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Analysis of Casting Defects using Casting Simulation Technique and Using Design of Experiment: A Review

Atul A. Bhujugade[#1], V B. Sabnis[*2]
[#]*Mechanical Engineering Department, Karmaveer Bhaurao Patil college of Engineering & Polytechnic, Satara.
Shivaji University, Kolhapur, INDIA.

***Abstract*— 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 mould enable predicting the location of shrinkage defects and optimizing the design of feeders to improve the yield; more advanced packages perform coupled simulation of mould filling and casting solidification. Simulation is the process of imitating a real phenomenon using a set of mathematical equations implemented in a computer program. In Casting simulation the mould filling and solidification analysis is done by using an algorithm or program based on finite volume method, to identify the hot spots and hence defects like shrinkage, hot tears, cracks, etc. [4]. In casting processes, there are various parameters which works at different levels may influence the casting defects. For each type of defect, several causes have been listed under differing categories such as design, moulding and pouring/melting related parameters. The literature review indicates that Taguchi Method is the best option for Design of Experiments. This paper reviews the various literatures on the casting simulation technique and DOE for casting defects analysis**

Keywords— *Casting defects, Casting simulation, Taguchi method, Optimization, Quality.*

I. INTRODUCTION

Foundry industry suffers from poor quality and productivity due to the large number of process parameters, combined with lower penetration of manufacturing automation and shortage of skilled workers compared to other industries. Global buyers demand defect-free castings and strict delivery schedule, which foundries are finding it very difficult to meet. Casting defects result in increased unit cost and lower morale of shop floor personnel. The defects need to be diagnosed correctly for appropriate remedial measures; otherwise new defects may be introduced. Unfortunately, this is not an easy task, since casting process involves complex interactions among various parameters and operations related to metal composition, methods design, molding, melting, pouring, shake-out, fettling and machining. For example, if shrinkage porosity is identified as gas porosity, and the pouring temperature is lowered to reduce the same, it may lead to another defect, namely cold shut. Casting defects analysis is the process of finding the root cause of occurrence of defects in the rejection of casting and taking necessary steps to reduce the defects and to improve the casting yield. Techniques like cause-effect diagrams, design of experiments (DoE), casting simulation, if-then rules (expert systems) and artificial neural networks (ANN) are used by various researchers for analysis of casting defects.

II. LITERATURE REVIEW

V. V. Mane et al. [1] The principle of manufacturing a casting involves creating a cavity inside a sand mould and then pouring the molten metal directly into the mould. Casting is a very versatile process and capable of being used in mass production. The size of components is varied from very large to small, with intricate designs. Out of the several steps involved in the casting process, moulding and melting processes are the most important stages. Improper control at these stages results in defective castings, which reduces the productivity of a foundry industry. The casting process has a large number of parameters that may affect the quality of castings. Some of these parameters affecting quality are controllable, while others are noise factors. There are several guidelines for the design of green sand casting parameters.

In casting processes, there are various parameters which works at different levels may influence the casting defects. For each type of defect, several causes have been listed under differing categories such as design, molding and pouring/melting related parameters. The focus of the design of experiment is on the robustness of the casting parameters. The literature review indicates that Taguchi Method is the best option for Design of Experiments.

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Taguchi approach is suitable in using experimental design for:

(a) Designing and developing products/ processes so as to be robust to component variation;

(b) Designing products/processes so as to be robust to environmental conditions; and

(c) Minimizing variation around a target value.

B. Ravi [2] Explained that simulation is the process of imitating a real phenomenon using a set of mathematical equations implemented in a computer program. In Casting simulation the mould filling and solidification analysis is done by using an algorithm or program based on finite volume method, to identify the hot spots and hence defects like shrinkage, hot tears, cracks, etc.

The simulation programs are also based on Finite Element Analysis of 3D models of castings and involve sophisticated functions for user interface, computation and display. The casting model (with feeders and gates) has to be created using a solid modeling system and imported into the simulation program. In addition, material properties (density, thermal conductivity, specific heat, latent heat, etc.) and process parameters (pouring time, pouring temperature, and casting-to mold heat transfer coefficient) have to be provided by the user.

H.C. Pandit et al. [3] Methods design is usually carried out manually on the part to be cast. The tooling is then fabricated; trial castings are produced in the foundry in trial run in small batches, and inspected. If these castings contain defects, then the methoding is modified and the process is repeated. Each such iteration can take up several days which delays delivery schedule is lead time and hence the customer is dissatisfied. After a few iterations, the foundry may find the best alternative for the methoding which may help to solve the problems stated earlier. It may also help to increase yield, reduce the rejection rates This is especially true in the case of large castings, where the cost of a trial or repair can be prohibitive.

B.Ravi [4] Casting simulation can overcome the above problems: virtual trials do not involve wastage of material, energy and labour, and do not hold up regular production. However, most of the simulation programs available today are not easy-to-use, take as much time as real trials, and their accuracy is affected by material properties and boundary conditions specified by users. The biggest problem is the preparation of 3D model of the casting along with mold, cores, feeders, gating, etc., which requires CAD skills and takes considerable time for even simple parts. Methoding is an important task in casting production, directly affecting casting quality and yield. It involves several decisions, such as the size of mold box and number of cavities, orientation. Casting simulation is used to modify such method and to get best alternative of process.

B.Ravi [5] Explained that Optimization is the process of finding the best way of using your resources, at the same time not violating any of the constraints that are imposed. By "best" we usually mean highest profit, or lowest cost. Even after spending significant resources (man-hours, materials, machine overheads and energy) for casting development, one of the following situations may arise during regular production.

(a) Under design: resulting in high percentage of defective castings. This usually happens when the number or size of feeders and gating elements are inadequate, or their placement is incorrect. Sometimes the cause is an undersized neck or a thin intermediate casting section, which prevents feed metal flow from the feeder to the hot spot inside the casting.

(b) Over design: leading to acceptable quality level, but poor yield and thereby higher cost. In this case, the number and/or size of feeders and gating elements is much higher than their respective optimal values. This situation usually arises because of lack of time or resources to fine-tune the methoding solution or to try other alternative solutions.

(c) Borderline design: irregular defect levels during regular production, although sample castings are defect-free. This happens when the methoding solution is just optimal (perhaps by accident), which will produce good castings only under controlled conditions. This is difficult to expect in practice, especially with manual molding and pouring.

B.Ravi [6] focused on casting simulation because it has proven its benefits. The software also facilitates electronic exchange of information between product, tooling and casting engineers, improving the level of communication between them and helping compress the total lead time to complete a project. They are developed over several years and involve several hundred thousand lines of code. The casting model (with feeders and gates) has to be created using a solid modeling system and imported into the simulation program.

In addition, material properties (density, thermal conductivity, specific heat, latent heat, etc.) and process parameters (pouring time, pouring temperature, and casting-to mold heat transfer coefficient) have to be provided by the user. The latter may require extensive experimentation to customize the software databases for a particular organization. After executing the simulation routine, the results can be post-processed to view color-coded temperature profile, velocity vectors or residual stresses.

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S. Guharaja et al. [7] Did optimization of CO_2 casting process parameters using Taguchis design of experiments. They found that CO2 casting process involves large number of parameters affecting the various quality features of a final product. They Considered weight of co2 gas, mould hardness number, sand particle size, percentage of sodium silicate, sand mixing time, pouring time, pouring height, pouring temperature, and cooling time of poured metal as process parameters.

Rahul C. Bhedasgaonkar et al. [8] combined design of experiments and computer assisted casting simulation techniques to analyze the sand related and methoding related defects in green sand casting. They have made many attempts to obtain the optimal settings of the moulding sand and mould related process parameters of green sand casting process of the selected ductile iron cast component. Casting simulation technique used for shrinkage porosity analysis by introduction of a new gating system and solid model developed for four cavities mould. Number of iterations using casting simulation software was performed for mould filling and solidification analysis to reduce the level and intensities of shrinkage porosities in cast component. Taguchi based L18 orthogonal array was used for the experimental purpose and analysis was carried out using Minitab software for analysis of variance (ANOVA) by considering green sand related process parameters considered are, moisture content, green compression strength, and permeability of moulding sand and mould hardness

Achamyeleh A. Kassie et al. [9] did statistical analysis in order to optimize process parameters. They observed that gas defect and shrinkage defects are major defects in steel castings. They have studied four process parameters such sand to binder ratio, mould permeability, pouring temperature and deoxident amount in three levels. Nine experiments conducted using Taguchi's DoE by changing selected variables.

Sandeep.v. Chavan et al.[10] explained that casting defect analysis and optimization using computer aided casting simulation technique plays vital role in manufacturing of metal parts and determining various casting defects. They found that the gating system is very critical to a die-casting die, but designing the gating system is an iterative process that can be very time-consuming and costly. They have carried out finite element analysis which consists of data collection, CAD model design, simulation and optimization.

III. CONCLUSIONS

The correct identification of the casting defects at the initial stage is essential for taking remedial actions. Analysis of defects like shrinkage porosities computer aided casting simulation technique is the most efficient and accurate method. The quality and yield of the casting can be efficiently improved by computer assisted casting simulation technique in shortest possible time and without carrying out the actual trials on foundry shop floor.

Design of experiments method such as Taguchi method can be efficiently applied for deciding the optimum settings of process parameters to have minimum rejection due to defects for a new casting as well as for analysis of defects in existing casting.

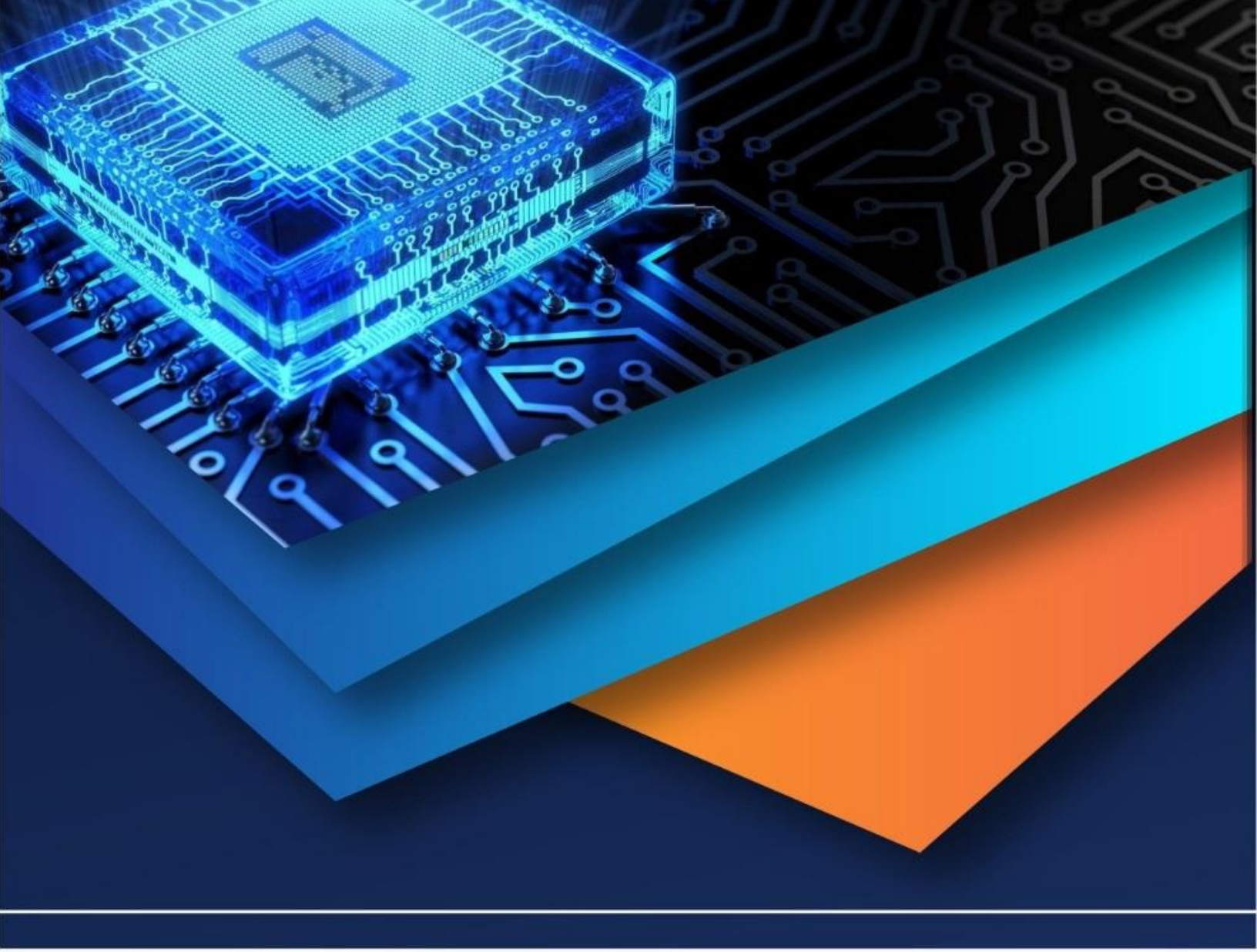
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