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Review of Casting Processes, Defects and Design

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Abstract **Casting is the oldest manufacturing method and well-known metallurgical process. Casting process basically involves introduction of molten metal into a mold cavity and subsequently the molten metal takes the shape of mold cavity. This paper presents an intelligent design environment to assist product engineers in assessing a part design for castability. The software simulates the way casting engineers decide the casting process, parting line, cores, mold box, feeders, gating system and mold layout, and analyzes each decision to suggest how the design could be modified to improve quality as well as reduce tooling and manufacturing costs. Usually there is more than one cause for the generation of nonmetallic subsequent to ladle metallurgy, and this paper briefly reviews several of the factors in liquid handling that remain as contaminating mechanisms It is argued that the clogging of the tundish-to-mold pouring system is due to nonmetallic formed primarily by reoxidation.**

Keywords — Casting types, Types of sands, casting defects, remedies, Design for Manufacture,

I. Introduction

Castings are one of the foremost metal shaping techniques known to mankind. Many battles were fought in early times which were won using arrow heads, spears, shields and hot oil cauldrons, one of the earliest castings mankind developed. Castings range from the humble chunks or hunks of low grade pig iron like those used as earth moving machinery counterweights, to those with complex non-ferrous metallurgical alloys which are used directly as precision parts like in the automotive industry. There are hundreds of casting processes, for thousands of metals and alloys for millions of parts which can be produced through castings. Apart from it being a basic low cost methodology for mass production of complex shapes and sizes which is the basic purpose or intent, castings can be used as far as ones fertile imagination exists. Time has never marred the importance of castings nor ever will, but yes technology has played an important role in making Castings more versatile, quicker, accurate, energy efficient and greener for the environment. Now with sophisticated I.T. tools, analysis and simulation softwares there is a revolution which has been bought across for the turnaround time to develop a casting and also how the casting would look like or behave when put to intended use.

In the casting manufacturing process solid metal is melted, which is then poured into the cavity which can also be termed as mould. The mould holds the molten metal which then solidifies and forms the desired component. Thus designs and shapes of high intricacy and detail can be achieved in a single step using casting process. Hence a designer can design and make any desired shape he wishes using metal casting process.

Casting components can vary in size, right from smallest component which can resemble the size of an ant to large components weighing in tons. There are numerous

II. Literature Review

A. Review Stage

From above discussion and findings, it is clear that many researchers have contributed to the optimization procedure by investigating various aspects of the casting process. They have mainly worked towards improvement in casting and elimination of defects such as differential cooling solidification, shrinkages, gating design, riser design, pouring conditions, porosity, mould wear, cold shunts and blow holes. advantages of casting for producing complex shapes, internal contours , irregular surface parts, long hollow sections, also for very large parts for which machining is difficult. Seeing all these advantages, casting is one of the most important manufacturing process. Process Optimization is necessary to improve the performance as per the industry standards. These performance members include improving productivity and cost by minimizing rejections. In the pursuit to achieve these improvements various process parameters such as runner and gate locations, shot pressure, number of risers, runner and gate shape, mould material and temperature of molten metal are needed to be optimized by controlling them efficiently.

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B. Final Stage

Casting is the foremost process in which broadly used methods for fabrication of metallic refurbishments outside the mouth. The technique of conducting casting is one of the oldest and most advanced of the metallurgical arts. The basic principle lying in casting is 'liquid observes to the shape of the vessel that clings it‟. The process consists of surrounding the wax pattern with a mould made of heat resistant investment material, eradicating the wax by heating and introducing the molten metal into the mould through a channel called "SPRUE". So during the process of casting there are chances of occurring defects. Minor defects can be managed but causing of occurring major defects can lead to more investment costs.

C. Types of Casting

1. Sand castings
2. Die castings
3. Investment castings
4. Permanent castings
5. Centrifugal castings.

D. Sand Castings

Sand casting is often utilized in industries For Instance: automotive, aerospace and design industries etc... To make parts of comprised of Iron, bronze, brass and aluminum. The metal of require is gets melted in a furnace at desired temperatures and poured into a mould cavity formed out of sand. This process is preferred because of inexpensive and relatively free of cost. However, flaws are very common in sand cast parts and these affects the properties of castings.

E. Die Castings

Die casting is a metal casting process that is characterized by forcing molten metal under high pressure into a mold cavity. The mold cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mould during the process. The casting equipment and the metal dies represent large capital costs and this tends to limit the process to high-volume production. Manufacture of parts using die casting is relatively simple.

F. Investment Castings

Investment casting is a manufacturing process in which a wax pattern is coated with a refractory ceramic material. Once the ceramic material is hardened its internal geometry takes the shape of the casting. The wax is melted out and molten metal is poured into the cavity where the wax pattern was. The metal solidifies within the ceramic mould and the metal casting is broken out.

G. Permanent Castings

Permanent mould casting is a metal casting process that employs reusable moulds ("permanent moulds"), usually made from metal. The most common process uses gravity to fill the mould, however gas pressure or a vacuum are also used. A variation on the typical gravity casting process, called slush casting, produces hollow castings. Common casting metals are aluminium, magnesium, and copper alloys. Other materials include tin, zinc, and lead alloys and iron and steel are also cast in graphite moulds.

H. Centrifugal Castings

Centrifugal casting or roto casting is a casting technique that is typically used to cast thin-walled cylinders. It is used to cast such materials as metal, glass, and concrete. It is noted for the high quality of the results attainable, particularly for precise control of their metallurgy and crystal structure. In the centrifugal casting process, molten metal is poured into a spinning die. The die can be spinning either on a vertical or horizontal axis depending on the configuration of the desired part. Ring and cylinder type shapes are cast vertically; tubular shapes are made with the horizontal centrifugal process. Either process may be used to produce multiple parts from a single casting. External structures and shaping can be cast in place to significantly reduce post- processing including machining or fabrication.

III. TYPES OF MOLDING SEND

- Greensand-It is aggregate of sand, bentonite clay, pulverized coal and water. The clay contain of green sand of 30% and water 8%.Clay and water are used for binding strength of sand. This sand is mostly used for ferrous and non-ferrous material. It is fine, soft and has good porosity.
- Dry sand-If the sand mould id baked in an oven, the moisture of this mould will be evaporated. This sand is called as dry sand. It possess major strength and used for large moulding.
- Loam sand-Loam sand is mixture of sand and clay with water. It contains 50% and 18% clay and water respectively. This is used for larger casting.
- Facing sand-The face of the mould is formed by facing sand. Facing sand is used directly next to the surface of the pattern and it comes in direct contact with the molten metal, when the molten metal is poured into the mould. It possesses high strength and refractoriness as it comes in contact with the molten metal. It is made of clay and silica sand without addition of any used sand.

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- Backing Sand-Backing sand or flour sand is used to back up facing sand. Old and repeatedly used moulding sand is used for the backing purpose. It is also sometimes called black sand because of the addition of coal dust and burning when it comes in contact with the molten metal.
- Core sand-The sand which is used to make core is called core sand. It is also called as oil sand. It is a mixture of silica sand and core oil. Core oil is mixture of linseed oil, resin, light mineral oil and other binding materials.

IV. Defects of Castings

The undesired irregularity in a metal casting process is called casting defect. Some defects are eliminated and some are repaired.

The three general origins of defects are:

- Casting design
- Technique of manufacture or the method
- Application of technique- workmanship

CATEGORIES OF DEFECTS

- Shaping faults in pouring
- Inclusions and sand defects
- Gas defects
- Shrinkage defects
- Contraction defects
- Dimensional defects
- Compositional errors
- Segregation

V. CASTING DESIGN TODAY

Casting continues to be the most preferred process to create intricate shapes in metal, but is alsoone of the most difficult to precisely model and control for achieving consistent quality. The range of variation in terms of geometric, material and process characteristics, and their uncharted effects on manufacturability makes every casting project a new challenge. It is no surprise that the foundry industry continues to suffer from poor utilization of material, energy and human resources: the average scrap rate is as high as 7% [1] and the average lead time to produce the first casting for approval is 10-14 weeks [2].

Today, casting engineers have access to a range of software, starting from database management and design calculations to process simulation and computer-integrated manufacturing, in increasing order of difficulty of installation and use. Of these, computer simulation of casting process has emerged as a powerful tool for achieving quality assurance without time consuming trials. Software packages for simulating the solidification of molten metal in the mold enable predicting the location of shrinkage defects and optimizing the design of feeders to improve the yield; more advanced packages perform coupled simulation of mold fillingand casting solidification [3]. It has been reported that simulation studies can reduce casting defects, manufacturing costs and lead time by as much as 25% [4]. Already, an estimated 1000 foundries (among 33,500 worldwide) are using simulation software to improve their performance and the number of simulation users is steadily increasing.

However, casting engineers only produce what product engineers design. Designers mainly focus on product function - creating an optimal shape to withstand operating stresses - aided by excellent Finite Element Analysis software available for this purpose. They are largely unaware of the casting processes, their capabilities and limitations [5]. This results in either over design (for example, unnecessary thick ribs leading to heavier castings) or under design (for example, inadequate fillet radius leading to casting defects). Many product features (for example, undercuts) require complex tooling, and others (for example, isolated mass concentration) require additional steps during casting (say, placement of chills). All these mean higher cost, lower quality assurance and longer lead time. Often, a product design causes severe problems at the casting stage, and the foundry may request the customer to either modify the design or pay a higher price to offset the costs of tooling modification, increased scrap and additional operations (such as heat treatment and machining). Significant design modifications at this stage could mean additional burden of redoing the tooling and planning the process again, besides losing the time and resources already spent on these activities.

Compared to the above, modifying the design of a cast product while it is still on the drawing board is as easy as erasing and redrawing a line. If the ratio of benefit to cost is considered, then it is immediately apparent that dramatic saving of resources can be achieved by predicting potential problems at the design stage itself, and preventing them through suitable changes to product features. This approach is termed Design for Manufacture.

VI. DESIGN FOR MANUFACTURING OF CAST COMPONENTS

Design for Manufacture (DFM) has caught the attention of both researchers and practicing engineers over the past one decade to bring about dramatic improvements in the ease of manufacture. The most popular method of DFM is reusing prior experience coded as design guidelines. Automobile companies were among the first to apply the principles of DFM to simplify product designs, particularly for machined parts, sheet metal parts and assemblies. One of the earliest examples was the Viper car project at Chrysler which was

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developed from scratch within 1 years and within budget. Gradually this approach has spread to the rest of engineering companies, many of them reporting savings of 20% of costs and 50% of time, besides improved quotations from vendors [6]. However, the guidelines may not be available for a radically new design (especially when new materials and processes are involved) and sometimes conflict with each other. Therefore many companies rely on design review committees (concurrent engineering team) comprising of experts in design, prototyping, tooling, manufacturing, marketing, maintenance and other areas evaluate the design and suggest modifications before it is finalized and released for further action. This is however, a reactive approach in which designers merely try to confirm the manufacturability of a particular design or improve it slightly. Product engineers need to be proactive and take advantage of the range of cast metals and processes to create a product which best satisfies the final requirements A.team of researchers from Concurrent Technologies Corp prescribed a combination of simulation-based DFM and Concurrent Engineering [7]. They visualized how castings will be designed and manufactured through electronic exchange of relevant information between designers and foundry engineers who may be using different CAD software specific to their tasks. However, simulation-based DFM of cast products calls for an in-depth knowledge of the process, as well as significant time and effort for design improvements. For this reason, very few engineering companies actually practice Design for Casting, including those who have captive foundries. Virtual prototyping of not only the casting process, but also the entire business has also been proposed [8], however any practical implementation of any such systems has not been reported so far.

VII. INTELLIGENT ASSISTANT FOR CASTING DESIGNERS

AutoCAST simulates the way casting engineers perform various tasks in casting design. The present work integrates the latest research work in parting line and cores [10], feeding [11], gating [12] and information management [13]. The entire casting design is analyzed using a set of castability criteria [14]. Depending on the results of the analysis, suitable design changes to improve castability are suggested through guidelines [15].

The software runs on Pentium computers with Windows-NT or Windows-95/98 systems. It comprises nine integrated programs for various tasks, linked by a casting project database manager. These enable casting design, castability assessment and concurrent engineering for the projects.

A. Casting Design

The design of the casting, which involves several decisions such as the orientation of the part in the mold, location of the parting line, design of cores, location and design of risers and gating channels and other casting elements such as feed-aids and filters, requires prior experience. In AutoCAST, this experience has been coded as a knowledge base of design heuristics. Further, toapply these heuristics to a given part, we have developed an advanced geometric reasoning engine, which can automatically 'understand' the shape of a cast part and suggest where to locate the parting line, riser or ingate. This helps the casting designer in speeding up his tasks.

The starting point for casting design is the 3D solid model of the part to be produced. The solid model can be created in CAD packages such as AutoCAD, I-DEAS, Pro-Engineer, SolidWorks or Unigraphics and exported in a standard format. Starting from this solid model, AutoCAST generates the complete casting design through several steps, which include casting orientation, mold box, parting line, cores, risers and gating. At the end of each step, the user has the option to provide his own suggestion for the corresponding design parameters. Given a part model, one iteration of casting design usually takes 20-30 minutes on a Pentium computer.

B. Castability Assessment

To assess the influence of casting design on castability – which is reflected in terms of quality assurance, costs (tooling and manufacturing) and lead time – we need to simulate the casting process. The latest approaches for analyzing the casting process, which combine the physics of solidification and filling with practical heuristics, have been implemented. This gives reliable results without the need for powerful computers.

Casting process analysis is supplemented with a criteria-based check of castability. This involvesanalyzing the shape of the part and the casting, as well as the results of solidification and mold filling analysis with a set of criteria. There are about twenty criteria, which include: part wall thickness, parting flatness, core length to diameter ratio, feeding efficiency, fettling of risers, difference between ideal and actual filling time, and others. Each criterion returns 100 if the casting design is ideal for the specific aspect, 0 if the casting cannot be produced, or an intermediate value. This provides a quantitative measure of the 'health' of the casting design for aset of aspects. Further, weights can be attached to the criteria and a cumulative assessment of the casting design can also be obtained.

Based on the results of criteria-based castability analysis, the software suggests illustrated guidelines for improvement. Each guideline comprises a pair of pictures, showing the problem and a possible solution, along with a written explanation.

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VIII. CONCLUSION

We also need to acknowledge the formation of front end integration for casting Industries in the form of engineering workshops to machine castings and finally offer the finished product ready for assembly and use. This was more a necessity and need. Though with all the technology, men and machines the defect free casting though minimised cannot be wished away or ruled out. Now Castings are produced in one country and exported to many others which is a global norm, due to many reasons which is another topic all by itself. The castings undergo machining in conventional machining centres & also in high end CNC machining centres. Discovering a casting blowhole or a defect after machining leads to the whole casting getting rejected and more often than not, the machining process is more expensive than the basic casting itself. Hence all major casting manufacturers have forward integrated to value add by creating castings and machining them to finished specifications themselves to ensure that the perfect end product reaches the customer and there is zero rejection.

Different types of possible defects on the work piece during casting have been reviewed. To control these defects, different remedies and causes are discussed. This study is useful for industries where casting is undertaken as a manufacturing process. This entire study is to minimize the casting defects and increase the standard of casting process. Design for Manufacture (DFM) has been successfully applied to machined, sheet metal and plastics parts to significantly reduce manufacturing costs and lead time. So far, it did not find wide acceptance in the casting sector owing to a lack of suitable software tool for this purpose. The Auto CAST software described in this paper aims to fill this gap. Early benchmarking results and beta tests have shown that it can be easily used by design engineers, who have limited knowledge of the casting process, to improve the design for ease of casting. This will enable product engineers to design more cost-effective parts through a better appreciation of the problems faced by casting engineers. It will also improve the level of communication between product, tooling and foundry engineers, leading to better and faster decision-making.

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