

ESI-Group Warwick Seminar

Sim-Cast Ltd

Provider of casting solutions

26th June 2007

By Dr Amarjit Mahal

- Sim-Cast are a technology company specialising in cost reduction and casting capability.
 - Helping foundries reduce costs by minimising waste
 - Helping foundries introduce new products quicker
 - Helping foundries produce more parts, faster
- Sim-Cast provide responsive, sustainable solutions via their 'Virtual foundry' to the investment casting industry
- Sim-Cast aim to develop relationships and work with their customers to maximise the potential solution benefits

Legacy Products

- Maintain and Improve quality, cost & delivery
- Minimise variation and operational disruption
- Deliver improvements for in service problems

Increased capacity

- Manufacturing capacity is starting to limit growth and delivery capability
- Driven by many factors including number of new products, reduced yields on newer materials

Higher costs

- Increased costs (energy, transport, raw materials) are driving the need to reduce manufacturing costs

People

- Becoming increasingly difficult to find resource
- Declining availability of qualified and experienced engineers

Customer satisfaction

- Reduce waiting times
- Increase flexibility to customers demands

New materials

- Higher temperature requirements lead to >Ru and increased cooling
- More efficient cooling leading to increasingly complicated core geometry.
- Newer alloys are more sensitive to process variation – Surface melting

New Products

- Increase of new design products
- Increase of improvement packages, driven by;
 - Performance
 - Cost

New technology

- Increased need for new furnaces with greater capability and capacity
- New manufacturing processes to deliver products quicker at equivalent or reduced cost

Expectations

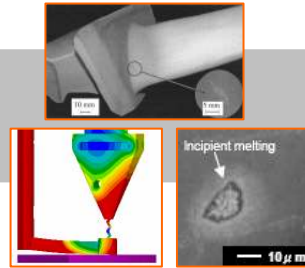
- Year on year improvement and cost reduction regardless of resources, problems and issues.

How Sim-Cast can help

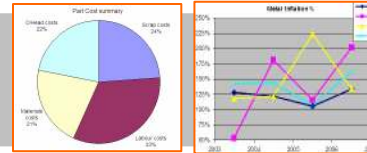
Sim-Cast



Product Solutions



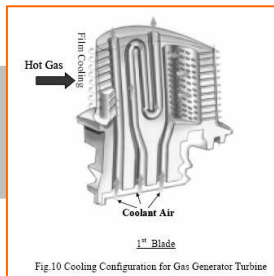
Yield improvement



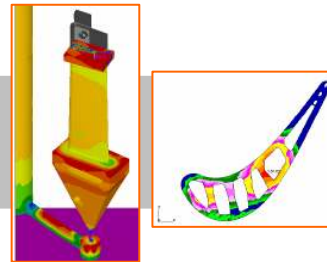
Material utilisation improvement

Product Development

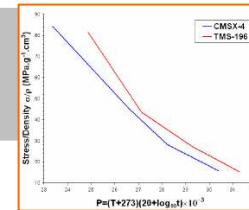
Product performance



Design studies



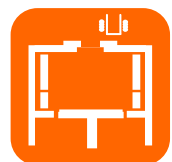
Design risk mitigation



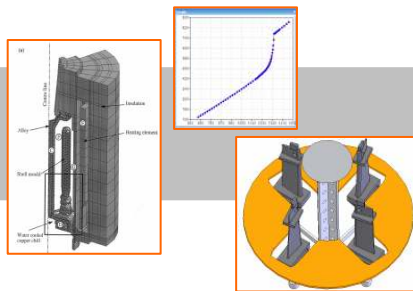
True lifing studies

DFM / MFD

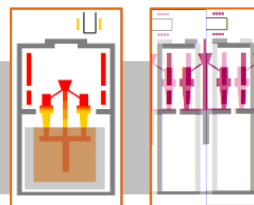
Manufacturing capability



Asset Solutions



Furnace component improvements



Furnace design capability studies



Coupled process models

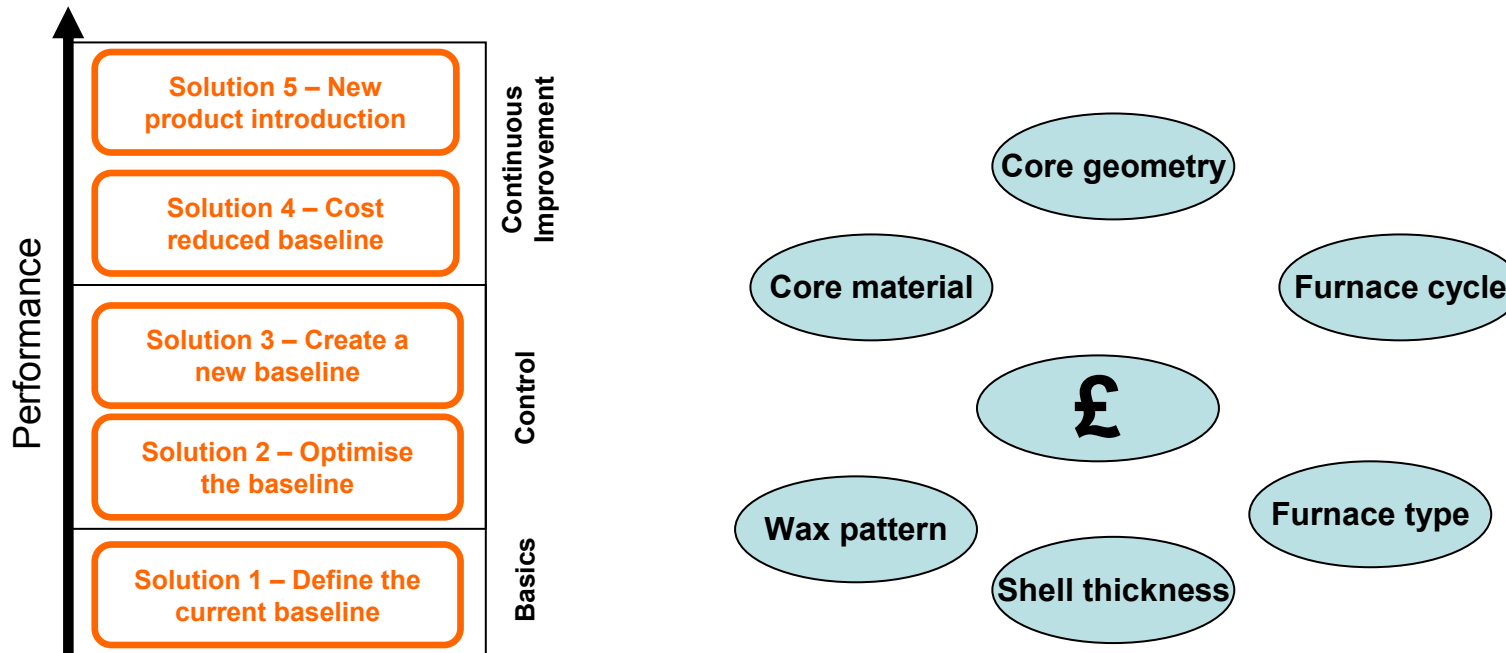
Process Improvement



Product Solutions

Sim-Casts scaleable solutions link together throughout the product lifecycle

- Basic capability – understand the process and product performance
- Control – define controls for the process to maintain product performance
- Continuous improvement – eliminate variation & waste, maintain control and build learning into New Products
- Controlled, measured, well understood incremental improvements



Casting defect prediction

Case studies

Thermal defects:

- Geometric secondary grain prediction – Single Crystal
- Porosity – Equiaxed

Mechanical defects:

- Recrystallisation
- Dimensional distortion and core breakthrough

Microstructural defects:

- Grain structure - Equiaxed
- Grain structure - Single Crystal

Filling defects:

- Inclusions,
- Misrun

Modelling processes improvements:

- Furnace withdrawal improvements - SX
- Sensitivity analysis - e.g. furnace ageing

Geometric secondary grain prediction - SX **Sim-Cast**

Problem definition

Thermal undercooling of overhanging features causes geometric secondary grains. This is due to heterogeneous nucleation of secondary grains from the mould wall.

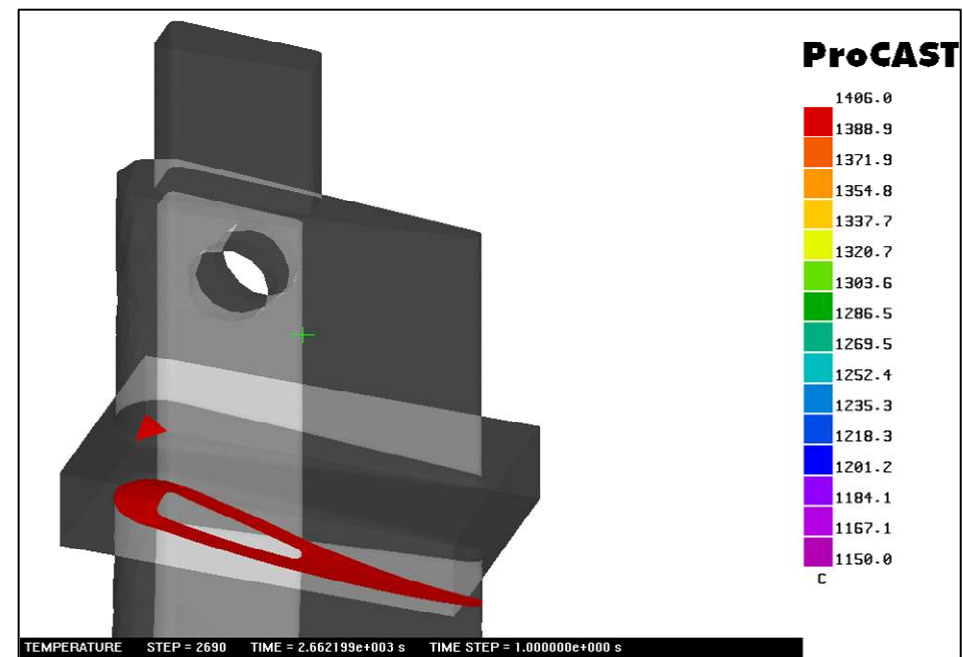
Process modelling

Process modelling predicted significant thermal undercooling, which was sufficient to nucleate a secondary grain and grow into a High Angle grain Boundary (HAB).

Problem solution

There are numerous parameters that can be altered to reduce undercooling to acceptable levels on the model, and hence eliminate or reduce geometric HABs.

Defect prediction



Geometric HAB on shroud platform corner

Problem definition

Porosity is found in most gravity castings. It is caused by shrinkage or evolution of dissolved gases and shortage of residual eutectic between dendrites during solidification. This leads to depressions, pores, pipes, cavities, etc, in the casting.

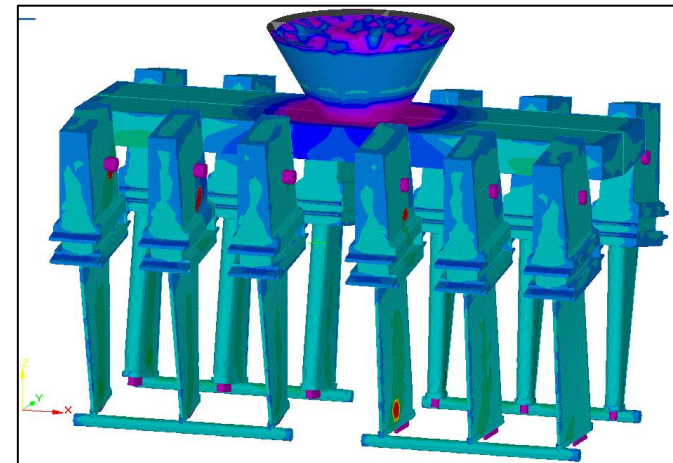
Process modelling

Severe shrinkage porosity was predicted to occur in areas of low thermal gradient/hot spots. These are the last areas to solidify and/or where the feed path is interrupted.

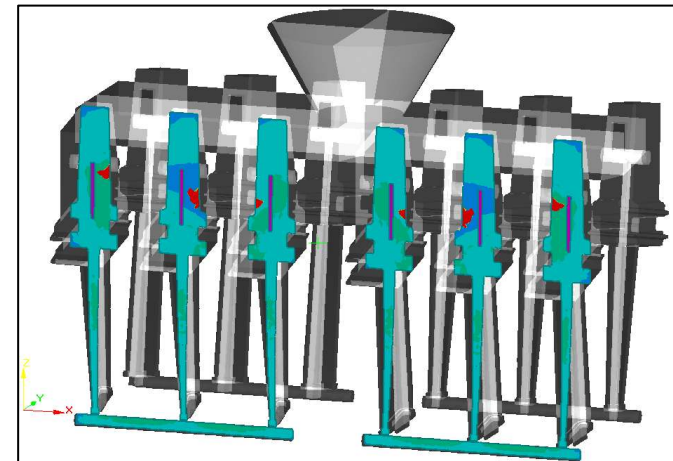
Problem solution

There are numerous parameters that can be altered to reduce shrinkage to acceptable levels on the model, and hence eliminate or reduce macro-porosity.

Defect prediction



Surface depression/pipe shown on pour cup



Internal cavities shown in root block

Problem definition

Freckling defect caused by thermo-solutal convection within the mushy zone. This is due to density inversions in the liquid phase during solidification.

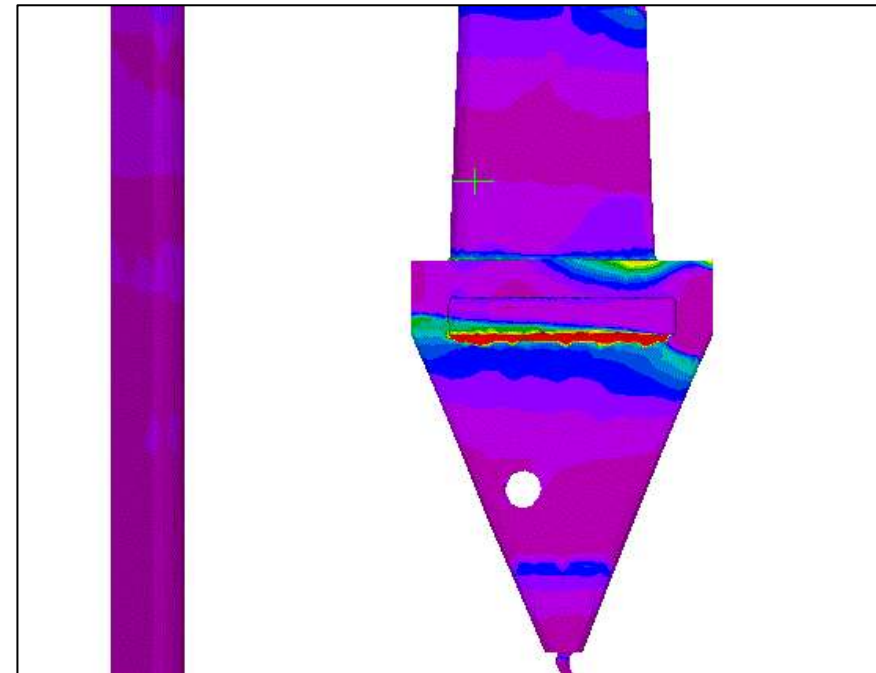
Process modelling

Freckling was predicted to occur in regions of large liquidus front curvature, primary dendrite arm spacing and casting volume, e.g. turbine blade root blocks.

Problem solution

There are numerous parameters that can be altered to reduce the likelihood of freckling occurring, and hence eliminate or reduce freckle grains.

Defect prediction



High freckling propensity in root block

Problem definition

RX is caused by differential contraction rates of the alloy, shell and core, which impart large strains on the casting during solidification. The result is single or multiple equiaxed grains evident after heat treatment.

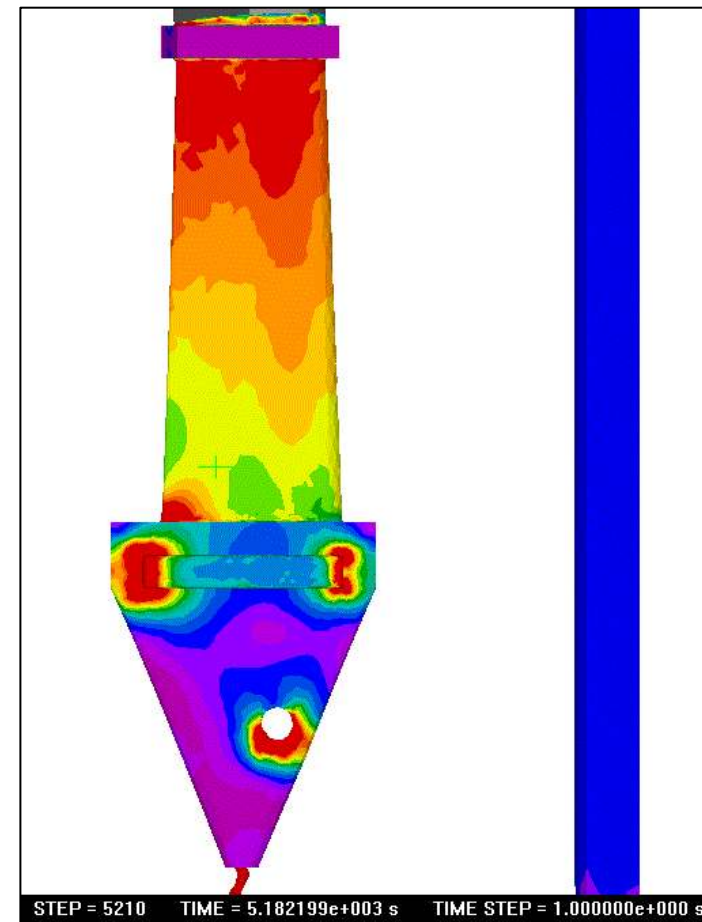
Process modelling

RX was predicted to occur in complex geometry, thin sections, regions of interface/restraint between casting, core and shell. This is consistent with actual blade castings.

Problem solution

There are numerous parameters that can be altered to reduce the resultant strain occurring, and hence eliminate or reduce recrystallisation.

Defect prediction



RX in the core prints & tip fillet radius

Problem definition

Dimensional distortions and core breakthrough are caused by resultant stresses that occur during casting. In some cases they can be rectified if machining stock is available, but in other cases they can cause scrap.

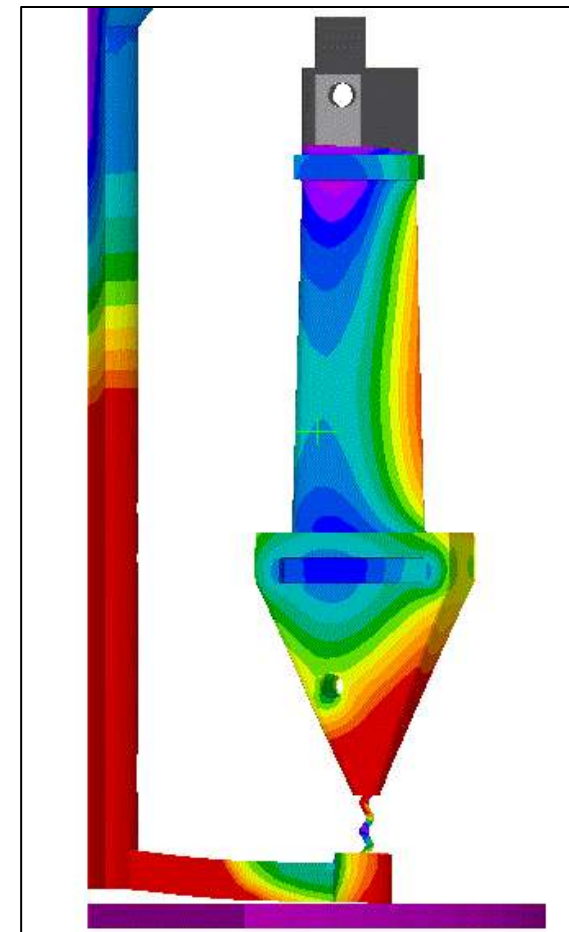
Process modelling

Distortions were predicted to occur in regions of complex geometry, thin wall sections, and regions of casting/core/shell where there is low restraint. This conflicts with the requirements for minimising RX.

Problem solution

Numerous parameters can be altered to reduce and even eliminate casting distortions and core breakthrough. Ultimately it should be possible to design castings (& wax pattern die) to account for distortions so that they contract to the desired nominal shape. Actual shape also useful for Design, Stress, Aero & Cooling.

Defect prediction



Significant distortion of aerofoil trailing edge

Problem definition

It is important to maintain a single grain in SX castings as the alloys used have low grain boundary strength. Therefore miss-oriented and spurious grains can be a cause of scrap.

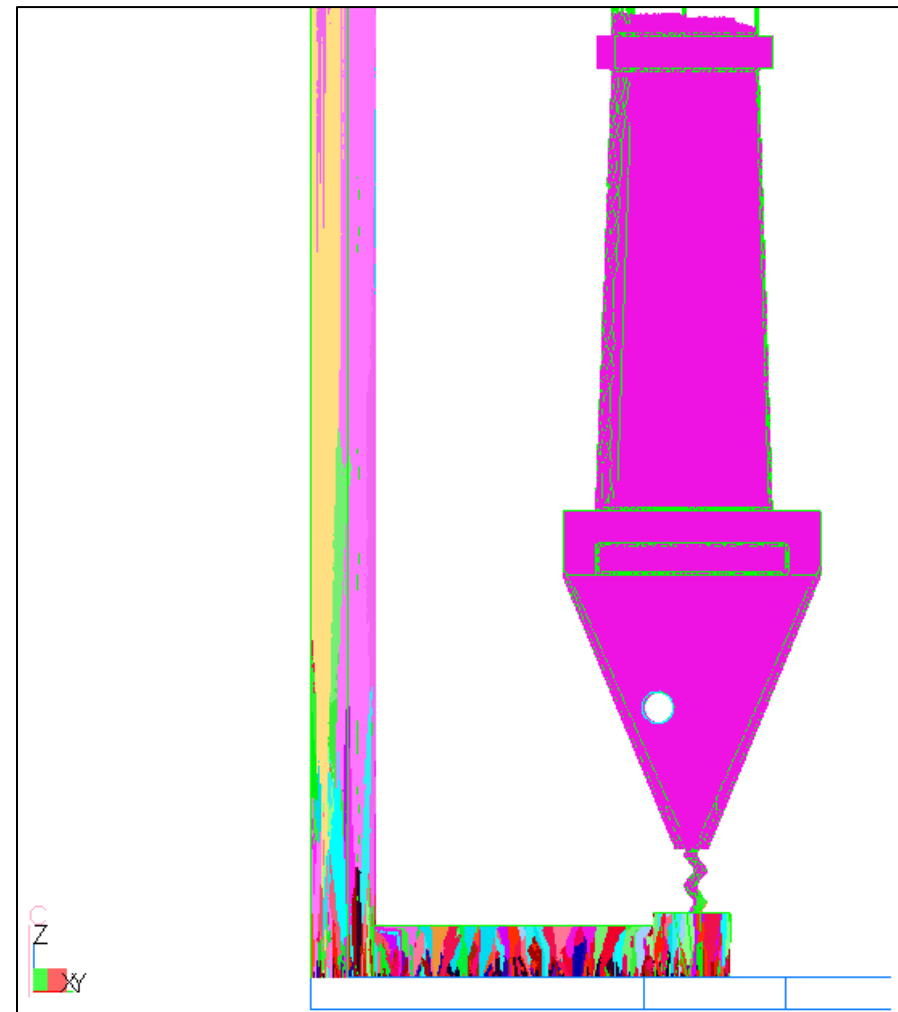
Process modelling

The grain structure that occurs in different regions of an SX casting was predicted. Typically, miss-oriented grains can propagate through the selector, and stray grains can nucleate elsewhere in the casting.

Problem solution

There are numerous parameters that can be altered to reduce miss-oriented and stray grains, and hence improve grain structure.

Defect prediction



Typical grain structure in a single crystal casting

Problem definition

Non-metallic inclusions (or particles) found in castings can originate from a number of sources, and can vary in size from microns up to a few millimetres. However, inclusions cannot be tolerated in highly stresses regions of the component.

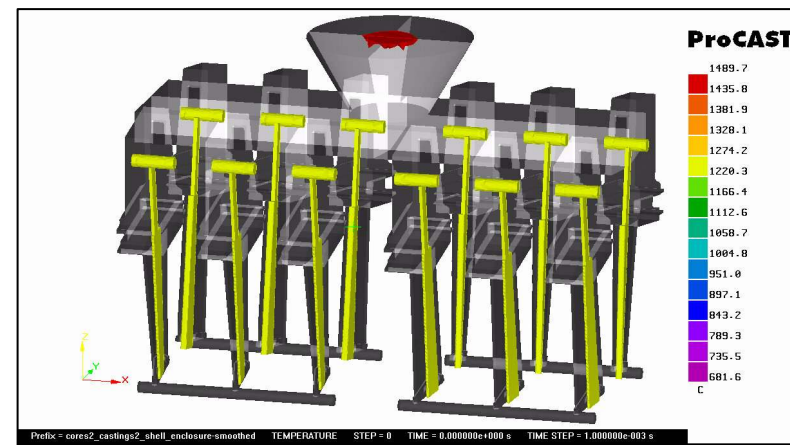
Process modelling

Filling models can be used to predict mould derived inclusions that occur due to delaminations, sharp corners, flow problems, etc. Furthermore, particle tracking can help with this.

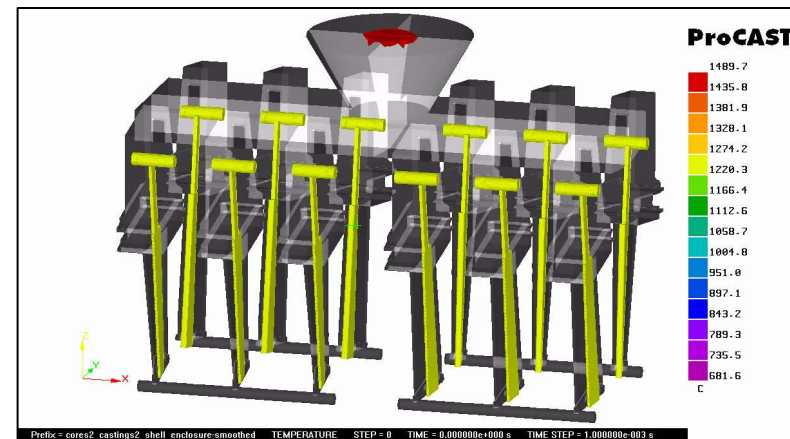
Problem solution

There are some parameters that can be altered to enable quiescent filling, and hence reduce occurrence of mould derived inclusions.

Defect prediction



Filling simulation of equiaxed casting



Filling simulation of equiaxed casting with particle tracking

Problem definition

Misrun is the result of lack of feed pressure, usually occurring in thin sections such as aerofoil trailing edges. This leads to incomplete fill of the nominal component cavity causing minus metal, i.e. scrap.

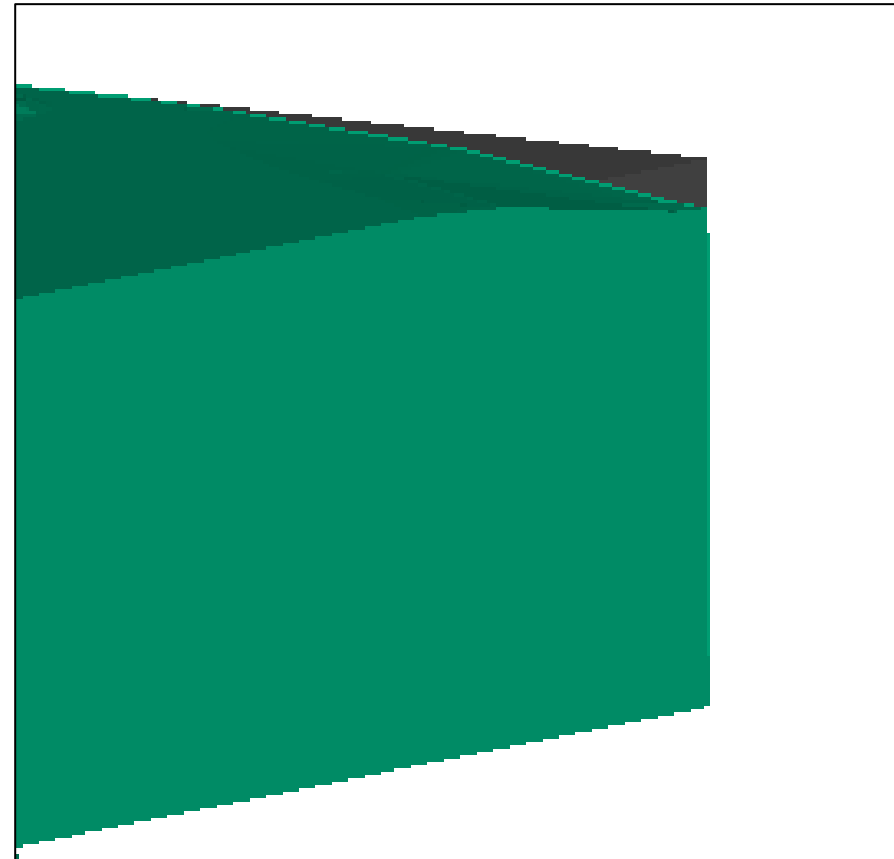
Process modelling

Misrun was predicted in the shroud corner of a root down turbine blade casting. It is also common to find misruns in ever thinner trailing edges, also causing scrap at later operations such as EDM of film cooling holes.

Problem solution

There are numerous parameters that can be altered to eliminate or reduce misruns.

Defect prediction



Misrun in shroud corner

Problem definition

Ageing plays a major part in degradation of furnace performance & hence casting quality. There are 2 main types of degradation, thermal & mechanical, which cause furnace performance to get progressively & unpredictably worse with each casting cycle.

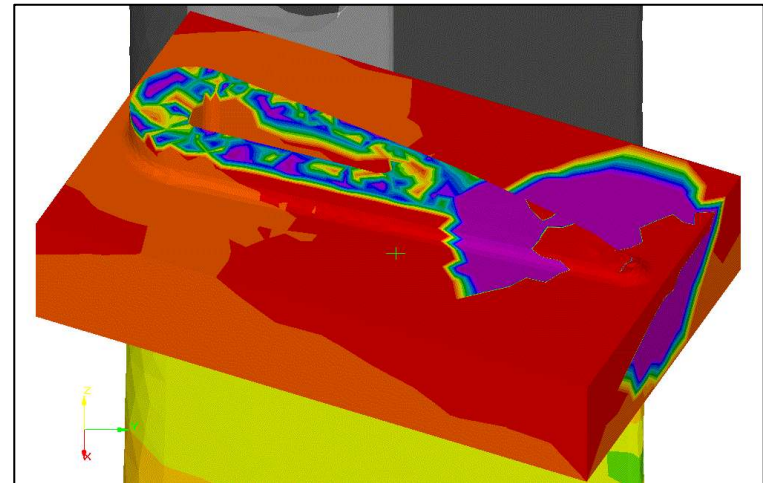
Process modelling

Process models are often used to improve the nominal manufacturing process. However, it is worth studying the sensitivity of the part and process to real variations such as furnace thermal ageing. E.g. predictions of casting porosity are shown for new furnace & aged furnaces

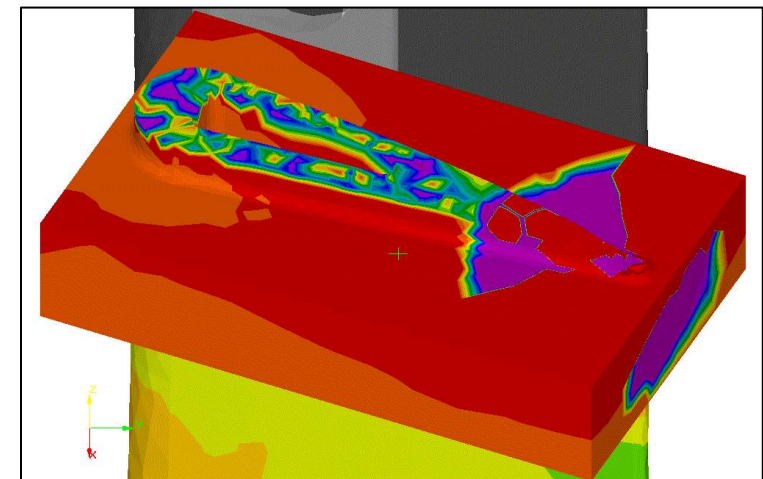
Problem solution

It is worth designing the part & process to account for process variations, e.g. by modelling the effects of furnace ageing on defects, such as shrinkage porosity, & reducing them to acceptable levels.

Defect prediction



Porosity - standard furnace



Porosity - aged furnace

Problem definition

Additional stock is needed for the casting process, but it is desirable to minimise material usage. NNS casting involves casting parts as close to the finished form as possible. But this can be difficult to achieve, as reducing stock also reduces ability to machine out defects.

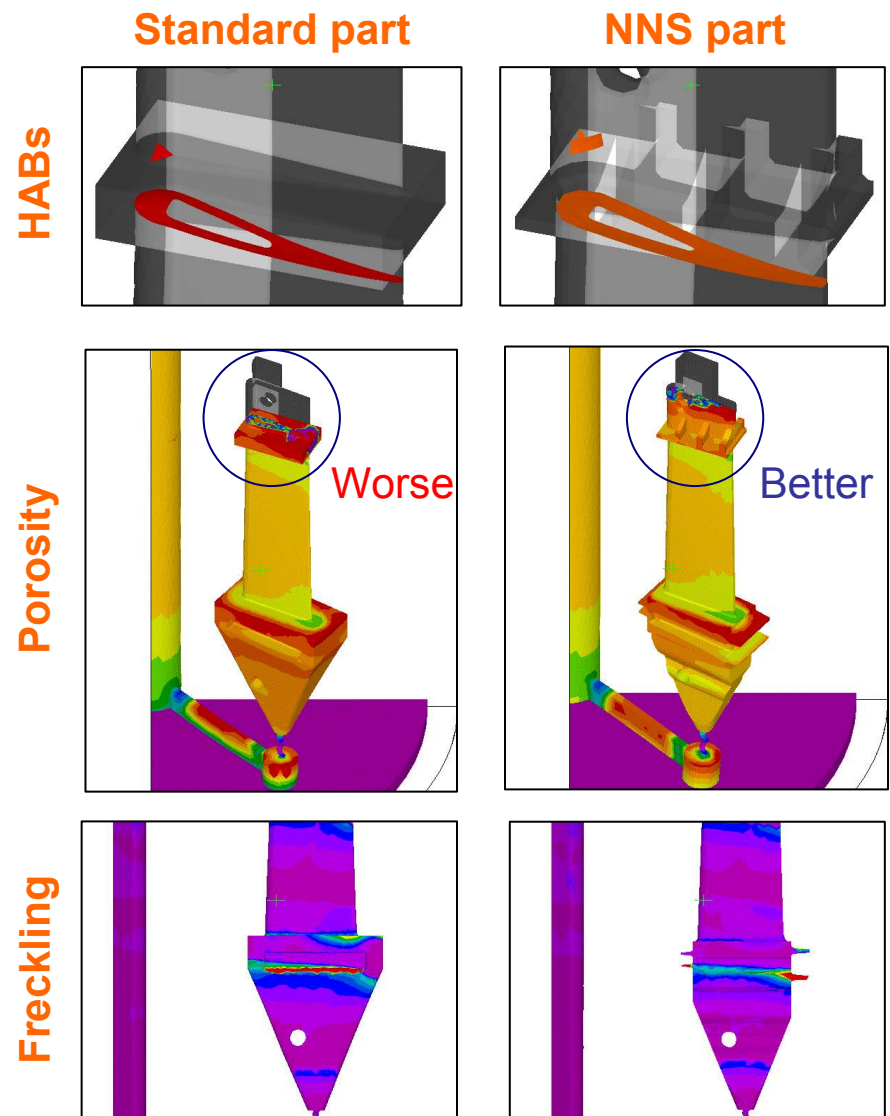
Process modelling

Modelling predicted where defects are likely to occur, so they can be eliminated without casting trials. This saves cost and foundry capacity, and achieves a more optimal casting technique than trials alone.

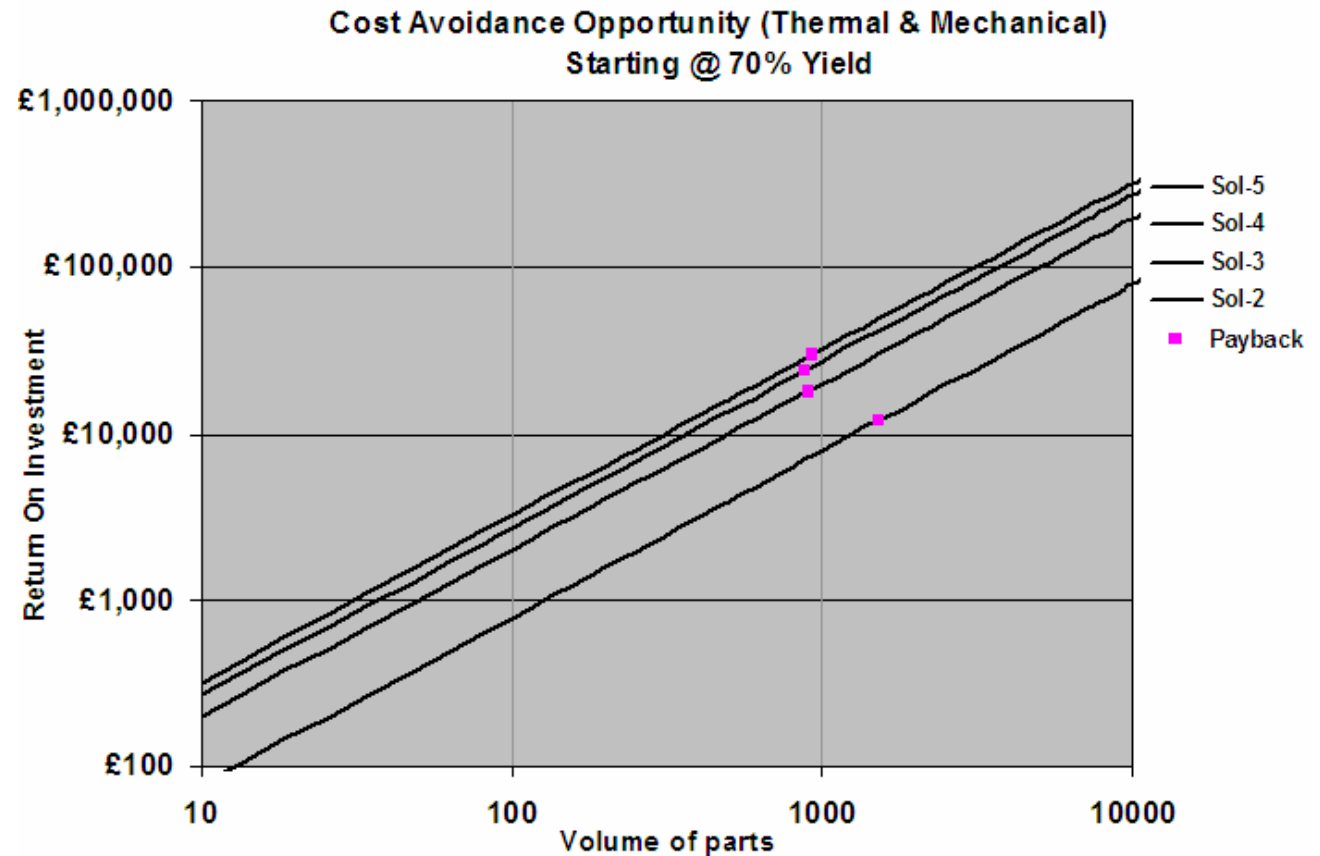
Problem solution

NNS parts are metallurgically cleaner because heat can be extracted more efficiently from a smaller charge. Thus the benefits include less spurious defects, less casting and machining stock, etc.

Defect prediction



- Typical returns on Sim-Cast solutions
 - Solution 2 - £8 / part
 - Solution 3 - £20 / part
 - Solution 4 - £27 / part
 - Solution 5 - £32 / part



- **We can help reduce cost through metal utilisation and yield improvement**
- **We can help reduce casting trials and development time for New Product**

Introduction

- We can model over 70% of casting scrap in the foundry
- We can model the consequence of process variation
- We have reliable methodology (model building, interpretation, etc), based on over 10 years of experience of using these models in a real foundry
- We have Thermal, Mechanical, Microstructural and Filling modelling capability
- We have an unsurpassed record of defect resolution
- We can offer our process modelling expertise to fit within aggressive customer lead times
- Sim-Cast can also be used to complement existing process modelling capacity

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