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SPECIALISTS IN THE DESIGN AND PRODUCTION
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72ND WORLD FOUNDRY CONGRESS

22nd-25th MAY 2016, PORT MESSE
NAGOYA, JAPAN

The theme for the 72nd World Foundry Congress, to be held in Japan in May 2016, will be 'High Quality of Castings'.

The event will be held alongside the FOUNDEX 2016 exhibition in Nagoya. The World Foundry Organization and the Japanese organising committee will shortly be issuing a call for papers. www.wfc2016.jp

Global vacuum technology company Oerlikon Leybold Vacuum has opened a new sales and service office in Utrecht, in the Netherlands. The former premises didn't have enough space for the growing local business and another benefit of the new location is improved infrastructure. The new site includes a sales office, a service facility and a warehouse.

www.oerlikon.com/leyboldvacuum



The latest Foundation Degree in Casting graduate Richard Waters collected his certificate from ICME national president Constantine Theoharis FICME at the recent ICME Awards Lunch. Read more about the lunch celebration on page 30. For more information on the Foundation Degree in Casting and how this can aid your career prospects contact Tim Baron at ICME, Tel: +44 (0) 121 601 6979, email: tim@icme.org.uk



CMF CHIEF EXECUTIVE DESIGNATE

Dr Pam Murrell FICME has been appointed chief executive designate of the Cast Metals Federation, and will take over from John Parker as chief executive on 1st February 2015.

Murrell joined CMF from her position of chief executive of the Institute of Cast Metals Engineers and has, over many years, gained widespread experience in all aspects of the foundry industry.

As a metallurgist and thanks to her work with ICME, Pam has a foot in each of the educational, promotional, technical, business and trade association camps of the UK cast metals industry.

"I am delighted to have the opportunity to carry on John Parker's good work in supporting the UK castings industry through my new role within the Cast Metals Federation," she said.

"Manufacturing in the UK is now being recognised as a vital part of this country's economy, and the castings industry - as a vital part of the manufacturing supply chain - has a real opportunity to raise its profile further and to gain the support from government in order to thrive. The new interest in a *National Strategy for the Metals Sector* is just one example of the way in which the industry, through its trade body, can collectively work to improve the business and the CMF will be fundamental in maximising the opportunities for its members."

Murrell is also a Fellow of the Institute of Cast Metals Engineers; trustee of the Tor Lodge and Applecross Trust; and board member of the Foundry Equipment & Supplies Association (FESA).

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NEW TECHNOLOGIES USED IN THE CASTING PROCESS

ASK Chemicals has received an *Innovation Award for Sustainability* from BMW.

The announcement was made in October when the BMW Group held its BMW Supplier Innovations Awards 2014 ceremony to celebrate the achievements and innovations of its suppliers. ASK Chemicals was one of eight companies singled out as 'most innovative suppliers' in the category 'sustainability'. The prize was accepted by CEO Frank Coenen, ASK Chemicals, for the development of the INOTEC™ generation of inorganic binders for high-volume series production of engine castings.

The industrial implementation of the innovation is a joint feat by BMW and ASK Chemicals, which set high benchmarks for emissions protection and economy. Both partners were willing from the very beginning to systematically make the project a reality, despite the enormous demands of the production process. "In the years of collaborative development between ASK Chemicals and BMW, the composition and manufacture of inorganic binders were perfected to such a degree that they were able to replace organic binder systems in high-volume series production. This has enabled the BMW Group to implement zero-emission foundries and to further improve working conditions for its employees. At the same time, productivity and the quality of the casting components have increased," said BMW of its reasons for honouring the supply company. In a statement ASK Chemicals said: "Working together, BMW and ASK Chemicals have developed and brought to market a key technology that is a major milestone for the automotive industry. Many renowned car manufacturers have followed this example and are today also intensively utilising inorganic core production technology."

Coenen said the award would continue to spur the company on: "The innovation award is an incentive for us to keep on researching and developing products, in order to bring these to industrial viability together with our partners," he said. "However, the idea and the innovative product are nothing without the resolute will of the user to successfully implement a new technology on an industrial scale."

www.ask-chemicals.com



Klaus Draeger, board of management of BMW AG, purchasing and supplier network (left), and Frank Coenen, CEO of ASK Chemicals, Hilden

A Carrasco, D Peña and J Izaga - IK4-Azterlan Metallurgical Research Centre, Durango, Spain; G Trillo and M Manzanares - FONDESAL SA, Rubí, Spain; J Prat - ASK Chemicals España SA, Getxo, Spain

Net/gross yield optimisation on high value added steel casting

ABSTRACT

The manufacturing of cast steel components presents numerous improvement opportunities in a whole range of materials, from manganese steels to nickel based alloys, with a high level of complexity and a large amount of critical requirements. Among all the possible advances, this paper focuses exclusively on the optimisation of the production yield, defined as the ratio between the weight of the cast part itself and the total amount of metal poured into the mould (net weight/gross weight ratio = yield).

Most of the companies belonging to the cast steel component manufacturing sector have utilised, in different degrees, casting process simulation tools that are currently available in the market. Jobbing shops, or producers of short production runs, make up a key segment of the steel casting industry. The aforementioned simulation software can be used by these metal casters as a tool to provide a low risk and a low cost review of the existing patterns, in such a way that the 'traditional design criteria' of the feeding systems can be submitted to optimisation strategies, focusing mainly on yield.

The work presented in this paper is based on an intensive review of the feeding systems that are currently employed in the manufacturing of cast steel components, where special attention is paid to yield optimisation due to its direct and significant influence on the manufacturing costs.

This work has been developed from a complex variable matrix that takes into account the materials to be cast (liquid state metallurgy and solidification), the novel state-of-the-art feeding systems (core-sleeves, padding-sleeves and Exactcast™ mini-risers patented by ASK Chemicals) and some advanced feeding concepts (thermal modulus, volume minimisation and feeding distance).

The industrialisation stage has been performed at the facilities of ASK Chemicals and in several foundries, particularly at FONDESAL, leading to yield levels over 60% in parts subjected to radiographic controls.

The R&D project entitled 'SUPERALLOY' serves as a basis for this paper, where the main achieved results are published, new feeder designs and compositions are proposed and the latest news regarding the feeding systems of the short-term future are presented.

INTRODUCTION

The casting technologies applied to steels and complex alloys present a number of particular features that have limited their advances in terms of net/gross yield and productivity, especially if compared to other cast metal families.

When studying the particular characteristics shown by the cast steel components, special attention must be paid to feeding systems and metallurgical considerations, since it is these areas where important improvement opportunities materialise. As the size of the risers is reduced, the thermal solicitations are minimised and, in consequence, the metallurgical properties in the neighbouring areas are significantly improved.

Yield is an area to be investigated, since plenty of industrial applications can still be found in which the yield hardly reaches 40% (fig.1).

These general reflections have been the basis for the configuration and the starting of the 'SUPERALLOY' project. Conventional design concepts were reviewed, paying attention to the criteria for modulus, volume and feeding distance.

This paper focuses on the manufacturing of cast steel components, where relevant improvement margins exist, since a set of convenient circumstances converge on them. The high level of detail that must be paid to these parts and their production batch size - often small or even unitary - have become a barrier to any work on improvement strategies in terms of net/gross yield because of the concern of 'getting the part right'.

In those cases in which the productive activity belongs to market nichés with high technical requirements, simulation tools are employed to validate the designs so that foundries can securely go ahead with less conservative designs.

In the following section of this paper some of the new calculation criteria are presented and discussed. Special attention is paid to the development of advanced feeding systems in which the insulating/exothermic behaviour and the geometric design are balanced.

EXPERIMENTAL PROCEDURE

The experimental stage of the work started with the review and comparison of the calculation and design methods that are applied in a representative number of steel foundries, resulting in a variable matrix where different materials (low and medium alloy steels, manganese steels and stainless steels), various sizes (small: less than 25kg, medium: 25 to 150kg, and large: up to 4,000kg) and batch sizes (single part and mass production) were recorded together.

In all cases, the same model is found to approach the problem:

- Feeder design is well taken care of
- Filling system design is not taken into account, only the choice of the pouring method being mentioned (basin or direct pouring)

In the experimental stage, both the modelling and the validation of these calculation methods are studied, paying special attention to the yield optimisation. Prior to reaching for any industrial application, verifications are made by using simulation tools in whose databases the thermo-physical characteristics for the feeding device mixes have been uploaded.

As previously stated, all efforts are exclusively focused on the redesign of the feeding systems which apply the thermal modulus criterion as a priority.

Design Criteria

When building the concept of the feeding system, several factors are considered. The most important of them being: contraction, feeding distance, volume to be fed and modulus.

The combination of these variables must be balanced through the use of advanced simulation tools in such a manner that calculations are notably simplified and gain in reliability.

Two priority working lines have been established, deepening on the areas of contraction/modulus.

- **Contraction.** The contraction model that has been applied is built in three phases: liquid contraction that depends mainly on the overheating of the alloy; solidification contraction that relies on the solidification range of the alloy; and the solid phase contraction. The feeding system can exert influence on the first two, while the third obeys the physical behaviour of the alloy and it is not possible to change it noticeably.

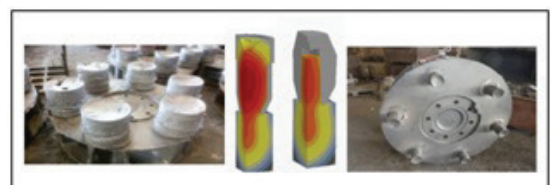


Fig.1 Example of yield optimisation

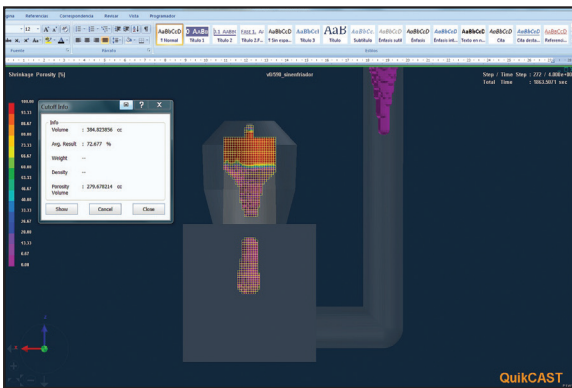


Fig.2 Simulation supported porosity prediction

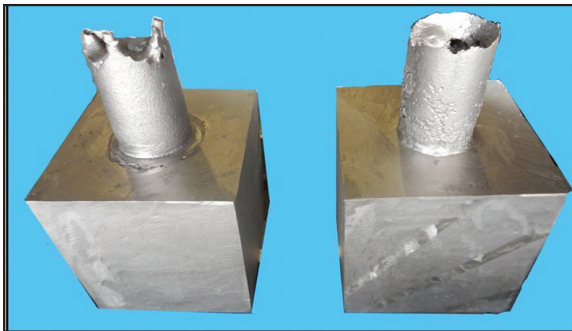


Fig.3 Test parts and corresponding risers (MPart = 3.33cm)

- **Thermal modulus.** It is one of the design key points and thus, the modulus of both the part and the feeding system are studied with the safety factor set around 25% ($M_{Feeding} > 1,25M_{Part}$).

Simulation Tools

In the course of the ‘SUPERALLOY’ project, novel design concepts have been handled, considering that “a single cast component must be treated as if it was a series production part”. This preliminary approach introduces important design novelties making the use of simulation tools essential.

Part soundness (absence of shrinkage porosity) has been considered a key point both in laboratory scale and in industrial productions.

In all cases, subsequent adjustments have been carried out taking the conventional designs as reference. For virtual validations, several moduli are employed performing defect prediction calculations for all cases (fig.2).

Test Part (Specimen)

In order to minimise the impact of incidences in industrial parts, every single design change has been preceded by the fabrication of the corresponding specimens. The specimens used were prismatic blocks of side = 200mm and geometric modulus = 3.33cm (fig.3).

The feeder of every specimen is built with the riser sleeves under study, analysing the results in terms of characteristic contraction model followed by all cases.

Both destructive and non-destructive techniques are employed to assess the soundness and the amount of contraction in every specimen.

Industrial Trials

All the validations have had to undergo their corresponding industrial trials (fig.4), where soundness

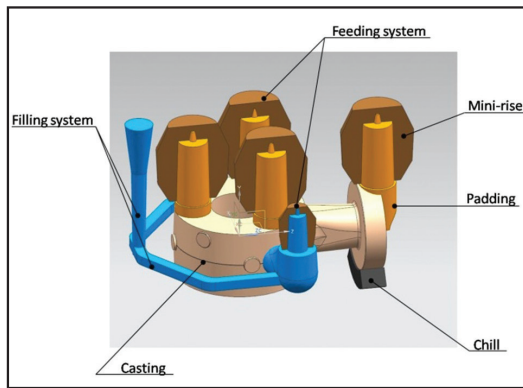


Fig.4 Constitutive elements of a design

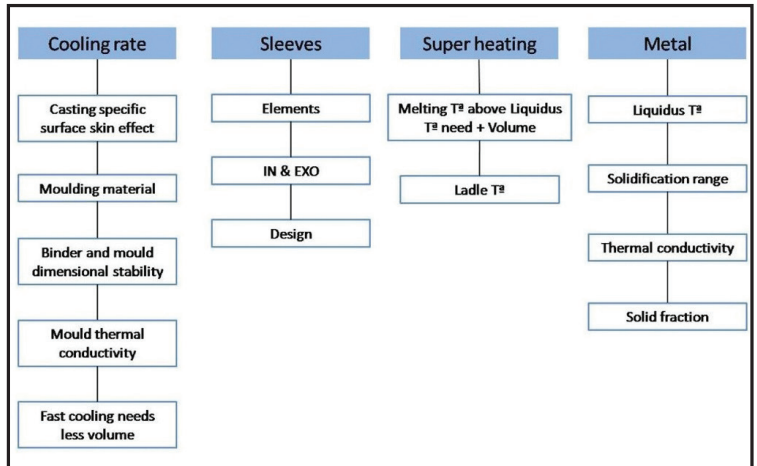


Fig.5 Most significant process variables

and net/gross yield are inspected.

The preliminary requirement has been, in all cases, guaranteeing the part’s soundness and no melt was carried out assuming unnecessary risks.

Studied Process Variables

The basis of this paper is the optimisation of the yield and, thus, the process variables affecting the contraction model have been identified and evaluated. Amongst all of them, the most significant ones have been selected and they have been assessed in terms of contraction (fig.5).

The most relevant process variables are:

- Solidification rate
- IN-EXO riser sleeves and feeding system designs
- Metal superheating

RESULTS AND DISCUSSION

The feeding elements that have been developed in the frame of this R&D project and the validation tools that have been employed take into account the multiple factors affecting the contraction model of the studied alloys. It is then necessary to remark on the following key points.

Solidification Rate

From the industrial practice point of view, the contraction due to the liquid-solid interval is considered a property of each alloy and it is not possible to act upon its behaviour.

The analyses that have been performed with virtual tools have outlined that as the cooling rate increases, the shrinkage associated to the liquid-solid interval is reduced.

In order to experimentally verify this behaviour, a specimen based test has been designed and carried out. Utilising the very same moulding and feeding system, with three different mini risers KMV 1650, KMV 780 and KMV 590 with modulus of 5.7, 4.2 and 3.9cm respectively are moulded, one of them having a chill at the bottom while the two others do not. In this condition, metal from

Fig.6 The specimen was free of shrinkage porosity in the three shown cases. Sample #1 without chills and samples #2 and #3 with chills

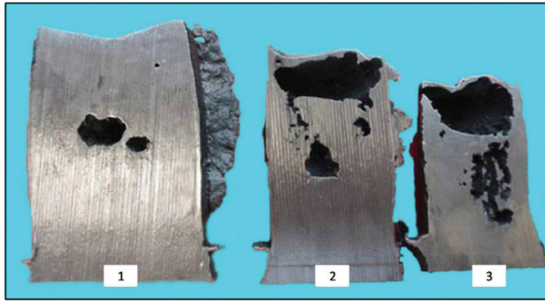


Fig.7 Microsphere fixing mechanism detail

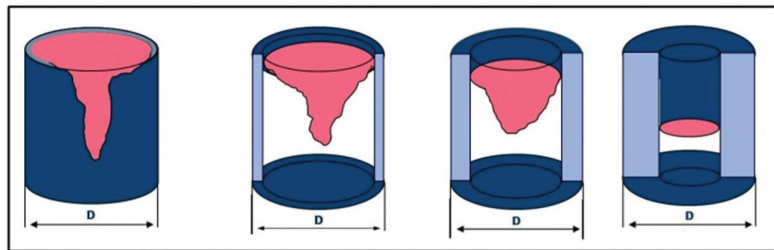
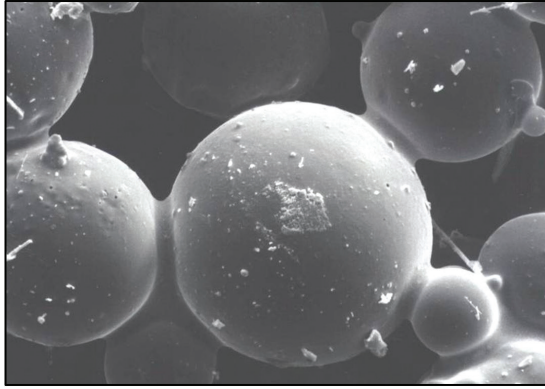


Fig.8 Contraction models for different formulae

the same ladle is poured in both moulds and, after they are cooled down, the shrinkage cavities are evaluated.

It is verified that the shrinkage defects related to the primary and secondary contraction are bigger in the case of the specimen without chills. The increase of cooling rate by the means of using a chill changes the thermal modulus, which is evident, but it also changes the contraction model (fig.6).

Sleeves

The IN-EXO sleeves and the feeding systems that have been developed combine, in a balanced way, their insulating-exothermic capacity, their geometry, and their composition. With the target of optimising their thermal performance, the main variables driving their functional response have been modified so that the IN-EXO character is reinforced.

Components

Different formulae have been employed to optimise the insulating and exothermic behaviour. Regarding the formula, an alumino-silicate microsphere (fig.7) based insulating system has been employed and bound together with an exothermic compound via the cold box technique.

Insulating (IN) and exothermic (EXO) capacities

The feeding performance optimisation strategy is based in the insulating capacity and the exothermic properties of the risers themselves. Prior to the industrial tests, every single one of the IN-EXO formulations has been subject to measurement and evaluation (fig.8).

Assessments are carried out using the ETNA system (a proprietary method developed by ASK Chemicals), so that it has been possible to identify the factors controlling the insulating capacity of each mix and its exothermic behaviour.

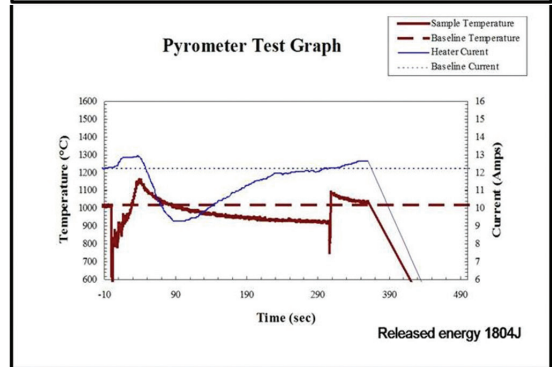
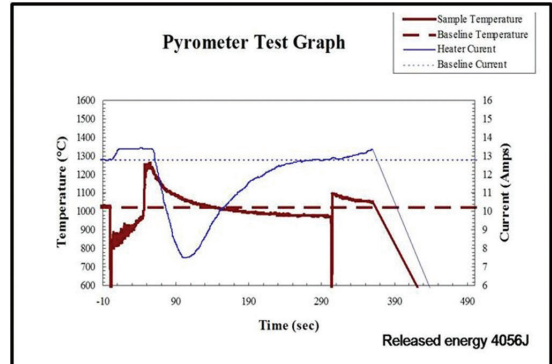


Fig.9 ETNA Test. Insulating-exothermic behaviour for two different formulations

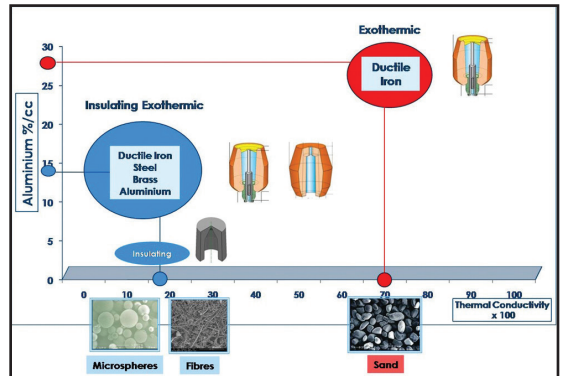


Fig.10 Geometries and formulations tested in the 'SUPERALLOY' project

After the ETNA tests (fig.9), pairs of 'test parts' are cast modifying exclusively the exothermic capacity of the IN-EXO sleeves. The results show that when increasing the exothermic level, riser volume demands are reduced.

Geometries/Models

Depending on the application, three base designs have been employed as starting points.

- **IN-EXO sleeves:** due to their specifications they require a smaller weight of metal than conventional sleeves, considering the modulus is kept constant.
- **Padding sleeves:** an adaptation of their geometry to each application eases metallic padding removal or increases the feeding distances; in this way avoiding the use of chills.
- **Well sleeves:** the parts of the mould that are affected by the feeding elements are covered with IN-EXO mixes, improving the thermal response of the surrounding area.

New designs and geometries have been developed in which remarkable benefits have been identified, since the possibility of increasing the riser's action radius area



Fig.11. Manganese steel part: conventional riser (far left) versus mini-riser behaviour (middle and right)



Fig.13 Yield optimisation example (stainless steel)



Fig.14 Yield has been improved from 58% (top) to 76% (bottom), in addition to optimising finishing times (carbon steel)

and the feeding distance can be added to the IN-EXO response of the mix itself (fig.10).

Tested Materials

The behaviour of different iron based materials has been studied and it has been made evident that not all of them follow the same response model. The obtained information belongs to low and medium alloy steels, stainless steels of different nature and manganese steels.

The relationship between alloy chemistry, solidus and liquidus temperature, solidification range (short and long range alloys), and solid fraction has been studied.

From a feeding capacity and simulation validity point of view, the solid fraction criterion (expressed as the solid phase/liquid phase ratio) has been related to the

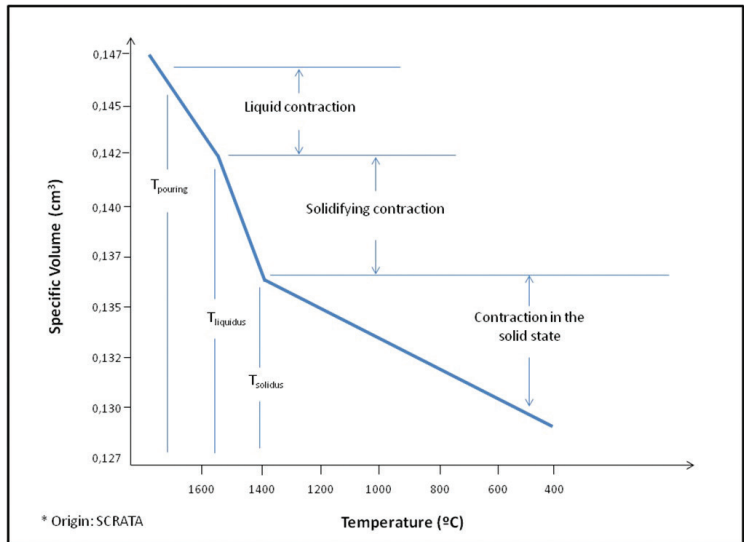


Fig.12 Modelling of the three contraction stages

solidification range of the alloy, finding that as the range increases the feeding system ‘works better’ (fig.11).

Metal Superheating

The criteria that are managed for the definition of an alloy’s superheating temperature are very subjective and its effect in the contraction is seldom considered.

In a generic way, it can be stated that as the superheating temperature is increased, the tendency to shrink also increases (fig.12).

When optimising the response of the IN-EXO mini-risers, the volume increment per each 100°C of superheating has been used as reference, which corresponds to values around 1%.

Metallurgical Considerations

The productivity and cost reduction advantages that come along with the yield optimisation must be added to a complete set of metallurgical improvements that have showed up in the different melts of the experimental stage. Amongst the discovered advantages, it is worth citing:

- Lower mould thermal inertia meaning a reduction in local thermal loads, which becomes a foundry related defect prevention tool (cracks, segregations, etc.).
- More favourable micro-structures and minimisation of the grain growth phenomena.
- Lower amount of scrap and higher material rotation. The furnaces are loaded with higher ingot percentages, which directly increase the quality of the metal.
- Lower material loss due to non-reusable in-house produced scraps (contaminated risers).
- Risers with reduced section can help avoid, in some cases, the annealing/tempering treatment needed to cut out the feeding system without generating cracks in the part.

Industrial Trials

With the objective of performing the industrial validation of the new feeding systems and generating a set of representative real part examples that show the competitive advantages achieved in the development of the ‘SUPERALLOY’ project, several real-foundry industrial trials have been performed.

The scheme of the melts has been pretty simple, since the use of traditional feeding systems and advanced ones has been compared, making clear the direct improvements in terms of yield.

The industrialisation stage has been carried out on components belonging to different customer-sectors, and consequently, good internal soundness has been established as an indispensable condition for the acceptance of every test.

In advance of each industrial assessment the corresponding preliminary validations are done, employing the thermo-physical characterisation of the new formulations as the input data for the calculations. Some examples are presented in the figures on the previous page, so the yield improvement that is achieved by applying the developed knowledge can be clearly visualised (figs.13 and 14).

CONCLUSIONS

The control over the simulation tools that are currently available, provided that the thermo-physical characteristics of the new formulations are properly implemented, allows a company to perform melts, even single part batches, bearing yield optimisation criteria at all times.

The feeding systems for any steel cast component can be successfully built with IN-EXO mini-risers, padding sleeves and well sleeves.

Net/gross yield outperforming 60% has been achieved, although the right design criteria must be employed and rigorously implemented into the process. Giving up the yield improvements means letting important competitive advantage opportunities go.

To be able to produce sound parts, free of shrinkage porosity and with high yields, the right correlation has been put in place between the metal superheating, the IN-EXO level of the feeding systems and the cooling capacities of the mould.

ACKNOWLEDGMENTS

Acknowledgement and recognition must go to the Ministerio de Ciencia e Innovación, for the support the authors have received in the INNOXCAST project (IPT-240000-2010-027) and in the 'SUPERALLOY' project, that have served as a basis for the preparation of this paper.

We would like to extend the acknowledgement to the people of the engineering and fabrication area of FONDESAL, since without their active implication it would not have been possible to finish these important developments and to all the foundries where this innovative technology was industrially tested.

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This paper was presented at the World Foundry Congress 2014 held in Bilbao in May 2014. It received second prize in the WFO Best Paper Competition. It is reprinted here with the permission of the World Foundry Organization, www.thewfo.com

LANCASHIRE BRANCH

Modelling and solidification simulation – 35 years of history in 35 minutes

The presentation at the October meeting was a joint one by Simon Olive FICME and Russell Grey of Magmasoft UK who are responsible for selling and support of Magmasoft throughout the UK and Ireland.

The talk outlined the history of Magmasoft from conception around 1980 to the current situation.

The talk gave the details of the company's initiation, its headquarters in Aachen (Germany), its research and development facilities, and how the company is structured worldwide employing nearly 300 people.

An abundance of Powerpoint images which included clarifying filling patterns of moulds, predictions to casting simulation and gas porosity, were discussed in detail.

Advances in software and hardware which have allowed Magmasoft to predict to casting engineers gas porosity, mechanical properties, oxide film formation, inclusion modelling, pre-oxide inclusions and the availability to solve machine shop problems as well as a host of other benefits were outlined in-depth.

The talk ended with a long and lively question and answer session.

After the talk, branch president Tom Hogan MICME presented Paul Wieckowicz IEng Prof MICME with the *Meritorious Services Medal*, which Paul was unable to receive at the ICME Awards Lunch, as well as a bottle of bubbly to branch secretary Ricky Cairns CEng Prof MICME which was a prize from ICME head office for a member recruiting competition.



Paul Wieckowicz IEng Prof MICME and Tom Hogan MICME



Tom Hogan and Simon Olive FICME



Ricky Cairns CEng Prof MICME and Tom Hogan

NORTH EAST BRANCH

David Corrigan Prof MICME, the retiring president of the North East branch, receives his Past Presidents Badge from Dave March FICME, the current president at the meeting on 20th September

