Inegi Uses ProCAST to Manufacture Customized Hip Prostheses in a Cost Effective Way

inegi driving innovation

THE RAPID MANUFACTURING CENTER

dt2 NEW CONCEPT

análisis y simulación

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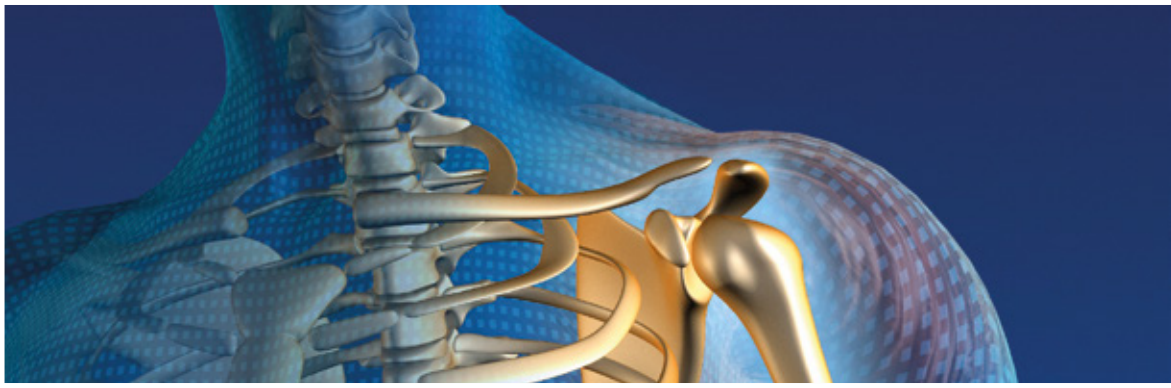

Challenge

Manufacturing of Hip Prostheses involves casting of parts that have a challenging length-to-diameter ratio. Using intricate casting processes and valuable titanium alloys the objective is to achieve very high levels of soundness so that a prosthesis will have a long life even when required to withstand over a million cyclic loads per year as it does its job within a human body.

The long and costly lead times of the conventional trial and error approach to prosthesis design had to be replaced by new methodology employing advanced casting simulation to achieve a cost effective manufacturing process.

Benefits

- Shop floor trial and error cut drastically by virtual mold assessment and by re-designing of gates, risers, and wrapping schemes.
- Foundry men now have a software tool that guides them towards optimal solutions
- Shortened time to delivery
- Significant cost savings.

"Scientific methods can always save us time and cost. ProCAST is just that tool helping foundry men find the right solutions. For investment casting process, ProCAST can generate different layers of shells and with wrapping outside. This helps predict the temperature field more precisely."

Nannan Song,
Senior Researcher
Advanced Foundry and Rapid Prototyping Technologies, Inegi

Story

A hip prosthesis (Fig.1) is a highly customized product, tailored to the exact morphology of a patient. Yet whatever the complexity in its design, it is expected to withstand an equivalent of over one million cyclic loads each year during its functional life inside a human body.

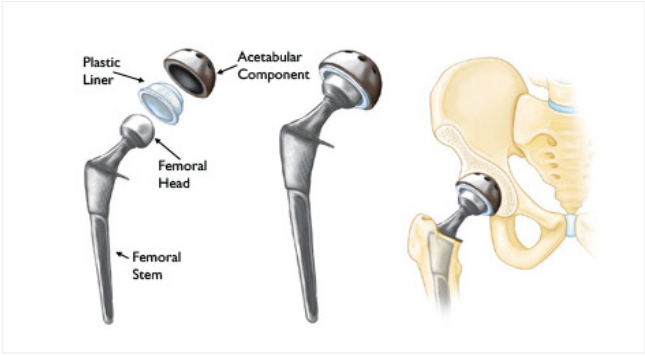

Fig. 1: Hip prosthesis. Image Courtesy: http://orthoinfo.aaos.org

Although modern medical imagery allows a very accurate design based on the patient's characteristics, manufacturing with such high specification levels is still very widely based on a trial and error methodology, which is both expensive and time-consuming.

Inegi, a non-profit organization in Portugal providing R&D support to a broad range of industries, has elected to turn to simulation to identify the most efficient process design suitable for a specific prosthesis. Their challenge has been to reduce casting defects, such as shrinkage porosity and residual stress, as these can accelerate fatigue failure and reduce the life of the prosthesis. The aim is to improve the patient's comfort and safety while reducing costs of manufacturing and replacing prostheses.

Product & Process Design

Investment casting is best adapted for products with unique features requiring exceptional precision. To manufacture a hip prosthesis, a prototyping machine must produce the prostethis model

Fig. 2: Wax pattern.

along with its carefully designed gating system. The prototyped model is then used to shape a wax pattern (Fig. 2), which in turn is the basis for the investment casting process.

A typical stem of a hip prosthesis can be anywhere from a few mm in thickness up to 2 cm, while the length could be between 10 and 15 cm. Such high length-to-diameter ratios typically create low temperature gradients during the casting solidification. This leads to centerline shrinkage along the stem section, which can reduce the product lifetime. Also, feeding of the stem is from the prosthesis head, through a neck narrower than the connected stem, which reduces the feed length. The neck & head themselves are susceptible to shrinkage porosity. Figure 3 shows shrinkage porosity validation on a cut section sample in the prosthesis head. In these conditions, the solution to avoid defects would then have to involve a mix of modified gating and process re-design. A trial and error method to eliminate undesirable porosity in the prosthesis would prove both time-consuming and costly, as several models would need to be produced, starting from the prototype stage, to achieve a suitable wax pattern.

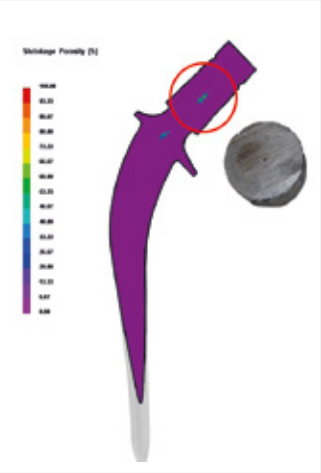

Fig.3 Shrinkage porosity observed in the cross section of hip prosthesis head predicted in ProCAST

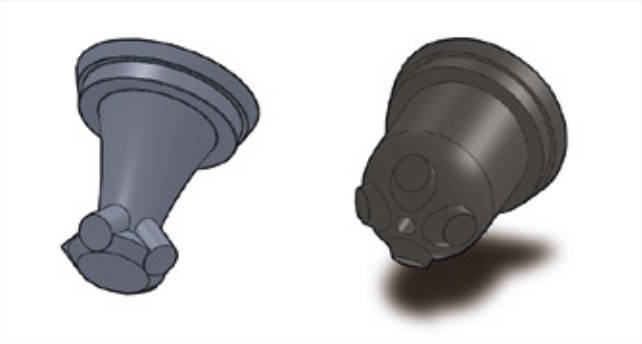

Fig.4 Original and redesigned gating system

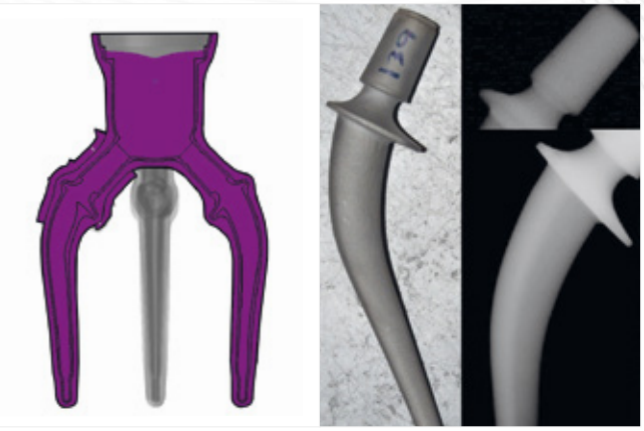

Fig. 5: The final optimized design free from shrinkage porosity as predicted in ProCAST (left), manufactured hip prosthesis (center) and x-ray validation of simulation results.

Switch to Simulation

Initially, the design and production of such hip prostheses at Inegi was achieved by conducting trial outcomes directly on the shop floor. Typically various trials were made with different casting and shell preheating temperatures, all unsuccessful. The resulting products were often unsatisfactory, exhibiting centerline shrinkage and having an undesirable surface finish.

Because of these difficulties, Inegi sought the assistance of Análisis y Simulación and ESI's ProCAST simulation software. To obtain the high temperature properties of the specific Ti6Al4V alloy used for the prostheses they used ProCAST's thermodynamic database. ProCAST also helped Inegi obtain greater insight into the best filling sequence and the consequent temperature gradients at various sections in the casting and shell.

Inegi were able to set up different groups of simulations, used to determine the best adapted gating design (Fig. 4) . Inegi created a unique wrapping configuration around the shell, managing the heat distribution to maintain the feed path to the stem region during the solidification process. Castings produced with this configuration were free from any centerline shrinkage, and can be expected to meet the high performance requirements of the hip prostheses. Their surface finish was improved by changing the face coat material of the shell. The high level of quality of the produced hip prostheses was confirmed by x-rays (Fig. 5).

Based on this success, Inegi continues using ProCAST to simulate their casting processes.

About Inegi

INEGI is an interface Institution between University and Industry, oriented to the activities of Research and Development, Innovation and Technology Transfer. It was founded in 1986, among the Department of Mechanical Engineering and Industrial Management (DEMEGI) of the Faculty of Engineering of the University of Porto. Being a non-profit private association and recognized as being of public utility, INEGI is currently considered an active agent playing a significant role in the development of the Portuguese industry, and in the transformation of its competitive model. http://www.inegi.pt/inicial.asp?LN=EN

About Análisis y Simulación

Análisis y Simulación is a Spanish engineering company devoted to the implementation and integration of IT engineering solutions: for development and innovation R&D, optimization of manufacturing processes and product data management through the entire product lifecycle. Since 2007 Analisis y Simulación is the exclusive agent for ESI Group casting solutions (ProCAST and QuikCAST) both for Spain and Portugal. Análisis y Simulación can support the end-user at different stages: advice and consultancy, software implementation and integration, maintenance, technical support, software application training and so on. http://www.analisisysimulacion.com/index.php

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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.

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