get it right®

SHEFFIELD FORGEMASTERS uses ProCAST to design and manufacture the largest ingot ever made in the UK

SHEFFIELD FORGEMASTERS INTERNATIONAL

THE "BIG" CHALLENGE

Sheffield Forgemasters (SFIL) known for their ability to produce large steel castings had a task cut out to produce an ingot weighing approximately 300 tons, larger than any ingot made by them in the past. Ingots of this size offer no room for error, and foundries need to "get it right" the first time and every time.

THE STORY

Sheffield Forgemasters (SFIL), with their years of experience, had developed a mold design expertise to optimally utilize their current facility. A new approach with a range of engineering, design and metallurgical skills of their engineers coupled with the usage of ProCAST, resulted in new sucessful ingots within the confines of the existing capital equipment.

THE BENEFITS

- Ingots of high surface integrity and improved axial ultrasonic tests.
- Many operative benefits in the subsequent forging operation.
- Dramatical shortening of lead time for design and commercialization of a new mold.

"Using ProCAST software, SFIL was able to analyze several virtual scenarios before delivering a 'right first time' ingot casting. After forging it to produce the final roll shape and Non Destructive Testing (NDT), it was evident that this was the highest integrity ingot ever produced at SFIL"

Dr Jesus Talamantes-Silva
Group Research and Development Director
Sheffield Forgemasters International Ltd

PROCESS

Steel Ingots are forged to their final shape to be ready for use at the end application. Sheffield Forgemasters' requirement was to deliver forged plate mill rolls greater than 150 tons of finished weight. These rolls are used in the ship building industry to roll flat products up to 5m wide, about more than one meter wider than traditional mills. The performance benefits of forged rolls, versus traditional castings, has created a strong demand for this product.

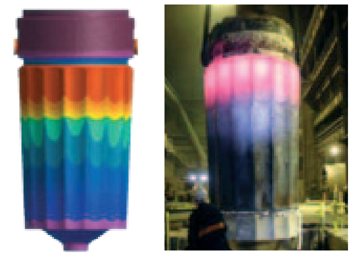


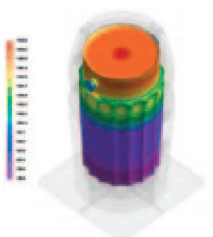
Fig 1: Simulation vs Foundry

TRADITIONAL APPROACH

The traditional approach to new ingot design is an evolutionary process utilizing experience to extend the size capability envelope of existing molds with good production histories. In this present case, the 'traditional' approach yielded a solution which proved to be impractical with local logistical constraints. It also appeared to make inefficient use of time and materials.

ALTERNATIVE

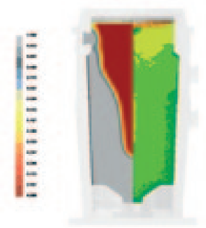
The alternative was to model a new ingot configuration suiting the local logistical constraints and reproduce solidification characteristics as in the traditionally designed ingot. It was apparent that commercially available casting simulation software was not adequate due to the sheer size of the planned ingot. **ESI Group carried out special developments inside ProCAST to obtain meaningful filling and thermo-mechanical results within reasonable computation times, allowing several scenarios to be tested in a relatively shorter time.** This integrated modeling work allowed Sheffield Forgemasters to custom design an optimum ingot size and shape to meet the requirements of the forgings in terms of both final shape and quality.



Temperature plot (°C)

1ST GENERATION INGOT MOLD

The first outcome of this work was the "1st Generation Ingot Mold". This was a 113" large ingot mold, accommodating 16 flutes versus 8 flutes in the traditional approach, developed with a new heading practice to ensure enhanced feeding during solidification, leading to an ingot which exhibited improved central consolidation. Experimental results coincided extremely well with the simulation model predictions both in terms of cooling and solidification characteristics. Figure 1, shows a comparison.



Solidification (left) & Shrinkage Porosity plot (right)

NOVEL TRUNNION DESIGN

Along with the new heading practice, came a problem of surface tears. However, with the implementation of simulation modeling to include thermal, filling and stress based considerations, the true cause was determined: the enhanced feeding had resulted in a non-uniform thermal contraction during solidification leading to high stresses. This did not affect the integrity of the final product, however, there was a slight modification needed in the forging operation to minimize the extent of surface break-up.

The surface tears were observed below the trunnions and this was attributed to their incorrect collapse during thermal contraction. The trunnions are in fact cast to the head of the ingot and act as lifting pins while de-molding the ingots. The conventional practice at Sheffield Forgemasters has been to use low strength refractory material around the trunnion blocks, providing enough strength to accommodate high amounts of liquid steel, while allowing some downward movement of the trunnion assembly during thermal contraction.

A novel trunnion block incorporating a hollow core was designed, allowing much easier collapse during the thermal contraction of the ingot and significantly reducing cracking across the product range.

The successful implementation of the enhanced modeling approach proved Sheffield Forgemasters' capabilities to design and fabricate custom ingots for demanding applications with high degree of confidence, within a strict time frame.

2ND GENERATION INGOT MOLD

The advantage of an in-house simulation tool meant further innovations could be tried out. Sheffield Forgemasters sought to achieve benefits that were greater, than the ones which were already apparent from the profitability review of the product. This time the approach was to enhance the solidification from the bottom of the mould, whilst developing the optimised heading practice established by earlier modelling work.

Fig 2: Mold design development

PRACTICAL CONSIDERATIONS

Several practical considerations had to be addressed while re-designing the final mold and later implementing it in the foundry. The mold internal volume had to be optimized given the external restrictions imposed by the vacuum tank. This meant lower clearance, and difficulties in de-molding the ingot. The top of the vacuum tank was rebuilt to make it detachable so as to have better access of the trunnions. Due to the change in the cross section of the ingot, with shallower and more flutes, the stability during transport and height of the insulating box had to be reworked. Due to the lower H/D (Height and Diameter) ratio of the ingot, the laying down procedure had to be modified. And finally the sinking bottom plate had to be redesigned for easier stripping for the forging process.

The 130", 300 ton Ingot after mold stripping

RESULTS & BENEFITS

Overall simulation brought enhancements across the product range. **ProCAST casting simulation results were in agreement with the final inspection results, showing that the computational model was a true representation of the actual ingot manufacturing.** Apart from the high surface integrity and improved axial ultrasonic results, Sheffield Forgemasters developed new approaches like the improved heading practice, novel trunnion design and sinking bottom design, and the shallow fluted 32 sided design enhanced the cogging operation by reducing the number of cogging heats.

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