aided by standard & intuitive workflows.

**ESI's Casting Simulation Suite has proven to be an indispensable tool for foundries to validate decisions during prototyping, improve yield, and reduce manufacturing cost.**



## Modeling Casting Defects

- **Solidification**
  - Piping
  - Shrinkage Porosity & Hot Spots
  - Gas & Microporosity
  - Burn-on/ Penetration
- **Filling**
  - Misruns & ColdShuts
  - Air Entrapment
  - Oxides & Air Entrapment
  - Surface Defects
  - Inclusions & Core Gases
- **Stress**
  - Hot Tears & Cold Cracks
  - Surface Cracks
  - Residual Stresses & Distortion
  - Die Fatigue
- **Metallurgy & Specifications**
  - Stray Grain
  - Freckle
  - Segregation
  - Mechanical Properties
  - Dimensional Tolerances

## Modeling Casting Processes

- **Gravity Casting**
  - Sand / Permanent Mold / Tilt Pouring
- **Investment & Shell Casting**
- **Low & High Pressure Die Casting**

## Additional Processes

- **Continuous Casting**
- **Centrifugal Casting**
- **Lost Foam & Semi-Solid Modeling**
- **Core Blowing & Gassing**

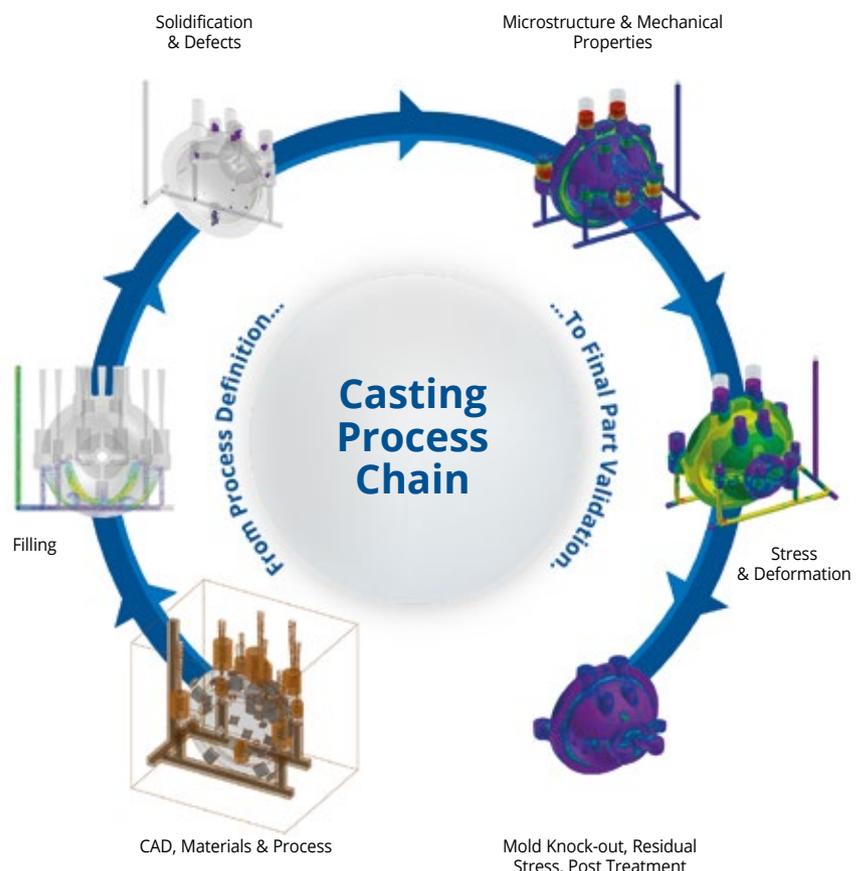
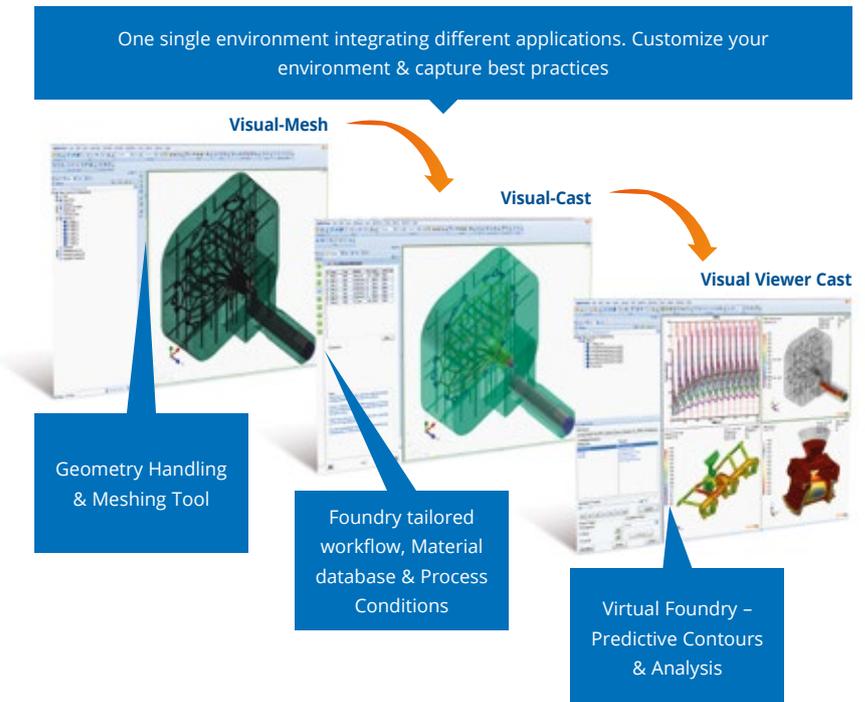
# Visual-Environment: A Streamlined and Productive Interface

ESI's Casting Simulation Suite, ProCAST, is fully integrated with ESI's open collaborative engineering environment, Visual-Environment, allowing for interoperability and chaining between casting software and other simulation disciplines. Within Visual-Environment you can find Visual-Mesh, Visual-CAST, Visual-Viewer and Visual-Process.

**Visual-Mesh** comes with a CAD reader and specific tools to facilitate the link between CAD environment and meshing operations.

**Visual-CAST** provides foundry tailored wizards and data checks which guide users to set-up their casting process. An extensive material database is available with standard and commonly used alloys, dies, chills, sand molds & cores, ceramics, filters, insulation & exothermic sleeves. In addition, it also features a **unique thermodynamic material database calculator** which allows the user to directly enter the chemical composition of the alloy and automatically predict temperature-dependent properties required to accurately simulate the casting process.

**Visual-Viewer** is a complete, productive and innovative post-processing environment for foundry applications with a state-of-the-art plotting and animation control solution. It enables you to boost the productivity of your foundry engineers by performing automated tasks and generating customized reports within a multi page/window environment.



# From Quick Model Set up...

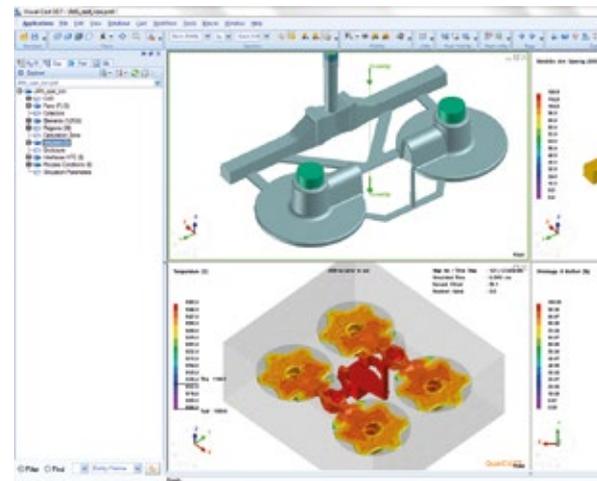
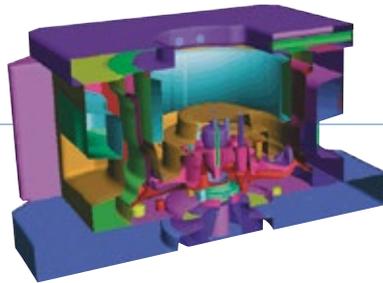
Originally created in 1985 by foundry professionals from Aluminum Pechiney, ESI's QuikCAST is today fully integrated into ESI's ProCAST and available in the Visual-Environment. ESI's QuikCAST meets industrial needs delivering rapid and realistic predictions, allowing foundrymen the ability to simulate the entire casting process from filling to solidification, including defects prediction.

Air back pressure, filters, mold roughness, thermal exchanges, die coatings and gravity are accounted for to accurately simulate most casting processes ranging from sand to gravity, high and low pressure die casting, for all kinds of castable alloys. Its validated technology is based on powerful solvers with efficient self-correction features which result in comprehensive, realistic results without mesh dependence. ESI's QuikCAST has proven to be an indispensable tool in the foundry.

It is also used at an early stage for mold and process development for cast part quality assessment, and has become a staple in foundries today.

## Fast Automatic Volume Block-Structured Mesh Generation

All separate mold components (molds, core, sleeves, pouring cups, chills) are easily assembled in QuikCAST. An automatic volume mesh generator is provided to generate the block-structured mesh used for mold filling and solidification in just a few minutes.



Simple and straightforward workflow from pre to post-processing, all integrated Visual-Environment.

## Easy Process Definition and Databases

**Visual-CAST** provides an intuitive interface for users to set-up their casting process. Hydraulic, thermal and contact conditions are defined on surfaces or volumes.

A model can be completely remeshed without losing the model set-up. Properties and parameters can be retrieved from extensive databases describing:

- Alloys (aluminum, steel, cast iron, magnesium,...)
- Mold materials (sand, cores, tool steel,...)
- Air vents
- Die coatings

## Benefits:

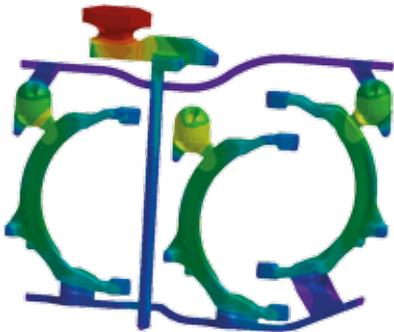
QuikCAST offers a complete industrial solution and delivers realistic predictions at each step of the casting process.

Visual-CAST offers an easy-to-use, fast and efficient simulation solution enabling you to:

- Study production feasibility and optimize the casting process
- Shorten lead time for mold development
- Reduce trial and error
- Improve part quality and yield
- Investigate new materials and processes
- Access to ProCAST advanced solvers

# ...to Fast Process Evaluation

Model all of your shape casting processes with ESI's QuikCAST using the Visual-Environment



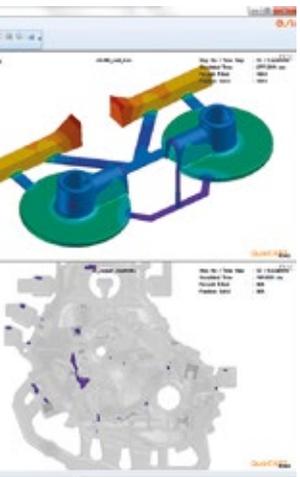
Casting of a cast iron part on a vertical molding machine

## Gravity Casting

Most gravity casting processes, including sand mold, permanent mold and tilt pouring, can be quickly modeled with ESI's QuikCAST.

Exothermic sleeves, chills and filters (porous or extruded foam filters) are easily and automatically set up according to the process parameters. The embedded thermodynamic database in Visual-CAST offers graphite precipitation, thereby accurately predicting the shrinkage porosity, taking into account the expansion of cast irons.

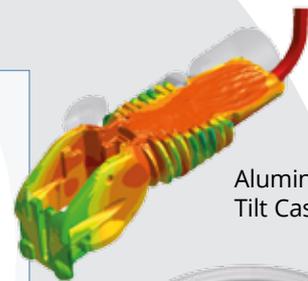
Misrun, Gate balancing, Thermal Modulus and Hot Spots results can be visualized to validate the size and the position of the risers.



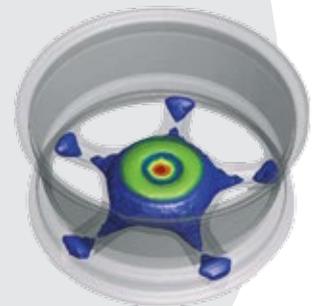
## Low Pressure Die Casting

ESI's QuikCAST has a complete set of dedicated tools to model the low pressure die casting process.

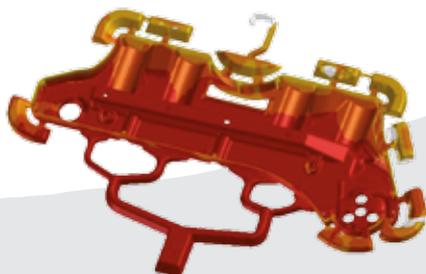
During solidification simulation, the evolution of the solid fraction is calculated and used to predict shrinkage locations. Air back pressure calculations together with appropriate user-defined pressure conditions allow the simulation of vacuum casting processes.



Aluminium Tilt Casting



Low-Pressure Die Casting



Aluminium High-Pressure Die Casting

## High Pressure Die Casting

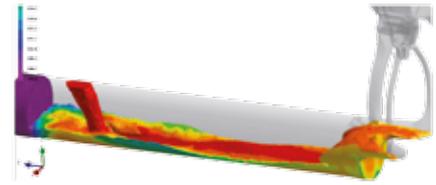
ESI's QuikCAST allows you to perfectly simulate the piston displacement during the first phase injection as well as its influence on porosities during the third phase.

Visual-CAST allows the definition of the mold cycling sequence, cooling and heating devices through specific menus of the user interface, allowing faster pre-processing times. Advanced post-processing features, like particle tracing, are available to facilitate visualizing the metal flow.

# ProCAST: Designed By Foundry Experts ...

## Low & High-Pressure Die Casting

Allows for the reproduction of shop floor conditions by performing several production cycles to obtain steady state die temperatures and thereby study filling, solidification, intensification pressure effect, cooling channel design & process parameters optimization. Vacuum process, gas porosity - due to undissolved hydrogen, stresses in casting, stress release on die removal & part ejection and die life can all be predicted in order to reduce manufacturing costs and assess in-service part performance. Specific needs including squeeze, semi-solid materials, shot sleeve modeling for cold chamber, goose neck modeling for hot chamber machines and riser tube modeling in low pressure die castings can be achieved.



3D Shot Sleeve Modeling with Filling Issue



Aluminium High Pressure Die Casting



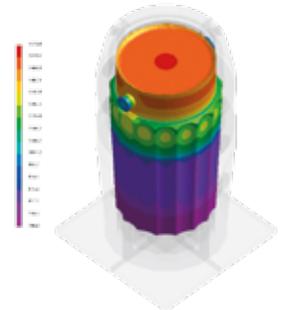
Low Pressure Die Casting of an Alloy Wheel

## Gravity Die Casting and Tilt Pouring

Use ESI's ProCAST to simulate gravity die casting including tilt pouring processes. You can freely define the axis and velocity of rotation.

## Investment Casting & Shell Molding

ProCAST is able to automatically generate a mesh representing the shell mold suitable for Investment Castings & Shell Molding processes. Furthermore, it has dedicated features to address the specific needs of investment casting foundries like allowing for non-uniform shell thickness to be blended and multiple shell layers to be created. Also, radiation with view factors, including shadowing effects, which are critical for high temperature alloys, are taken into account.



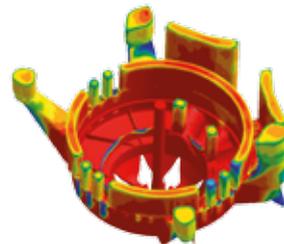
Large Steel Ingot Casting

## Sand Casting

The key to success in a Sand Casting foundry is the optimization of the gating system and eliminating the risk of shrinkage porosity. ESI's ProCAST allows comprehensive modeling of **any sand casting process**, including the high pressure molding lines, and allows users to study effects of feeder locations, filters, chills, insulation & exothermic sleeves on the casting process and quality. Different aspects, including filling, solidification & residual stresses can also be studied.

The standard porosity model of ProCAST also accounts for the effect of expansion of cast iron during solidification and mold rigidity which allows or restricts this expansion. A more comprehensive approach consists of running coupled, thermal microstructure and porosity calculations, including inoculation. The microstructure solver computes the evolution of different phases and predicts local density variations which provide more realistic porosity results. Specific microstructure models exist for different **cast irons**: GI, SGI, CGI and Ni-Resist.

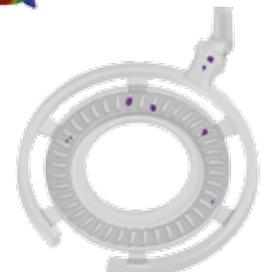
Tilt Pouring



Aluminium Gravity Casting



NGV Blade with Realistic Shell Modelling

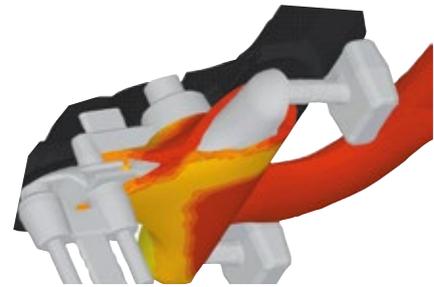


Shrinkage Porosity in a Cast Iron Brake Disc

# ... to Solve Foundry Problems

## Cold Shuts and Misruns

Some critical processing conditions such as cold mold, slow filling, and low casting temperature can lead to problems during filling. The fully coupled thermal and flow computation enables the designer to assess the temperature drop of the melt during mold filling. Premature solidification adversely influences flow behavior: by capturing these phenomena, ESI's ProCAST also predicts when and where incomplete filling or cold shuts may occur. The necessary design changes can be tested and validated, at very low cost, directly on the computer.



Metal Front Progression around a core

## Piping, Shrinkage & Gas Porosity and Hot Spots

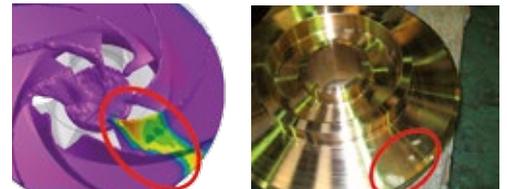
Piping & Shrinkage porosity are readily addressed by the standard solver; Hot Spots & Niyama are additional results provided by this standard solver. ProCAST provides a dedicated module to model gas porosity by accurately computing interdendritic shrinkage and accounting for gas content.



Shrinkage Porosity Prediction

## Air Entrapment, Air Entrainment, Inclusions, Oxides and Core Gases

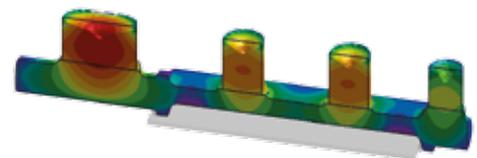
Air bubbles, or oxide layers, trapped in areas where fluid flow is restricted may locally weaken the component in service. Turbulence during filling may lead to inclusions. These defects can be precisely analyzed in ProCAST which helps designers optimize their gating system and better position the vents & flow offs.



Surface Defect Prediction

## Material Age, Flow Length, Colored Flow and Thermal Modulus

Molten metal is tracked throughout the filling. ProCAST provides useful qualitative criteria like age, length and colored flow to help design & balance the running system, like in the case of multiple ingates. Thermal modulus is a useful output to redesign the feeding system.



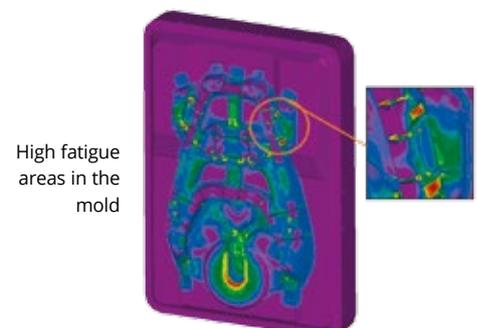
Thermal Modulus showing the feeding pattern in a Steel casting

## Burn-On/Penetration

Very high temperatures in the Mold could lead to burn-on / penetration defects.

## Die Lifetime, Hot Tearing and Cracks

ProCAST allows a unique coupling between thermal, flow and stress calculations. The full analysis is performed simultaneously on the same mesh. With ProCAST you can investigate the thermal shock on the tooling during mold filling as well as the influence of gap formation between the casting and the mold during solidification. Hot tears, plastic deformations, residual stresses and distortions are some of the issues which are being tested by our customers.



High fatigue areas in the mold

# Advanced Analysis

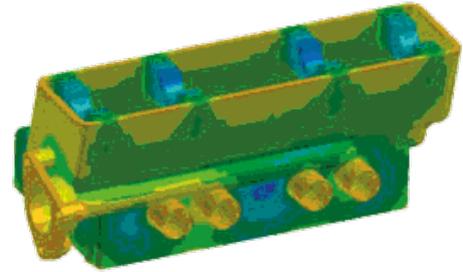
## Microstructure and Heat Treatment

Microstructure formation is an important phenomenon affecting the end properties of an 'as cast' component. ProCAST allows for the calculation of the types of phases present - the volume fraction of the phases, the grain size, and grain shape - which all determine the mechanical properties.

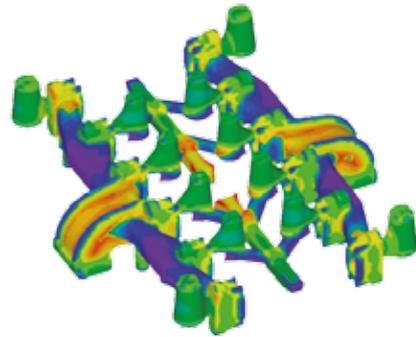
The solid state phase transformation and the resulting mechanical properties during heat treatment can also be simulated with ProCAST using models based on Time-Temperature-Transformation (TTT) or Continuous Cooling-Transformation (CCT) diagrams.

The microstructure solver also calculates the macro-segregation based upon the composition of the alloy.

Originally developed by Rio Tinto Alcan, a heat treatment advisor calculates the mechanical properties (YTS, UTS, E% and HB) throughout the entire range - from T4 through T6 and T7 - based on Mg variation and aging parameters for the most commonly poured aluminum A356/357.



Elongation (Al) after T6 Treatment

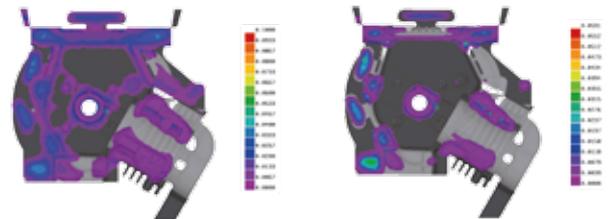


As Cast Elongation (Cast Iron)

## Advanced Porosity Modeling

Developed in collaboration with: Assan, Doncasters, Elkem, EPFL, Hydro Aluminium, Pechiney, Rolls-Royce, Sintef, Snecma and VAW.

Most simulation solutions restrict porosity predictions to shrinkage porosity. ProCAST is the first commercial software that implements a physics-based approach for the modeling of shrinkage and gas porosity. It includes a gas segregation model along with the proper treatment of solubility limit and pore nucleation.



No pressure intensification

Application of pressure intensification

Reduction in Shrinkage & Gas porosity due to the effect of the third phase piston intensification can be identified with the simulation.

## Grain Structure Modeling

Developed in collaboration with: ABB, AETC, EPFL, Howmet, PCC, Rolls-Royce and Snecma.

Grain structure of 'as cast' components are important for controlling casting conditions and optimizing component performance. ProCAST computes grain structure, including columnar to equiaxed transitions, for any dendritic alloy. It allows controlled solidification conditions to generate single crystal or directionally solidified grain structure. ProCAST couples a Cellular Automaton (CA) model with the Finite Element (FE) heat flow computations. For this reason, the grain structure module of ProCAST is often referred to as the CAFE module by industry experts.



Prediction of stray crystals in SX part



Grain Structure in Continuous Casting

# What does Optimization Mean for Casting?

Automatically derive the best design and/or process conditions to reach optimal manufacturing conditions and product quality

ProCAST solvers are linked with the ESI's Optimization solvers in order to run an automated trial and error approach. The computer performs the best chosen trials and makes decisions to improve process conditions and/or materials properties. This is all based on user-defined goals. Visual-Environment provides a set of guided work flows so that users can set-up these computer trials with ease. Several types of calculations can be set to drive the manufacturing decisions, such as Design of Experiment, Optimization, Process Robustness and Inverse Modeling.

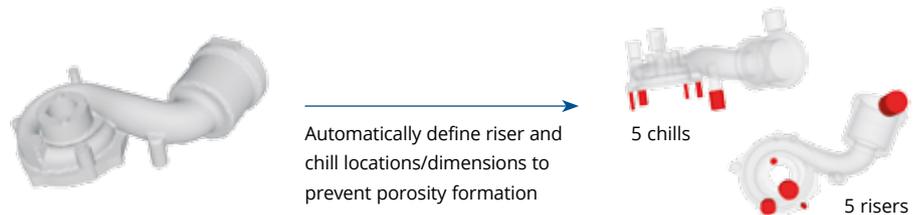
## Design of Experiment

Design of Experiment allows users to identify the sensitivity of the most influential process variables (e.g. *increasing the shell temperature vs. adding insulation wrap*). It also allows users an opportunity to compare these influential variables to the economical (e.g. *energy costs for maintaining higher melt temperatures could be more than production losses*) and manufacturable aspects (e.g. *creating a specific tool for feeding could be difficult*) during production. This output could also be used to determine the optimization goals, in-line with the known production constraints of a foundry.

## Design Optimization

Automatically find the best design for:

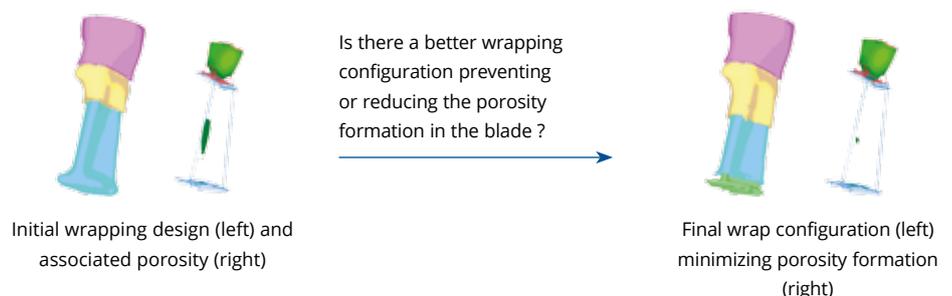
- Riser locations & dimensions
- Chill locations
- Ingate positions
- Runner dimensions



## Process Optimization

Automatically find the best process variables such as:

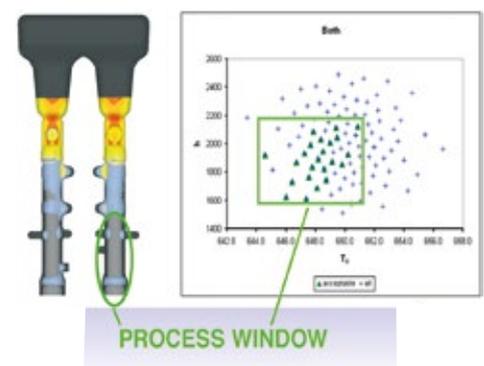
- Pouring temperature
- Pouring rate
- Die temperature



For user-defined objectives like minimizing porosity, improving die-life, minimizing oxides, avoiding air entrapment in the shot chamber, etc.

## Process Robustness

Allows Foundrymen the possibility of evaluating the robustness of one's process against the natural variation that occurs on the shop floor. (e.g. Metal pouring temperature). This application will automatically run a set of calculations accounting for this natural variation and provide the user with a process window, showing the maximum and minimum variations allowed in the process while still obtaining the desired results



## Inverse Module

The Inverse Modelling enables the automatic calculation of material properties or boundary conditions (e.g. interface heat transfer coefficient) based on experimentally measured temperatures at given locations or times.

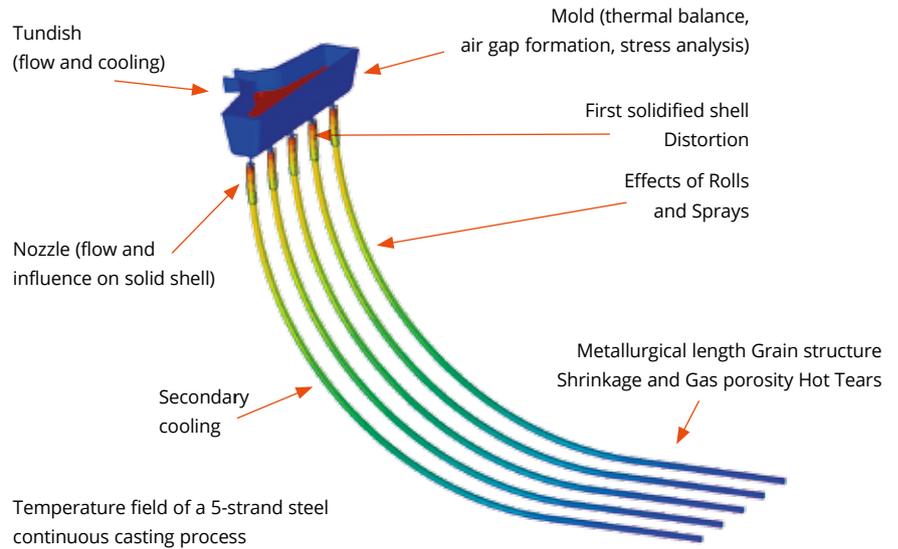
Above: Models an acceptable process window to achieve the desired part quality (based on porosity prediction)

- The average porosity is less or equal to the value obtained under the reference conditions
- The maximum local porosity is less or equal to the value obtained under the reference conditions

# Additional Processes

## Continuous Casting

ProCAST provides a complete solution for continuous and semi-continuous casting process, including Direct Chill (DC) casting simulation. The software can simulate steady-state conditions as well as the initial and final stages of continuous casting processes. MiLe algorithm is also available to study through the continuous casting process. ProCAST also offers a unique capability: the user functions which allow more advanced end users to program their specific process requirements. For example, user functions allow you to define boundary conditions as time, temperature and space-dependent in order to accurately model any specific casting process.

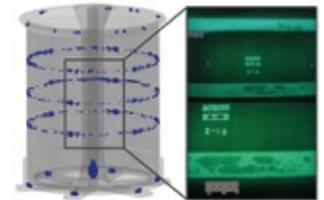


## Centrifugal Casting

Centrifugal & Corioli's force are accounted for in ProCAST to model vertical centrifugal castings, including the effect of these forces on porosity prediction.



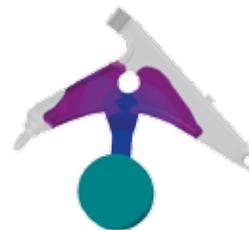
An engine casing cast using centrifugal process



Porosity validation on a cylindrical centrifugal casting

## Lost Foam

ProCAST includes all of the required features to take into account the effects of liquid metal and foam interaction during a lost foam casting process.



Semi-Solid Modeling



Lost Foam Process

## Semi-Solid Modeling

ProCAST is equipped with different models to address the various physics of Semi-solid modeling.

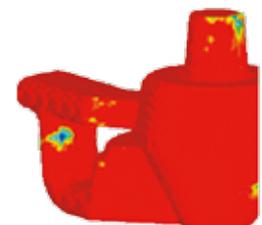
## Core Blowing

Developed in collaboration with: Ashland, CTI, CTIF, IMFT, Infun, Laempe, Teksid and Weir Foundries

The Core Blowing module predicts blowing and gassing defects including incomplete fills, low compaction and poorly hardened areas.



Unfilled or poorly compacted areas



# Selected Customer Testimonials

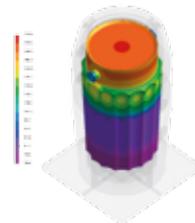
"The objective of DSB EURO s.r.o. is to satisfy the requirements of our customers regarding the quality of our products at the highest level. ProCAST helps us not only enhance the quality of our castings but also ensure a better competitiveness. Using ProCAST enables us to deliver castings on time and to cut down unnecessary and repeated rework operations.

Finally, thanks to ProCAST we received the "European Quality Award" in 2008 which opened us opportunities for new cooperation."

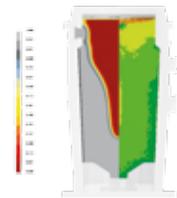
**Ing. Pavel Veselý, Production Director, DSB EURO s.r.o.**



Final design after 5 iterations showing no more hot spot in the part.



Temperature (°C)

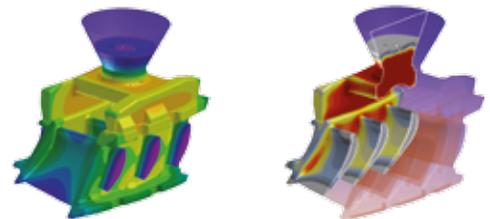


Fraction of Solid on the left and Shrinkage Porosity on the right

"Using ProCAST software, Sheffield Forgemasters International (SFIL), was able to analyse several virtual scenarios before delivering a "right first time" ingot casting. After forging it to produce the final roll shape and NDT testing, it was evident that this was the highest integrity ingot ever produced at SFIL."

**Jesus Talamantes-Silva, R & D Manager, Vulcan SFM**

"When you have the right tool in your hands, you can easily get quick and optimal solutions arising from extremely complex problems in superalloy foundry. ESI Software does have the potential to do this."



Temperature contours and fraction of solid

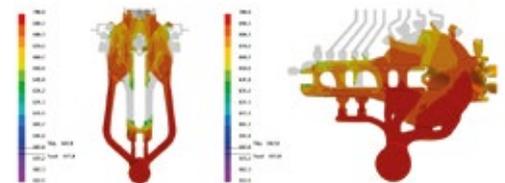
**Ciro Caramiello, PhD - Process Modelling, EMA Rolls Royce**

"If time and cost weren't constraints, we could solve many issues without simulation. Thanks to ESI's QuikCAST casting simulation software, we can test and improve our designs, while building our internal expertise relative to various scenarios unseen before."

**Tu, Chin-Huang, General Manager, Zheng Yang Mould Manufactory**

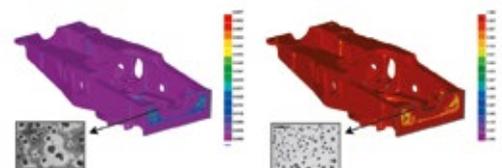
"ProCAST recent developments prove to be excellent for predicting the microstructure and the basic mechanical properties of casting materials. In addition ProCAST solves one of the main complex phenomenon in cast iron solidification i.e. graphite expansion.

Using the microstructure module, the simulation of local graphite expansion is possible with a sensitively higher accuracy for shrinkage defects prediction. The microstructure module opens a new line of possibilities and makes other types of analysis possible, particularly related to the adjustment of the metallurgical quality level using the inoculation parameters in simulation."



Initial Design showing unbalanced filling

Final Design showing improved flow characteristics, leading to high surface quality



Good co-relation between simulation and production

Pearlite Fraction

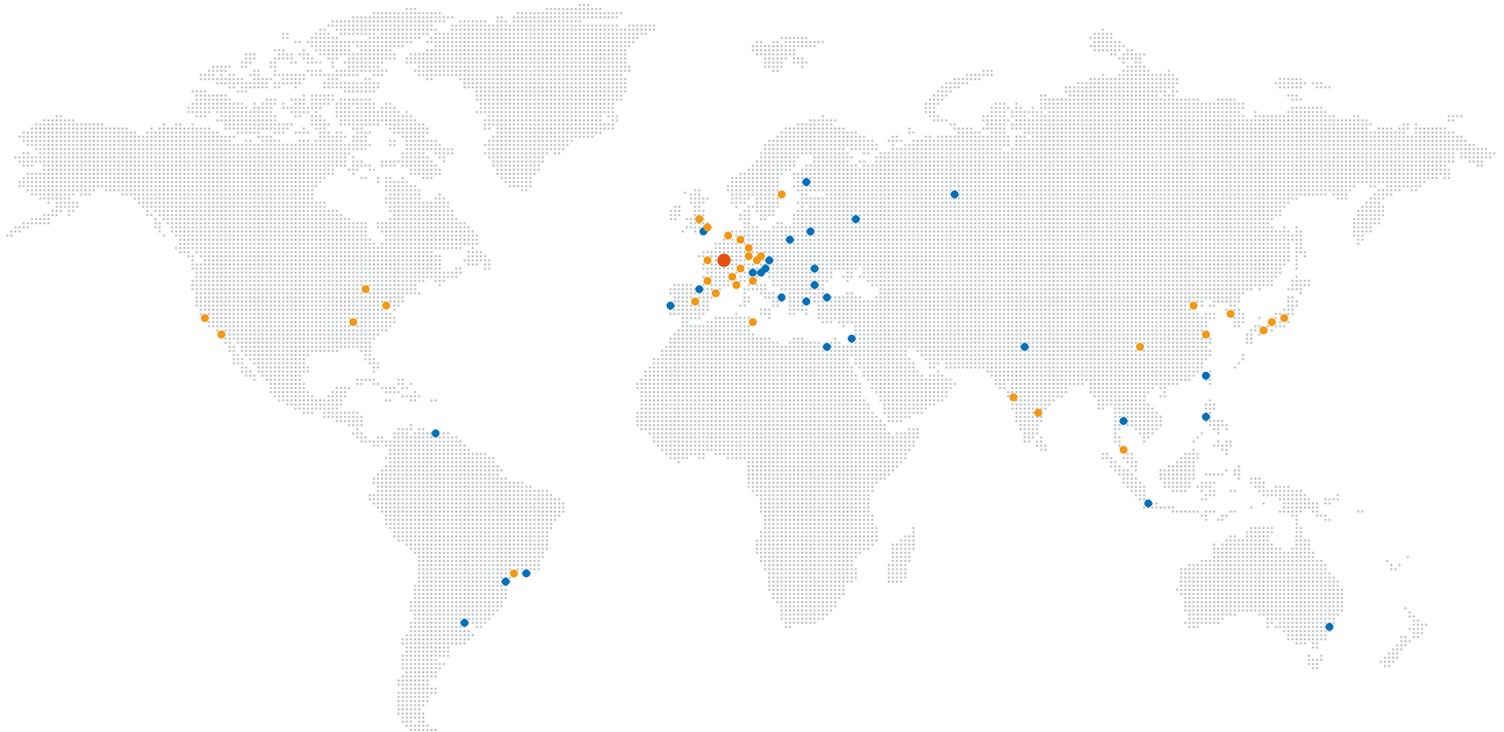
Ferrite Fraction

**Dr. Antton Meléndez Arranz, Foundry Project Manager, Inasmet - Tecnalía**



Customer Portal  
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## ABOUT ESI GROUP

ESI is a world-leading provider of Virtual Prototyping software and services with a strong foundation in the physics of materials and Virtual Manufacturing.

Founded over 40 years ago, ESI has developed a unique proficiency in helping industrial manufacturers replace physical prototypes by virtually replicating the fabrication, assembly and testing of products in different environments. Virtual Prototyping enables ESI's clients to evaluate the performance of their product and the consequences of its manufacturing history, under normal or accidental conditions. By benefiting from this information early in the process, enterprises know whether a product can be built, and whether it will meet its performance and certification objectives, before any physical prototype is built. To enable customer innovation, ESI's solutions integrate the latest technologies in high performance computing and immersive Virtual Reality, allowing companies to bring products to life before they even exist.

Today, ESI's customer base spans nearly every industry sector. The company employs about 1000 high-level specialists worldwide to address the needs of customers in more than 40 countries. For further information, visit [www.esi-group.com](http://www.esi-group.com).