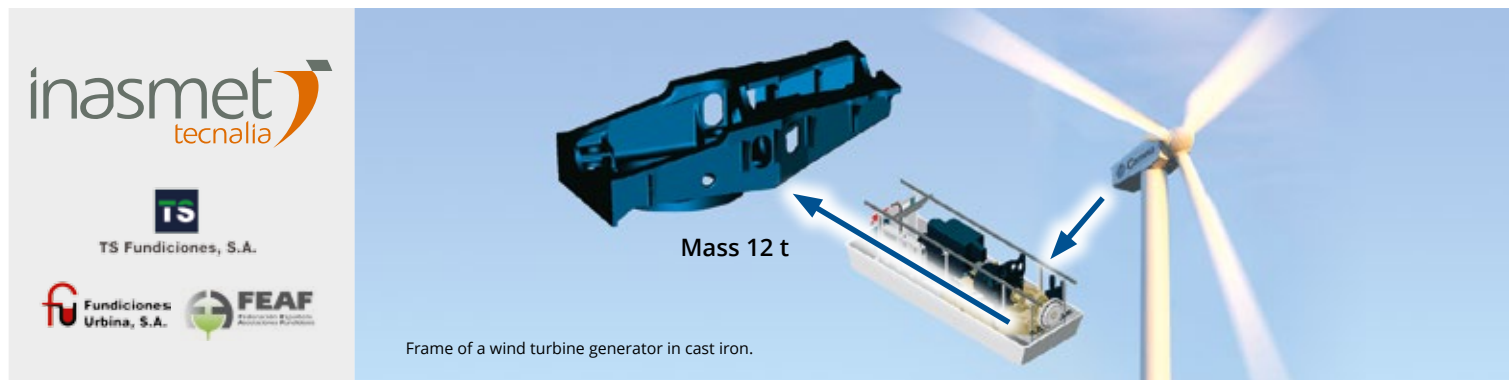


# Inasmet-Tecnalia standardizes the quality of large-size cast iron castings with ProCAST



## 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.

## 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

*"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

## Background

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 micro-model 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.

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.

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.



Inasmtec-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.

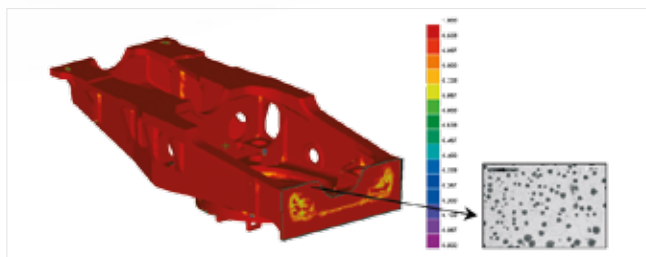


FIG 1: GOOD CORRELATION BETWEEN SIMULATION AND REAL PART.

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.

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.

Inasmtec-Tecnalia then used microstructure calculations can then be used

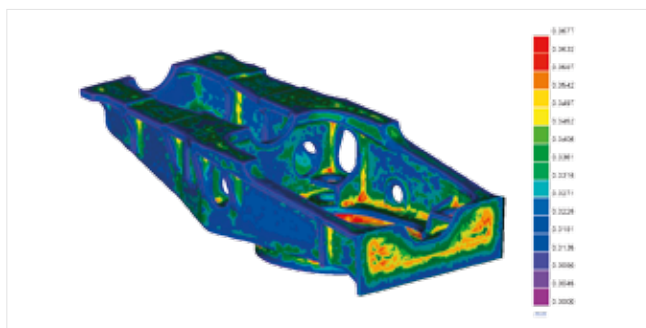


FIG 2: GOOD CORRELATION BETWEEN SIMULATION AND REAL PART.

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.

## Porosity prediction

	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.

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



Fig 3: Isolated pocket of liquid in X-ray view.

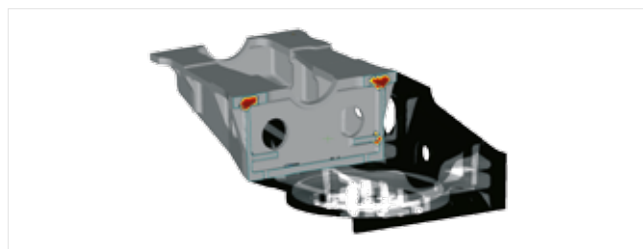


Fig 4: Sliced view of the hot spots.

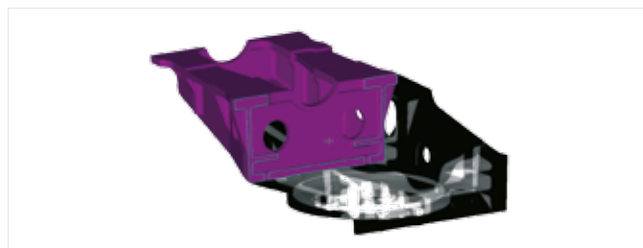


Fig 5: Sliced view of shrinkage porosity showing soundness casting due to accurate modeling of the graphite expansion.

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.

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



## About INASMET-TECNALIA

Inasmtec is a research center located in Donostia, San Sebastián, Spain. Inasmtec 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.

## About ESI GROUP

ESI is a pioneer and world-leading provider in Virtual Prototyping that takes into account the physics of materials.

ESI boasts a unique know-how in Virtual Product Engineering, based on an integrated suite of coherent, industry-oriented applications. Addressing manufacturing industries, Virtual Product Engineering aims to replace physical prototypes by realistically simulating a product's behavior during testing, to fine-tune fabrication and assembly processes in accordance with desired product performance, and to evaluate the impact of product use under normal or accidental conditions.

ESI's solutions fit into a single collaborative and open environment for End-to-End Virtual Prototyping. These solutions are delivered using the latest technologies, including immersive Virtual Reality, to bring products to life in 3D; helping customers make the right decisions throughout product development. The company employs about 1000 high-level specialists worldwide covering more than 40 countries. ESI Group is listed in compartment C of NYSE Euronext Paris.