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A Literature Survey Of Methods To Study And Analyze The Gating System Design For Its Effect On Casting Quality

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Abstract

For the optimum design of gating system, the study of filling process is of great significance since it directly affects casting quality. The goal of proper mould filing cannot be achieved without proper gating design which influences the flow pattern, further affects the temperature distribution and modifies the progression of solidification. But it is not only expensive but difficult to observe the molten metal flow in the mould directly due to the opacity of sand mould.For the study and analysis of flow of molten metal through the gating system and into the mould cavity, many researchers have tried various techniques which can be broadly classified as direct observation method and through modelling the process by water analogy or by computational modelling.To get accurate and dependable prediction of the subtle transient events, one has to make a judicious combination of both methods for casting with an alloy system. Many researchers attempted to use numerical simulation techniques to analyse the molten flow through the gating system, which has an advantage to accurately predict subtle transient events and gain more profound information about the behaviour of metal stream. Considerable materials are available in literature to understand the influence of gating system design on mould filling using various techniques of direct observation validating the given design of gating system by using real time X-ray radiography to observe the flow of molten metal in a sand mould, or by using contact wire sensing method along with computerized data acquisition, or by using water analogy method to observe the flow of water in a transparent mould.Also few researchers attempted optimization of gating system in casting to control defects and maximize the effective yield of the cast products. This paper comprehensively review the available literature for various techniques to study, analyse and predict the flow behaviour of the melt in order to minimize the related defects arising due to melt flow and also increasing the effective yield of the casting with minimum effect on its quality.

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1. Introduction

Casting is the most direct and versatile process of manufacturing in which metal objects is formed by melting and pouring it into moulds. The quality of sand casting predominantly relies on different factors like the melt quality, Methodology for introducing the liquid metal into mould cavity and subsequent metal solidification. The study of filling process is of great significance, for the design of gating system. A well designed gating system should fill the mould quickly, yet quiescently, with minimum turbulence; promote directional solidification; minimize air aspiration thereby reducing re-oxidation and slag formation during mould filling. It should also prevent mould/core erosion and facilitate slag entrapment in the gating system prior to entry of molten metal into the cavity.
Many researchers have tried various techniques which can be broadly classified as computational modelling, physical experimentations (36). Some researchers attempted to use numerical simulation techniques to predict and analyse the molten metal flow characteristics, which has an advantage to accurately predict the subtle transient events and gain more profound information about the flow behaviour (3-11). Also, considerable volumes of materials are available in literature describing an efforts made to understand the influence of gating system design on mould filling either by using direct observation techniques like open mould and through a glass window , by real time X-ray radiography to observe the molten metal flow in a sand mould, by using contact wire sensors along with computerized data acquisition, or by water analogy method to observe the flow of water with tracers or coloured water in a transparent mould. Few researchers attempted optimization of gating system in casting to control defects and maximize the effective yield of the cast products.
This paper attempts to comprehensively review the available literature for various techniques to study, analyse and predict the flow behaviour of the melt, methods advantage and its limitation to analyse the flow characteristics in order to minimize the related defects arising due to melt flow and also increasing the effective yield of the casting with minimum effect on its quality.

2. Literature Survey

Different approaches for study, analysis & visualization of flow through the gating systems are attempted by various researchers through decades which has been presented in their research papers. The purpose of this section is to broadly classify & review the current status of research, pertaining to flow study. The existing literature can be broadly grouped as the methods that deals with: Computer Modeling; Water Modeling; Direct Observation; Contact Wire Sensors methods; and Optimization techniques.

2.1 COMPUTATIONAL MODELING

Early in 1965, Harlov et al. developed a new technique called Marker and Cell (MAC) for numerical investigation of time dependent flow of an incompressible fluid. Navier-Stokes equations were written in finite difference form with a finite time step advancement, while pressure and velocity components were the primary dependent variables. In early eighties (1981) C.W. Hirt developed a concept based on treating complicated free boundary configurations, which was simple yet powerful method called Volume of Fluid (VOF). This method was found to be more efficient and flexible than those existing methods for treating free boundaries. W.S. Hwang and R.A. Stoehr (1983) suggested the suitability of the approaches of fluid flow modeling useful for different purposes. They suggested the Bernoulli's equation approach and Saint Venant Equation approach to be useful for modeling flow of metal through full channels and partially filled channels, like sprue, runners and in gates, respectively. While Marker and Cell (MAC) technique to be useful for plotting the entry of metal with a free surface into the mould cavity. D.H.St.John et al. (1981) adapted a finite element model originally written for flood wave problem for calculating the free surface flow of liquid metals in down runners and gates. Flow patterns predicted by the models were compared with actual flows of metals in sand molds using X-ray technique and with flow of water in clear plastic systems and further refined the model. K.S.Chan et al. (1991) demonstrated a new 3 dimensional technique for handling air-liquid interfaces, as applied to metal casting process. Computations were performed to simulate two distinct filling problems, first dealing with slow filling of a large sand casting mould and other dealing with more rapid situation encountered in

PDC and results were compared against water model experiment. Interesting features learnt and analysed from results were surface behaviour such as waves on air voids. Also remedial changes in the casting geometry would able to be introduced to effect improvements. K.Venkatesan (1995) used a numerical model based on FLOW 3D, to simulate the transient, inertia dominated and complex cavity filling in HPDC. To check its accuracy, a comparison with water analogy results from literature was conducted and found to simulate well. Further experiments were carried out to evaluate the effect of gate velocity and fill times on the filling patterns in the dies, which indicated jetting and consequent air entrapments commonly seen even at large fill times. They found that critical factors determining a continuous fill pattern was gate velocity and not the fill time. It was also found that increase in gate area at identical fill times resulted in reduction in gate velocity. S. Sulaiman et al. (1997) carried out simulation of metal along the runner and gating system of PDC with the aid of FORTRAN program to find out the plunger pressure of the injection system during the casting process and to understand the effect of branch angle of the runner and gating system with four gates from 40o to 90o. The results showed that the smaller branch angle requires less plunger pressure and needs longer time to fill the system. Further S. Sulaiman et al. (2000) made a complete filling analysis by combining the network element method and fluid flow analysis to describe an incremental movement of flow front. They developed 2 dimensional scheme which can provide reliable results like pressure, velocity and temperature variation within the cavity. The authors further investigated the effect of draft angle in PDC over metal filling process and found that as the draft angle increases, cavity fill time increases. Also that the time required for filling is inversely proportional to flow rate. Paul Cleary et al. (2002) described the advances in modeling of casting processes using Smoothed Particle Hydrodynamics (SPH) in HPDC. They compared the simulation results of 2 GDC orientations using SPH and Magma soft, with experimental results from the corresponding Water analogue models. They observed that both the numerical methods were being able to predict the overall structure of filling process, but the natural free surface capability of SPH allows it to better capture the free surface wave behavior and fine details of the flow. X. Yang et. al(2004) proposed a numerical algorithm, Oxide film entrainment tracking (OFET 2D), for predicting oxide film defects distribution in the liquid aluminum throughout the filling & incorporated into the free surface tracking code developed for simulating filling. From simulations they found that the in gate velocities significantly affect the number & distribution of the oxide film defects generated from the filling. The reduction of in gate velocities can effectively reduce the defects, which can be achieved by the use of a vortex flow regime to dissipate the kinetic energy of the metal in the runner. Carlos Esparza et al. (2006) presented a methodology for optimization of 3D gating system using FDM programs. They chose two design variables: runner depth and runner tail slope for optimization. The optimization procedure when coupled with casting process simulator, enabled them to find a design of better quality. It was also found that starting the optimization with low values of runner depth and high value of runner tail slope yields better designs. Zhizhong Sun et al. (2008) proposed a Taguchi method based optimization technique for design of gating system using Magma Soft. Considering the multiple performance characteristics like filling velocity, shrinkage porosity and product yield, four gating parameters in-gate height and width and runner height and width were optimized. ANOVA was used to analyze the effect of gating designs on cavity filling and casting quality and found that runner height and width are the most significant factors contributing more than 80%. Shengyong Pan et al. (2010) presented a novel sharp interface for incompressible 2-phase numerical model for mould filling process. A simple discretization method and a density evaluation methods were proposed to overcome the difficulties while solving 2-phase Navier-Stoke's equation with large density ratio and viscosity ratios. The numerical method was to simulate three mould filling examples which were validated with two water filling experiments and one in-situ X-ray imaging experiment of pure aluminum filling. Y. Wang &R.A.Miller (2011) used CFD method to study the effect of runner design on the filling patterns of a HPDC die casting with 6 specimen cavities. Two runner designs were compared; one with constant cross section area main runner, & another with tapered main runner with cross section area reduced proportional to the volume ratios of the cavity. The application of the tapered runner design significantly improved the filling pattern in that filling time & pressure distribution were well balanced among specimen cavities with different volumes. Jun-Ho Hong et al. (2012) attempted an optimal gating system design by considering two diagnosis parameters, flow rate difference and arrival rate difference of molten metal flow patterns to study the complexity of the runner system using numerical system and comparing it with water analogue test model for a simple plate with eight in-gate combinations. From results the runner system with two in-gates at extreme ends and sprue at the Centre has most ideal results of minimum value of both parameters. In 2013, K.H.Renukananda et al. computationally compared the flow of water and LM6 aluminum alloy through a horizontal multi gating system using Nova Flow. The flow of water was compared with water modeling setup, in order to reduce the dependence on computation intensive CFD based simulation for quicker optimization of gating system design. The numerical comparison found that the volumetric flow rate of molten metal was about 1.7 times that of water. Though, the water modeling comparison confirmed the trend of discharge as in the previous literature which found higher flow rates from the last in-gate. Amir Baghani et al. (2013) also numerically studied the effect of sprue base size and design on flow patterns of aluminum gravity casting. Focusing on streamlines and velocity distribution, they found that the curved sprue base produced no vortex flow at the sprue bottom with nearly full contact between runner wall and liquid metal. In-gate velocity was dependent on distance between sprue and gates, gating system geometry and gating ratio while it was independent of sprue base system design. Hong Zhao & Li HengLuo (2013) explored the application of stepped gating system in LFC, by simulating their patterns using FLOW-3D. They studied 2 step gating systems: with & without auxiliary sprue and 2 gating system pattern density: filled with EPs & without EPS. The results indicated that with open gating system (ie. Without EPS), the liquid metal starts filling through all the in gates almost at the same time. And with an auxiliary sprue system, the flow of liquid metal volume goes on decreasing from first (bottom) in gate to the last (top) in gate. They concluded that the liquid metal volume through each in gate basically represents the way of horizontal movement velocity of liquid metal front. JianWenming et. al(2014) used numerical simulation of filling & solidification process for optimizing the gating system to eliminate the shrinkage porosity of an aluminum alloy intake manifold casting with the initial design, the filling of molten metal was not stable & the casting does not follow sequential solidification causing shrinkage porosities. The gating system was improved step by step based on simulation results. Finally the casting practice validated the simulated results with smooth surface & good internal quality casting.

2.2 WATER MODELING

PD Webster (1967) investigated the flow of metals in runners; in first stage confirmed previous findings of ratio of sprue to runner for aluminum alloys to be in the range of 1:3 to 1:1.5 In IInd stage he studied the flow patterns at the sprue-runner junction using water models as well as sand molds with fused silica glass window. The study found a considerable contraction of the stream of metal at the point of junction causing suction of gases into metal stream which results in defective casting. F.J Bradley et. al.- (1992) presented a hydraulic based model for calculating the flow distribution the approach used was a pipe- node- path representation of the of the gating system for analysis of complex 3-D configurations. Computer simulations of total flow and flow distribution in a pouring cup plus sprue-runner-2 in-gate horizontal gating system were compared with water modeling and experimental results were found in good agreement with each other and with reasonable agreement with previously published molten steel experimental results. Van Der Graaf et al. (2001) studied the bottom filling process of a thin, vertical plate cavity. Visualization experiments of the mould filling process were carried out with a water in a Perspex model and with as cast iron and aluminum in a sand mould provided with a glass front. Such observations explored the behavior of the liquid surface and in case of liquid metals, gave an impression regarding temperature distribution and velocity fields across the cavity. Both CFD results and DPIV provided quantitative data about the surface behavior and velocity pattern during stages of filling. Although CFD results and DPIV findings do not completely agree quantitatively but the trends were similar. Fu-Yuan Hsu et. al.(2009) proposed a diffusing runner that could reduce the flow velocity under the critical velocity of 0.5 m/s without flow separation from runner wall. A CFD package and water analogy method were employed foe exploring and verifying the new designs. The efficiency of the diffuser was quantified by measurement of coefficient of discharge Cd. Analysis of results showed that, Kinetic energy had been efficiently transformed into pressure head through this diffuser while preventing the harmful oxide films and bubbles. JinwuKang et. al(2013) presented a new water analogue model, assembled by slices of transparent glasses cut by laser cutting machine, to simulate the filling process of a heavy steam turbine housing casting. The water filling process was observed &analyzed. It was found that there was an alternating flow in the gating system resulted by different height & position of in gates which is also responsible for uneven filling. The design was improved & it was proved to be more effective through experimental study. M. Afsharpouret. al. (2014) investigated the effects of pouring basin and sprue design on bubble entrainment phenomena during pouring and molds filling using several transfer water models of gating system which were imaged and subjected to computer image analysis. Results showing the amount of bubbles in mould cavity as a means to compare efficiency of the investigated pouring basin and sprue design. The results concluded that the base design was of barriered basin. While other recommendations for sprue design were, reducing sprue diameter and slope for a sprue well for reduction of bubble entrainment. K.H.Renuknanada et.al. (2012) in his initial paper made a comparison of discharge through multiple gate horizontal runner using Nova soft simulation and water modeling setup with centre sprue and slide sprue arrangement. The results matched with the previous literature trends of discharge and also established the ratio of discharge between the different gates. K.H.Renuknanada (2013) the authors compared the flow of water and LM6 aluminum alloy using numerical simulation and water models to investigate the effect of number of gates open on the total discharge across various combinations of open gates and found different for each combination. It was concluded that while both metal and water flow showed similar trends, the volumetric flow to molten metal was about 1.7 times that of water. As in previous studies K.H.Renuknanadaet. Al. did not validated result with actual metal flow experiments. In this paper (2015), investigated to check the validity of water models for understanding the flow of liquid metals. Three fluids were considered for experiments: Al-Si alloy, zinc and water with the parameter of interest were flow sequence, velocity and discharge through four gates. It was found that the proportion of flow through the four gates found to be nearly same for all three fluids, while the first gate filled first and the last gate had maximum volume of discharge. The results established the usefulness of water models to investigate mould filling in metal casting and provided valuable insights for balancing the flow through multiple gate. V. Jaigenesh and K. Prakasan in his initial paper (2013) concerned their work with the hydraulics and flow characterization in the pressurized, horizontal gating system using transparent water models applied scaling factors for length and scaling to obtain maximum similitude with real casting. Flow behaviour was visualized in down sprue, runner, in-gate and mould cavity using water model and real casting in sand moulds. By comparing the difference in flow behaviour in both approaches, they found that the flow becomes less turbulent with increase in aspect ratio and also reduction in pouring hight can control mould entry velocity. In ability of water model to predict the possibility and degree of turbulence was also observed. V. Jaigenesh and K. Prakasan (2015) the author studied the influence of hydraulics and geometric variables on discharge variation across the gates using Taguchi's technique. The factor selected were metallostatic head, runner aspect ratio, Gating ratio and types of gates. ANOVA was applied to determine statistically significant factors and their percent contribution and found that Gating ratio was having a maximum influence on discharge variation.(followed by runner aspect ratio, head and type of gate).In their latest paper V.Jaiganesh (2016) investigated the hydraulics and flow behaviour of an aluminum alloy .They conducted their experiments in two parts using runners and 2 ratio and four types of in-gates Flow measurement experiments were conducted to measure the discharge and velocity through each in-gate and understand the influence of hydraulic and geometric variables. Flow visualization experiments were conducted for direct observation of flow behaviour in critical sections of the gating system and mould cavity using water modeling and real time experiments with molten metal in sand moulds. Comparison of filling pattern provided an useful insight into the performance of gating system. From Ist part it was found that the gate farthest from sprue. IInd part concluded that rhe transport of turbulence into runner is inevitable for all runner aspect ratio, but can be minimized by using wide and shallow runner. It was also observed that during major portion of fill time the entire cross section of gates were not utilized, which could to air aspiration.

2.3 DIRECT OBSERVATION

J.Runyoro and Prof. J.Campbell (1991) investigated the efficiency of various sprue'smoulded in sand by demonstrating maximum allowable in-gate velocity by video recording the direct observation of metal emerging from vertical in-gates moulded in sand. They tested velocities from 0.1 to 2.0 m/s and found that at 0.50 m/s metal emerges from in-gate by simple flooding without leaving the mould wall contact, while at 0.85 m/s mushroom jet formation was observed. It was also found that drag co efficient was minimum when sprue taper is approx. twice of theoretical. S.M.H. Mirbagheri et al. (2003) compared experimental results of casting of aluminum alloy with transparent mould to verify the developed mathematical model based on SOLA-VOF technique which was modified to take into account the effect of gas pressure and coating permeability during filling stages of mould cavity. M. Masoumi et al.(2005) studied the effect of gate geometry and size on the flow pattern by pouring molten metal of aluminum alloy into a sand mould. Direct observation by fixing a grid glass in the cope was used for video recording and was further analysed by computerized system. The result showed that an increase in width of gate with constant thickness resulted in three different patterns of metal front as narrowing, expansion and deviation. NielsSkatTiedje et al. (2011) investigated the factors that control velocity in different parts of the gating system, with a focus on local pressure in the gating system. For analysing how the gating system geometry influences the pressure field in the liquid. They used the combination of direct observation experiments and numerical modeling to analyse how pressure waves are formed and how they influence the melt flow in the initial phase of mould filling.

They found that the filling time and flow pattern compare well, but was different from free surfaces. They also recommended the use of streamlined gating system that can suppress shock waves and hydraulic jumps, to confine and guide the melt on its way to the casting.Zhao Haidong et al. (2008) established a mould filling simulation model, taking into account the mass, momentum and energy transfer within free surface elements to describe its shape and location. The simulation results were compared and verified with X-ray observation of actual mould filling process of the casting where the liquid flowing in the runner and in-gate as well as evolution of free surfaces were analysed. They found that when using pressurized feeding system and sand mould with good air permeability, back pressure of gas in the mould cavity has minor effect on changing the liquid metal flow. Mark Jolly et al. (2009) investigated the L-Shaped junction in running and gating system using aluminum gravity casting using computational modeling. They conducted a three part experiment in which the first and the second part they explored 2-D and 3-D model of L junctions. In the final part, a 3-D L junction geometry was constructed with in a runner system and casted under x-ray facility for its validation and studing the filling sequence of runner system. They quantified the efficiency of sprue runner junction by measuring co efficient of discharge Cd. The value of Cd for a single gate system was quantified as 0.70, while for multiple gate was to be 0.68, indicating the casting fill time to be 1.43 times longer than friction free condition and 30% overall frictional loss. Zhao lei et al. (2011) attempted an in-situ observation of porosity formation during directional solidification of two Al-Si alloys at near eutectic (13% Si) and hypo eutectic (7%Si) by using a micro focus X-ray imaging. Observation of porosity formation was conducted in the X-ray temperature gradient system (XTGS). From the radiographic images analysis it was found that in near eutectic alloy, spherical pores nucleate and grow in the liquid melt ahead of eutectic S/L interface, while in hypo eutectic alloy, it grows into irregular morphology in confined inter dendritic region. Thus the different porosity morphology of two alloys attributed to two different solidification modes between. S. G. Liu et. al(2015) studied the effect of pressurizing speed of low pressure casting mold filling & mechanical properties of A356. The mold filling behaviour was calculated by 2-phase flow model using VOF method. Real mold filling process was observed by X-ray radiography & was compared with the simulated results for accuracy. For low pressurizing speed, the mold filling velocity first increases dramatically, then kept unchanged, while it increased slowly under high pressurizing speed. High gate velocity caused the melt falling back under gravity with high speed, resulting in a rotating vortex which cause oxide film entrainment in LPC. The mechanical properties of the as cast A356 alloy were measured by Four point bend test.

2.4 CONTACT WIRE SENSOR METHOD

S.H. Jong and W.S.Hwang (1992) demonstrated the contact time technique to study the filling phenomena in two industrial castings in order to get information regarding the filling sequence, ratio among multiple in-gates and the last filled areas, which are important to evaluate the appropriateness of the running/gating system and to verify the accuracy of theoretical predictions of the mathematical modeling techniques. They also developed a software to transform the measured contact times into graphical patterns. It was found to be useful to provide information concerning the in mould phenomena, as it was easy to operate and claimed to be cheaper technique as compared to water modeling technique. It was also noted that this method is more suitable for castings of thin sections due to sensor wires were recommended to be inserted near the mould surface in order not to interfere with melt flow. Laurence Gaston et al. (2000) presented a 2-D finite element approach for a non-steady turbulent fluid flow with free surface, based on a velocity-pressure finite element Navier-Stoke's solver. They made 3 comparisons between numerical results and experimental results to illustrate the efficiency of this approach. The first one was with the presented approach and its validation with the second one in a mould filling in effective casting conditions and the third one with the help of water modeling. In the experimental work, a 3-dimensional mould equipped with contact sensors. The contact sensors were activated when the metal touches them and the activation time was recorded and the flow advance was tracked. It was found that the simulated flow was in good agreement with the measurements of the filling made by contact sensors. J.H. Kuo et al. (2003) developed a mathematical model to simulate the filling pattern in LFC and validated by equating the results with the experiments conducted with thermocouples embedded in the pattern of LFC by measuring the temperature data and filling pattern. In temperature measuring and recording system, the progress of the molten metal front inside the pattern was monitored by inserting a probes of K-type thermocouples (0.18 mm Dia.) surrounded by a ceramic tube (2 mm OD), which were connected to data acquisition system. The four thermocouples located at strategic locations detected the contact time of the metal front, indicating the sequence of metal front and cooling during solidification. J. kang (2003) developed a measurement system of liquid metal filling based on modified contact time method (MCTM). The filling of measured points was illustrated by a LED pattern and the filling time of all the points for analysis were obtained by recording a video. The method was free of limitation of signal acquisition channels, thus the filling at 100 positions ware measured and the filling profiles and filling velocities were obtained, which reflected the features of its filling process. They investigated the influence of some parameters like metallostatic head, density of EPS pattern, thickness of casting and permeability of sand mould on the filling process. The results showed that the front moves forward by the effect of initial speed and gravity during filling the area below the in-gate. Above the in-gate, the filling was stable, but slower than the lower half. It was also found that both height of sprue and the coating thickness have strong effect on the filling process. J. Kang et al. (2013) developed a wireless measurement system for filling process of the casting based on contact time method and an observation system based on high speed camcorders working under high temperature. By using these 2 systems, they observed and measured the filling process of a turbine blade and a hub castings. The velocity of the liquid steel in the mould was obtained by the calculation of filling time. The study showed that the two systems operate conveniently and reliably, also are effective tools for monitoring the filling process of the castings and future optimizing of the gating system.

2.5 OPTIMZATION TECHNIQUES

In order to improve the effective yield of the cast item & overcome the defects like Shrinkage, Gas Porosity, Slag inclusion etc.. Many researchers studied optimization of gating systems on the basis of Taguchi methods, Numerical simulation, Gradient Search method, Genetic Algorithm techniques. While few has used techniques like Response Surface Methodology (RSM), Artificial Neural Network (ANN), & Fuzzy Logic (FL) for modeling the process parameters for sand casting. S. Guharaja et al. (2006) attempted to obtain optimal settings of the green sand casting process in order to yield the optimum quality of castings. He considered process parameters considered for analyzing the effect of green strength, moisture content, permeability, & mould hardness & its levels on casting defects & subsequent optimal settings using Taguchi's parameter design approach. E focused on robustness of the green sand casting process. From the results of study he found that the application of Taguchi's method improved the productivity of the casting, also increased the stability and yielded optimized control of factors. Application of Taguchi's method reduced the casting defects of the molding process resulting in higher product yield. R. S. Ransing et al. (2006) reviewed a variety of optimization methods to undertake the optimization work in casting processes & emerged with two parallel streams of research strategies that took on the challenge, using either numerical modeling tools or the geometric reasoning techniques. They provided an overview of some achievements in the field of casting optimization by various researchers, who defined the objective functions for optimal feeder/riser design & implemented efficient sensitivity analysis. On the other hand reviewed the work to achieve similar objectives based on their methods on geometric reasoning techniques, to produce defect free castings. Guohang Zhang et al. (2014) presented an overview of using optimization techniques in casting numerical simulation. It used new software tools that actually use simulation results to help the user design of increased efficiency rigging system, to provide highest process yield while still guaranteeing casting quality. They proposed that once an acceptable design has been developed & been proven with simulation results, it is further submitted to automatic process optimization, Opti-Cast software starts automatically to change the parameters, & then evaluate the results of simulation again, until it finds the best combination between casting quality and yield, thus improving the design efficiency & making simulation more intelligent. NedeljkoDucic et al. (2016) presented a methodology of optimization of the gating system for sand casting using Genetic algorithm. Numerical simulation package Magma soft was used to verify the validity of the optimized geometry of the gating system. The geometry of the gating system was subjected to optimization with the objective to maximize the filling rate within the constraints posed by both the in-gate module & Reynolds number. Mold filling time was presented as a function of in-gate cross section & casting height. The proposed methodology provided a smooth, uniform, & complete filling of the mold with molten metal. Importantly, this methodology can also be applied to parts of complex geometry & gave significantly better results than the previous casting systems in terms of cast quality & yield. Girish Dutt Gautam et al. (2016), in their paper emphasizes the development of mathematical models for correlating the various green sand casting parameters on the average percent defects for achieving higher quality casting products by using Multiple Computer Aided Technology (MCAT's) such as RSM, FL, & ANN to predict average percent defects (%AD). The casting process parameters were used as inputs to the RSM, FL, &ANN to predict the %AD with mean average percentage error of 4.54%, whereas ANN model could predict with 1.79% error & RSM could predict with MAPE of 1.9%. Thus the model accuracy of FL model is worse than ANN & even RSM model.

3. CRITICAL SURVEY

A large number of investigations linking gating parameters with casting quality have been carried out by researchers and foundry engineers over the past few decades. A lot of efforts has been made to understand the influence of gating systems design on mould filling using various techniques. Computational modelling and physical experiments are the most commonly used for it. But it is important to verify computational model of mould filling with physical experiments. Numerical simulations have been widely used in research and production. However, the simulated results are been doubted due to lack of validation. As physical models are rooted in the minds of researchers, so they had attempted different methods to investigate the flow characteristics. Among them, water analogy was used for investigating flow characteristics of simple castings. The advantage is that the flow pattern is clearly visible in all parts of the gating system and mould cavity. An open mould or a temperature resistant transparent quartz glass window can be used to observe the melt flow. This method is most suitable for experimental study of thin section cast specimen. Development of high intensive X-ray provided a new method of using X-ray with high speed camera to capture the mould filling sequence in an opaque sand mould. This method is suitable for experimental study, but is limited by casting size and thickness, expenses, & safety issues. Also contact time method where a set of sensor wires connected to a circuit detects the melt flow front & calculate the filling speed. The temperature of the metal can also be detected using thermocouples wrt. time and solidification rate as well as direction can be determined by connecting it to computerized data acquisition system, but too many wires may cause trouble in production. Improper design of gating system influences the casting quality and lead to casting defects. Thus the optimization technique is important to improve the performance of the process. To get accurate and dependable prediction of the subtle and transient events, one has to make judicious combination of computational modelling and physical experiments to predict and analyse the behaviour of the molten metal through the gating system. This will give an advantage of being able to study the internal flow and gain more profound information about the behaviour of the melt stream.

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