Computer Simulation & Analysis
- An Effective Tool for Methoding
(Some Case Studies)

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Abstract
In today’s fast paced market casting simulation is very useful to methods engineers. It cuts the casting development time as well as cost. Traditional casting development approach of pour & check is getting outdated, and export-oriented, quality conscious foundries are looking for more effective approach for rapid casting development. The paper presents some case studies highlighting the use of casting simulation by some foundries for defect prediction, analysis and removal, as well as for yield improvement and process optimization.

What is Casting Simulation?
Casting simulation is deliberate creation of certain foundry conditions that exist on the shop floor, in order to analyze and study the resulting casting for defect(s), if present, with the help of a computer, without actually pouring the casting.

Today various simulation tools are available in the market. These are capable of simulating almost every casting (as well as post-casting) process like sand casting, permanent mould casting, investment casting, low pressure die casting, high pressure die casting and others.

Why Casting Simulation is Essential?
In today’s competitive environment, foundry engineers need to use all the tools to produce high quality castings with minimum scrap and with ever shortening lead-time. Customers today demand world-class performance. This means continuous quality improvement, cost reduction and shorter lead-time.

By simulating casting process(es) on the computer one can see whether the proposed design will work to produce a sound casting, even before pattern(s), core box(es) or die(s) are made and before any metal is melted and poured. Hence one can understand the advantages of simulation over conventional approach of casting development (Figs. 1 and 2). If a foundry is using 3D modeling for tooling, the only additional cost is the “simulation”, as the same model can be (rather has to be) used for simulation.

Nowadays even simulation is not very costly, as one can get it done with the help of an outside agency providing simulation services.

Apart from predicting the resulting casting quality, one can also understand from the simulation, whether the required casting quality will be achieved or not. Figs. 3 and 4 highlight how effectively one can slash the casting development time by using simulation.

Case Studies
1. Rejection Analysis and Rectification
This case deals with a 2-cavity, resin-coated silica shell sand moulded grey iron casting for a water pump housing. About 30% castings were getting rejected due to shrinkage getting opened in the bore as shown in Fig. 5. The shrinkage was due to the lack of feed metal and early solidification of vent type riser kept directly above the defect. The problem was analyzed with the help of simulation software (Fig. 5). To rectify the defect a larger size riser having modulus slightly higher than the calculated value was tried (Fig. 6). But the yield was reduced and it was slightly difficult to adopt this method in actual process. To remove the defect and to improve the yield, we could evolve with the help of simulation, vertical methoding system with the pad near the defect area. The pad worked as a feed path to feed the metal (Fig. 6a).

2. Re-designing the Component
This case deals with a volute body cast in stainless steel, produced by investment casting. Due to some foundry limitations only single casting direct pouring system was demanded by the customer. In the suggested layout heavy shrinkage was seen on the bottom heavy section. The machined drawing of the component was studied, and it was decided to remove unnecessary extra allowance in the casting by providing circular groove (as shown in Fig. 7). While providing the groove, only minimum required machining allowance was retained.
Fig. 1 (Above): Conventional Approach of Casting Development

Fig. 2: New Casting Development Approach Using Simulation Software
3. New Casting Development

This case deals with a green sand flywheel casting produced in grey iron. In the customer's suggested method (Fig. 8) the castings were showing heavy shrinkage. Blind live risers were suggested (Fig. 9) to avoid the shrinkage at the given location in trial methoding. Live riser diameter and neck size were further modified (from that shown in Fig. 9) to produce defect-free casting.

4. New Development and Optimization

This case deals with a multi-cavity resin-coated silica sand shell-mould casting. Customer's requirement was to produce maximum numbers of castings per match plate. Initially we fitted maximum numbers of castings in 3D model by trial and error, taking into consideration all foundry parameters like minimum sand wall thickness, ease of pouring and feeding, ease of knock-out of the castings and sand heating. In the first layout shrinkage was observed in the casting opposite the ingate (shown in Fig. 10). Here direct top risers were suggested (as shown in Fig. 11) to avoid the shrinkage. Gating system was finalized for simultaneous filling of all the castings without much temperature drop.

5. Shrinkage Removal by Layout Modification

For a grey iron differential case casting, the customer suggested the initial methoding. Trial methoding was showing heavy shrinkage at top and bottom hot spots in the casting. It was due to lower height of live riser and insufficient feed path. The methoding was analyzed by simulation (Fig. 12), and changes were suggested in the methoding (as shown in Fig. 13) to eliminate the shrinkage.

6. Heavy Casting with Various Layout Components

For a 2-tonne steel casting produced by CO₂-silicate moulding process, a complicated layout was tried for simulation to study the resultant effect of various components. The methoding was finalized and then released for production (Fig. 14). The layout simulation study was complicated due to the use of various mould components like exothermic sleeves, refractory gating components, various chills at different locations and adopting simultaneous pouring from two sides.

7. Flow Analysis

For an aluminium gravity die-cast housing, the customer suggested vertical layout (Fig. 15). In flow analysis heavy temperature drop was observed for vertical layout, as the metal has to travel a long distance through the die before it enters the casting cavity. Layout was modified to horizontal system by down sprue sand core inserts (Fig. 16) in the die cavity and temperature drop was minimized.

Concluding Remarks

These case studies illustrate how casting simulation software can be effectively used to cut down casting development time from months to weeks. It allows foundry engineer to analyze and modify the methoding for producing defect-free castings. Rejection analysis, cost saving and process optimization is possible with creative use of simulation techniques.
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Cold Box System of Core-Making
(Answers to Some Shop-Floor related Questions)

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The author had delivered on 30-9-04 an informative presentation on this subject to the members of Ahmedabad Chapter of IF. He had listed five questions related to Cold Box System of core-making and had provided answers to these questions. Towards the end he displayed various slides to illustrate how to use the cold box system. The participants enjoyed the presentation.

Experts in Cold Box system may not find any new information in these questions-answers. Shop-floor foundrymen, who have just started practicing this process, will find the content useful. Foundrymen who are not yet familiar with the cold box process, and hence have not yet derived its benefits, will find the content informative. Please note, this is a presentation by an active shop-floor foundryman, practicing this process for last several years, for other shop-floor foundrymen. The questions and answers are presented herewith.

— Editor

Q. 1: What is the Meaning of "Cold Box"?

Ans.: Cold Box process, as the name suggests, is a process of core making in which the core is cured at room temperature, without the use of heat. "Cold Box" is a 3-part system. It is slightly different from the "No Bake" system. "No Bake" is a 2-part system, in which two chemicals are used — a Resin and a Hardener; whereas in "Cold Box" system three chemicals are used viz. (i) Resin, (ii) Hardener, (iii) Catalyst.

No-Bake system needs some time (several minutes) to make the core, whereas in Cold Box system, as the catalyst is used, core making is possible in seconds only (and not in minutes). The catalyst is in liquid form. When heated, it gets converted to gaseous form, hence the core gets hardened fast.

Cold Box process was introduced in the foundry industry in the year 1968 (i.e. 36 years back). Phenolic resins are being used in other core-making processes for years: curing by baking (since 1950); shell cores (since 1955); hot box cores (since 1965).

Q. 2: What are the Advantages of Making Cores by "Cold Box" process?

Ans.: Many Advantages
• Very good core finish
• Requires very low power as heaters are not used. Only compressed air and normal lighting power is required.
• Does not damage core-box, hence longer core-box life.
• Economical in comparison to resin-coated shell sand cores.
• Faster production rate (as the process is very fast).
• Very low gas generation during metal pouring.
• As very little gas is liberated, pin-hole and blow-hole defects are rare.
• Use of cold box core promotes faster metal cooling, in comparison to hollow shell cores; resulting in pearlite retention in (ferrous) casting, hence improved wear resistance of the casting.
• Overall effect: more dependable casting delivery.

Q. 3: Which Materials are used in Cold Box Process?

Ans.: Washed silica sand and the following three chemicals are used in this process: Resin (Part 1), Hardener (Part 2), and Catalyst (Part 3).

1. Washed Silica Sand

Grain Shape: Round shape is the best for strength, sub-angular shape is preferred to avoid veining defects.

Contaminants: Clay and Iron oxides are major contaminants. Lower the contaminants, better it is. Clay...
content in the sand should not exceed 0.3%. Oxides content also should not exceed 0.3%.

Moisture: Dry sand is preferred. For best results, moisture in the sand must be below 0.10%. Normal usable range is up to 0.25%. Above 0.25% moisture, core quality deteriorates rapidly because, (i) water reacts with Part 2; and (ii) water increases sand friability. As a result, presence of water lowers core strength, hardness, and rigidity, and renders the core more friable.

Acid Demand Value: Acid Demand Value is important because cold box resins react prematurely in basic environment. Bench life gets shortened with sands having high ADV. The best results can be achieved with ADV below 5. Sands with ADV between 5 and 20 are often used.

pH Value: pH is important because highly basic sands will tend to shorten the bench life of the prepared sand mix. (pH need not be checked if ADV test is conducted.)

Sand Temperature: Sands in the temperature range of 21-27 °C will give the best performance, even though these can be used in the wider range of 10-40 °C. Increase in sand temperature increases reaction rate in sand hopper. Therefore, hot sand shortens usable life.

Resin (Part 1): Resin itself is made up of 3 components: Phenol Formaldehyde resin, Solvent and Additives. P. F. Resin controls tensile and hot strength characteristics of the phenolic urethane system. Solvent is used to reduce the viscosity of the resin to a useable level. Additives improve core release and help in humidity resistance etc.

Hardener (Part 2): It is a Polyisocyanate resin. Its technical name is Methylene Diphenylene Isocyanate (MDI). A solvent is used to dissolve the resin. The solvent is a complex mixture of aromatic hydro-carbons. It (i.e. the solvent) does not interfere with the bond reaction. It also does not evaporate too quickly on hot sand. Additives (i.e. release agents) are added in the hardener.

Catalyst (Part 3): Tertiary Amine catalysts are strongly basic in nature. In Cold Box system the amines commonly used are triethylamine (TEA) and dimethylamine (DMEA).

Q. 4: What is the difference between Cold Box core and the core made by any other process?

• Cold Box core finish is superior to that of CO2 core.
• Cold Box cores produce very accurate size castings as compared to the castings produced using shell core, CO2 core and No Bake core.
• Cold Box core does not produce gas like the resin-coated shell sand core, and hence does not produce pin-hole and blow-hole defects.
• As compared to resin coated shell sand, less power is used in cold box core.
• Cold box core cost is low as compared to that of resin coated shell sand core.

Cold box core productivity is very high as compared to that of resin coated shell sand core.

Q. 5: What is the addition rate of the binder, the hardener and the catalyst?

Ans.: Normally, the binder is used at 0.8 - 1.0% of the weight of the sand used. The hardener is also used in the same proportion, i.e. 0.8 - 1.0% of the sand weight. Catalyst is used at 0.02% of the sand weight.

The binder, the hardener and the catalyst, all three are supplied in liquid form. The catalyst is converted into gaseous form by heating it (to not more than 40 - 60 °C) in the core shooter itself. It is introduced to the core sand mix in the gaseous form.

Q. 6: Are any additives used in the cold box sand?

Ans.: In most cases no additives are needed. In some applications, however, cold box cores produce veining defects in the casting. To overcome this problem, mill scale (i.e. black iron oxide, Fe3O4) can be added in the range of 1-3% of the sand weight. Mill scale should not be powdery, but its size should be comparable to the size of the sand grains. (If excessive mill scale is used, it may start producing sand fusion related problems.)

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