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TECNOLOGIE D'AVANGUARDIA

Europea Microfusioni Aerospaziali uses ESI Software for the Optimization of Nozzle Guide Vane Blades

THE CHALLENGE

Determine automatically the best process conditions to reach the defined part quality without having to perform numerous simulations and make decisions after each run.

OPTIMIZATION

Today, ESI's casting simulation software can be used within an automatic optimization loop. Indeed, a specific ESI software tool allows to perform a DoE (Design of Experiments) automatically after defining your objective such as minimizing porosity without going against defined constraints.

With this module, one can also perform design robustness analysis in order to control the stability of the process.

THE BENEFITS

- Save money and time
- Improve yield
- Better control the process
- Design early for manufacturing

" 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's software does have the potential to do this."

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

OVERVIEW

Europea Microfusioni Aerospaziali (EMA), located in Italy, is a world class investment casting foundry for the production of components dedicated to civil and defense aerospace, marine and energy industries. The company is qualified to produce superalloys components, using the equiaxed, directional solidification and single crystal technologies.

EMA is owned by Rolls-Royce. The company has inherited a prestigious tradition of production and research from her mother company. This know-how has guided EMA to develop and refine innovative and industrially advanced methods.

INTRODUCTION

Thanks to the development of dedicated techniques over the last two decades, investment casting modeling with ESI's software has become reliable and efficient to optimize safety components such as turbine blades for jet engines. The solution includes dedicated superalloy material databases and ceramics characterization allowing very accurate predictions.

The study presented here refers to a stator type Nozzle Guide Vane (NGV) with three airfoils including cores.

ESI's software was used to carry out a DoE (Design of Experiments) with several independent variables covering about 103 feasibility hypotheses.

This work led to the automatic run of about thirty models, in batch mode (command line programming) as shown in figure 1, where some of the variables are described.

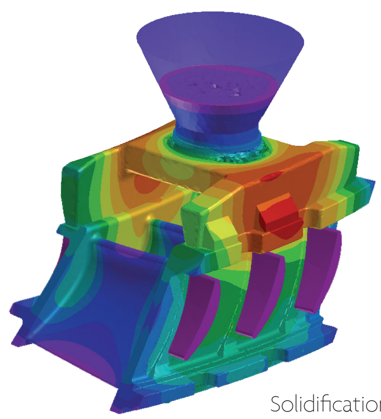

Fig.1:
Solidification Time

The parameters within the Ω operating domain are as follows:

$$\Omega = \begin{Bmatrix} T_{cast}, T_{preheating}, t_{preheating}, assembly\_geometry, \\ wrap, shell\_thickness, cast\_profile, etc... \end{Bmatrix}$$

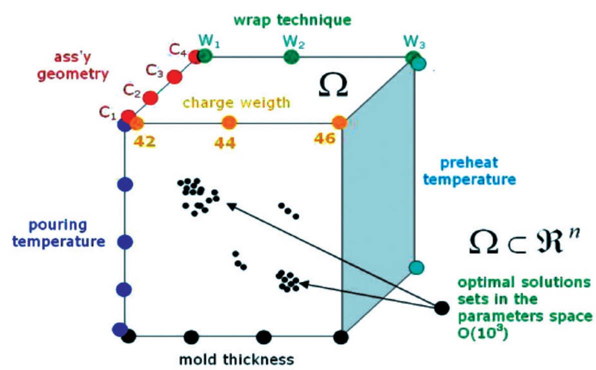

Figure 1:
Testing domain showing some parameters and their respective levels.

PREHEATING PHASE

The preheating phase includes preliminary heating of the shell before metal pouring. This stage is important as it significantly affects the final part integrity. Thus, preheating temperature and heat transfer losses are fundamental, and undergo the DoE parameter level. The former is the temperature reached by the shell at the end of the pre-heating cycle; the latter is the elapsed time from the time the shell is taken out from the pre-heating furnace to the time the pouring phase starts.

Figure 2 shows, in particular, the thermal field of the shell with a sliced view of the critical areas such as the LE (leading edge), the TE (trailing edge), and the core.

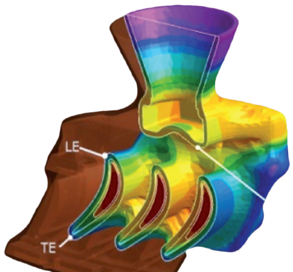

Fig. 2: Isotherms view just before the pouring starts

POURING PHASE

The pouring phase is the next important step in the investment casting process. The velocity profile, pouring angle and pouring time will influence the quality of the component (shrinkage porosity, local grain size, etc.).

Typically in a modeled DoE, it is important to take into account the thermal and fluid dynamics profiles, as well as the solid fraction and thermal flow during pouring. The filling phase is particularly important for equiaxed components (grain formation) compared with Directional Solidified (DSX) ones.

The filling phase is therefore always subject to a DoE study, at least for a couple of the above-mentioned parameters.

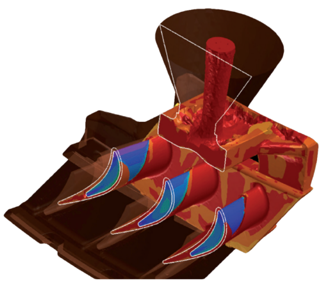

Fig. 3: Filling pattern temperature field

SOLIDIFICATION PHASE

The study of the solidification phase concludes the DoE analysis. In general, the cooling rates, the local solidification times and the shrinkage porosity prediction are analyzed. However, advanced metallurgical analysis such as grain structure or freckle prediction (SX) are also possible and will determine more directly the integrity and the specifications of the as-cast part.

CONCLUSION

The general aim of the DoE analysis is to achieve a Pareto optimality i.e. condition in which any change to a dependant variable, such as porosity, is impossible without adversely affecting the performance of another variable, such as grain structure for instance.

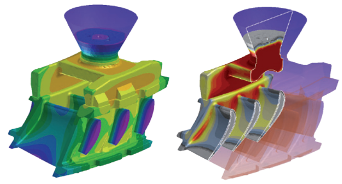

Fig 4: Temperature contours and fraction of solid

To fulfill this, the two following conditions must be met:

1) Pareto optimal solutions must be identified (e.g. maximizing performance only as regards porosity),

2) The process must be stable (design robustness).

Modeling casting processes is a very complex task in terms of testing domain: it may well be regulated by over one hundred variables. The advantage of using an optimization tool is straightforward. The tool helps find the optimal process parameters as well as evaluate the risk of possible casting rejections due to random fluctuations in the process.

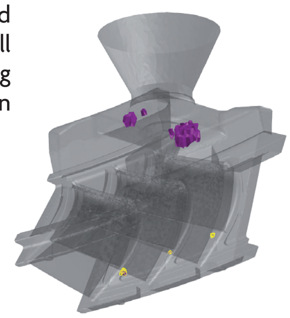

Fig 5: Final shrinkage porosity prediction resulting in a sound part as critical porosity remains in the risering system.

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