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Optimization of Green Sand-Casting Process Parameter of Foundry Industry by Taguchi Method : A Review

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ABSTRACT

A pattern is used to create cavities in a porous, reflective material, typically sand, and then liquid metal is poured into the voids, taking on the shape of the cavities to form the desired metal product. This process is known as casting. Many process variables in the green sand casting process have an impact on the casting quality. The goal of this review paper is to use the Design of Experiments method, such as the Taguchi method, to optimize a green sand casting process parameter. The Taguchi Method is a potent approach to tackling issues that can raise productivity, yield and process performance. Using Taguchi analysis, the impact of various process parameters at various levels on casting quality can be analysed and the various parameters can be tuned to their ideal values.

Keywords: Green Sand Casting, Casting Defect, Taguchi Method and Analysis of Variance (ANOVA)

I. INTRODUCTION

Due to the low cost of raw materials, the vast variety of castings in terms of size and composition and the potential for recycling the moulding sand, green sand casting continues to be one of the most popular casting techniques in use today. Given that it can be utilized for the majority of metals and alloys with high melting temperatures, including iron, copper and nickel, green sand casting is one of the production methods with the greatest versatility. In the green sand casting method, molten metal is poured into a sand mould, allowed to solidify and then the sand mould is separated to reveal the casting product. Depending on the needs of the customer, complicated shapes in a range of sizes are produced using green sand casting. Making a pattern, getting a mould ready, pouring molten metal into it, chilling the mould, shaking it out and fiddling are the basic casting requirements. The most common reasons for casting rejection include incorrect patterns, poor gating systems, poor sand management and incorrect compositions of the molten metal.

Dr.Taguchi has introduced several new statistical concepts which have proven to be valuable tools in the field of quality improvement. With exceptional success, several Japanese manufacturers have adopted his methodology to enhance the quality of their products and processes. W.E. Deming made the observation that 85% of bad quality is attributable to the production process and just 15% to the worker, and Taguchi has expanded on this idea. As a result, efforts have been undertaken to create production systems that are resistant to daily and seasonal variations in the environment, machine wear and other outside influences. Instead of making an effort to check the quality of a product as it moves down the manufacturing line, Taguchi processes an off-line strategy enhancement. He notes that the inspection, screening, and salvage processes cannot be used to enhance products of poor quality. No amount of inspection will be able to restore the product's quality; instead, it will just address the symptom.

Sir Ronald Fisher created the ANOVA in the 1930s as a tool for analysing the outcomes of agricultural studies. It is a straightforward technique with a lot of mathematical beauty that may be used as an impartial decision-making tool to identify any variations in the average performance of tested groups of objects. The decision considers variation rather than relying solely on judgement. The term "analysis of variance" refers to a group of statistical models and related processes in statistics that divide the observed variance into components resulting from various sources of variation. ANOVA offers a statistical test to determine whether the means of various groups are equal in its most basic form. The discussion of ANOVA will begin with a fairly straightforward scenario, no-way ANOVA and progress to more involved circumstances, like three-way ANOVA. ANOVA can be used with any set of data that has some structure, but it can also be employed in experimental settings that make use of orthogonal arrays. The designs of the experiments and the following analysis are inextricably linked. Two controlled parameters in the experimental condition are used in the experimental two-way ANOVA. In a two-way ANOVA, the total variation can be broken down into four categories: error, variation due to factor A, variation due to factor B, variation owing to the interaction of factors A and B. The total variation from the above is calculated, and the numbers of degrees of freedom are calculated. The F-test for variance comparison is used to determine whether these estimates are significantly different, with a degree of confidence.

II. LITERATURE REVIEW

Guharaja (2006) [1] made an effort to get the ideal green sand casting process parameters in order to produce the best possible spheroidal graphite cast iron rigid coupling qualities. Using Taguchi's parameter design technique, it was possible to determine how several process parameters, such as green strength, moisture content, permeability and mould hardness affected casting defects.

Jai Ganesh (2008) [2] stated that the tool for different process variables and its effect for reducing process variation is DOE. He selected Coimbatore based jobbing foundry for data collection of selected components based on consistency in production and number of defects. Pareto diagram was constructed to find vital few defects and it were observed that sand inclusion defect contributes to more than 50% of rejection. He used DOE to reduce the process variability and sand inclusion rejection percentage. ANOVA was done to calculate percent defects due to sand. The conclusion was drawn that the GCS, mould hardness number and moisture are factors responsible for sand inclusion defect.

Rasik Upadhyaye and Dr. Ishwar P Keswani (2012) [3] by increasing the signal to noise ratio and reducing the effects of noise components, the study enhanced the sand casting process parameters. To make the sand casting process more efficient, they applied the Taguchi method. A number of important factors were taken into consideration, including moisture, sand particle size, green compressive strength, mould hardness, permeability, pouring temperature, pouring time and pressure test. Based on the Taguchi Approach, they chose three different levels for experimentation. Major internal flaws such sand blow holes, pinholes, scabs, mould cracks and sand drops were seen. For the analysis, they used an L18 Orthogonal array. For each repetition, the signal to noise ratio is calculated. Determine the ideal parameters.

Suraj Patil (2015) [4] analysed green sand casting process using DMAIC method. The study was performed based on the casting part as Transmission case. They prepared input variables versus output variables matrix. They had given the rating to input variables to a relationship with output variables out of 10. Based on the higher ranking they selected various parameters like Green strength, mould hardness and pouring rate were identified. They selected the L9 orthogonal array for the experimentation. The effect of casting parameters on the casting defect was evaluated with the help of Taguchi Analysis. The optimum parameter setting was identified from the mean sand inclusion defects.

V.V.Mane and M.Y.Khire (2017) [5] analysed green sand casting process and optimized using Taguchi method and Grey relation analysis method. Defective castings have analysed to identify major casting defects such as shrinkage, blowholes by using Pareto chart. The Taguchi technique was used to measure a range of process parameters, including green compressive strength, permeability and loss on ignition, carbon equivalent, AFS number, mould hardness, active clay, and moisture content. Multi objective process parameter optimization is performed using grey relation analysis.

KarthickKumar and Arul Shankar (2018) [6] optimized green sand casting process using Taguchi based grey regression method. Percentage contribution of input parameters on output response was determined using ANOVA. They identified critical parameters like moisture content, green compressive strength, permeability, pouring temperature. They used L27 orthogonal array for experimentation.

Aloni, S. N., Chaudhari, S. S., and Shrivastava, R. L. (2020) [7] work presented the primary focus is on the investigation of the essential parameters of the green sand casting process for effective understanding of most influential parameters which affects the persisting defects in gray cast iron components. The study applies the Taguchi's 'design of experiments' approach for determining the optimal level of parameters to minimise the persisting defects in the foundry industry producing cast components required in the automotive, factory situated in central India. Besides, a mathematical model has been developed using multiple regression analysis for an individual defect. The outcomes of this study assure that the approach used in this work is useful to foundry industries to minimise the casting defects.

Vikas Yadav, Gaurav Kumar, Mukesh Kumar and Peeyush Vats (2021) [8] Taguchi's method and design of experiment are used to analyse sand and mould related defects. Standardization (optimization) attempt is done to obtain optimum values of process parameters by taguchi's method whose experimental approach of design is robust. The parameters affecting the process are chosen as sand grain size, clay content, moisture percentage, pouring temperature, pouring time, green strength, permeability, mould hardness, number of vent holes and number of ramming etc. An orthogonal array L27 is selected which is based on taguchi. In this study a cast iron alloy (FG260) retainer used in tractor is focused.

III.TAGUCHI APPROACH

According to the literature review, the Taguchi technique is the best choice for experiment design when several process parameters are involved. In experimental design, the Taguchi approach is appropriate for creating and manufacturing reliable goods or processes, regardless of variation in process parameter (within predetermined limitations) or variation in ambient variables.

The current study is focused on the sand casting process, which influences casting quality by involving many parameters at various levels. By choosing the ideal values for the process parameters of the green sand casting, the Taguchi method is employed to minimise the percentage of rejection caused by sand and moulding associated problems.

The methodology used to achieve optimized process parameters using DoE is as given in table:

Table 3.1 Optimized Process Parameters Using DoE Methodology

STEP 1 ⇩	Pick any sand and mold-related flaw that you have seen. Set the process settings with the goal of achieving "reduced casting faults"
STEP 2 ⇩	Determine the parameters with the greatest impact on casting flaws using a cause-and-effect diagram.
STEP 3 ⇩	Determine the parameters' values. Execute the experiments (trial castings) in accordance with the DoE (Taguchi method), then gather the data.
STEP 4 ⇩	Utilize statistical tools to analyse the data. The statistical significance of the parameters can be ascertained by doing an analysis of variance (ANOVA). To establish the preferred amounts of parameters taken into account for experimentation, means plots might be generated.
STEP 5	Choose the best control parameter settings and run confirmation studies then put the procedure into action.

IV. CONCLUSION

From the above review, by minimizing the effect of the reasons of variation without completely removing them, the Taguchi method's core concept is evidently helpful in the green sand casting process in terms of improving product quality. The Taguchi technique has demonstrated its efficacy in predicting the ideal casting parameters to achieve the best green sand qualities. By choosing the optimal performance under circumstances that result in a constant performance, this process allows the desired design to be finished. The Taguchi approach identifies the key influencing factors and offers a systematic, simple and effective methodology for the optimisation of close to optimal design parameters using just a few well-defined experimental sets.

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