# Inasmet-Tecnalia standardizes the quality of large-size cast iron castings with ProCAST

## THE CHALLENGE

Meet the customer's quality standard by accurately predicting and optimizing microstructure, mechanical properties and porosity formation in large cast iron wind power turbine castings.

## THE STORY

Cast iron are important industrial materials offering to the design engineer unique combinations of high strength, wear resistance, ductility and toughness. Cast iron can exhibit a wide range of properties obtained through the microstructure control. Therefore, in order to better understand the shrinkage behavior of cast iron during solidification, ESI has developed a micromodel to simulate the formation of the microstructure. The change in density during solidification and the resulting mechanical properties at ambient temperature can now be calculated based on the microstructure.

## THE BENEFITS

Foundry:

- Suppression/reduction of physical trials
- Reduction of recovering and rejecting causes
- Enhanced understanding of process capability
- Casting/process optimization
- Better fit with customer requirements

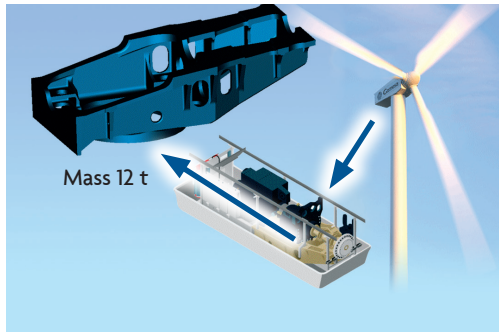
Customer:

- Effective and early design for manufacturing

## INASMET-TECNALIA

Inasmet is a research center located in Donostia, San Sebastián, Spain. Inasmet is a specific business unit of Tecnalia Corporation (1.300 people, 7 centers and E100M turnover) specialised in casting, area in which it has been working for over 45 years.

Shrinkage porosity is the most common solidification defect. Shrinkage happens in almost all metal alloys as they contract when cooling from the pouring temperature to the solidus.




Frame of a wind turbine generator in cast iron

Cast iron alloys solidification presents a more complex behavior, since the dissolved carbon partly precipitates as graphite with a lower density than the base iron. Graphite formation is thus associated with a volume increase. This expansion can compensate under certain circumstances the contraction of the metal to reduce or even avoid shrinkage. Therefore, the generation of shrinkage cavities in cast irons is closely related to the local density change during solidification. The expansion and shrinkage behavior is affected by alloy composition, cooling rate and other process conditions leading to the microstructure.

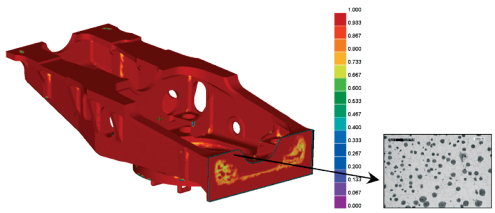
Today, advanced simulation can be used to understand and control such a complex behavior. In ProCAST, ESI has developed a comprehensive micromodel which can provide accurate microstructural information as well as mechanical properties, such as yield strength, tensile strength, elongation and hardness. The micromodel together with an extensive thermodynamic database have been coupled with the porosity model, resulting in an accurate shrinkage prediction by taking into account the complex phenomenon of graphite expansion.

## MICROSTRUCTURE AND MECHANICAL PROPERTIES

Microstructure formation during the solidification of alloys is a very important factor for the control of the properties and quality of casting products. To obtain microstructure predictions, ProCAST couples thermodynamic calculations (from CompuTherm® databases) with micromodels and macro-scale thermal and fluid flow calculations.

Inasmet-Tecnalia has applied this methodology to a 12T wind turbine frame in high tenacity ductile iron EN GJS 400 18LT. The presence of magnesium in the composition causes nodular graphite precipitation during solidification.

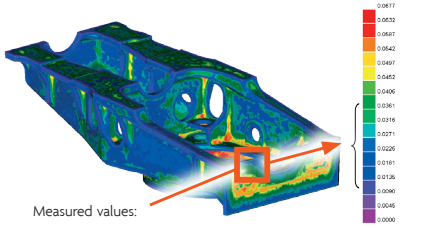
Pouring temperature is 1360-1370°C for a filling time of about 80 seconds. The mould is made of high resistance resin bound silica sand.



Fraction of ferrite

GOOD CORRELATION
BETWEEN SIMULATION AND REAL PART

Proportion of ferrite and pearlite as well as nodule count provide insight into the mechanical state of the as-cast part. Simulation results are compared with reality.




Graphite nodule radius

GOOD CORRELATION BETWEEN SIMULATION AND REAL PART

Inasmet-Tecnalia then used microstructure calculations can then be used to predict the final mechanical properties. In cast iron, the type, amount and morphology of the eutectic will determine the effective mechanical properties. The structure of the matrix is essentially determined by the cooling rate through the eutectoid temperature range. Slow cooling rates promote the transformation of ferrite, thus lower tensile strength as shown in this case study.

| | Ferritic | | Perlitic | |
|---|---|---|---|---|
| | *Measured* | *ProCAST* | *Measured* | *ProCAST* |
| Yield Strength (Mpa) | 230 | 215 | 267 | 275 |
| Ultimate Strength (Mpa) | 360 | 325 | 420 | 450 |
| Elongation (%) | 20 | 16 | 9 | 11 |

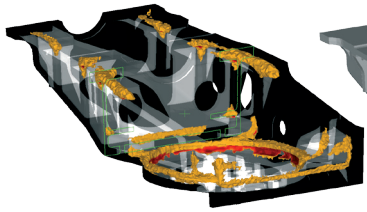
Comparison of mechanical properties prediction between ProCAST and measurements.

## POROSITY PREDICTION

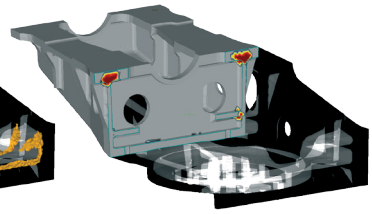
The final integrity of a casting, including mechanical properties and surface finish, is greatly influenced by the presence of porosity.

As explained earlier, graphite expansion exhibited by cast iron is not trivial to understand and subsequently very difficult to model. Indeed, it is required to consider microstructure, process conditions, material properties, inoculation, fading, density variation and mechanical properties of the mould to accurately predict shrinkage porosity in cast iron.

A good control over the metallurgical quality and the graphite expansion means no shrinkage, both in simulation and real part despite the presence of important isolated pocket of liquid as shown on the pictures below.

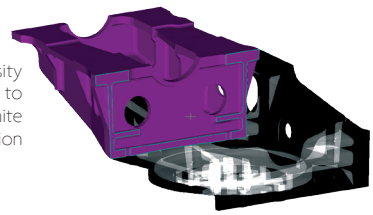


Isolated pocket of liquid in X-ray view



Sliced view of the hot spots

Sliced view of shrinkage porosity showing soundness casting due to accurate modeling of the graphite expansion



Inasmet-Tecnalia compared the predictions of microstructure mechanical and porosity with experimental results and found these to be in good agreement.

*"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."*

Dr. Antton Meléndez Arranz, Metallurgist Inasmet - Tecnalia

## ABOUT ESI GROUP

ESI is a pioneer and world-leading provider in virtual prototyping that take into account the physics of materials. ESI has developed an extensive suite of coherent, industry-oriented applications to realistically simulate a product's behavior during testing, to fine-tune manufacturing processes in accordance with desired product performance, and to evaluate the environment's impact on performance. ESI's solutions fit into a single collaborative and open environment for End-to-End Virtual Prototyping, thus eliminating the need for physical prototypes during product development. The company employs over 750 high-level specialists worldwide covering more than 30 countries. ESI Group is listed in compartment C of NYSE Euronext Paris. For further information, visit www.esi-group.com.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