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OPTIMIZATION OF GREEN SAND CASTING PROCESS PARAMETER BY TAGUCHI METHOD: A REVIEW

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Abstract. Casting is a age old production technique wherein cavities are formed by a pattern into a porous and refractive material, usually sand, and then liquid metal is poured into the cavity so that it takes up the shape of the cavity, thus forming the required metal product. Green sand casting process involves many process parameters which affect the quality of the casting produced. The objective of this review paper is to optimize green sand casting process parameter by Design of Experiment method such as Taguchi method. The Taguchi Method is a powerful problem solving technique for improving process performance, yield and productivity. Using Taguchi analysis the effect of various process parameters at different levels on casting quality can analyze and optimal setting of the various parameters can obtained.

Keywords: Green sand casting, Casting Defect, Taguchi Method, ANOVA.

1 INTRODUCTION

Although there are many new advanced technologies for metal casting, green sand casting remains one of the most widely used casting processes today due to the low cost of raw materials, a wide variety of castings with respect to size and composition, and the possibility of recycling the molding sand. The Green sand casting process is one of the most versatile processes in manufacturing because it is used for most metals and alloys with high melting temperatures such as iron, copper, and nickel. The Green sand casting process consists of pouring molten metal into a sand mold, allowing the metal to solidify, and then breaking away the sand mold to remove a casting product. Green Sand casting is used to manufacture complex shapes of various sizes depending upon the customer requirements. The basic requirements casting are pattern making, preparing a mold, pouring a molten metal, cooling of mold, shakeout, fettling. The main causes of rejection in castings are due to improper pattern, improper gating system, improper control of sand parameters, improper molten metal composition.

Dr.Taguchi has introduced several new statistical concepts which have proven to be valuable tools in the field of quality improvement. Many Japanese manufacturers have used his approach for improving product and process quality with unprecedented success. Taguchi has built upon W.E. Deming's observation that 85% of the poor quality is attribute to the manufacturing process and only 15% to the worker. Hence an attempt has been made to develop manufacturing systems that are robust or insensitive to daily and seasonal variations of environment machine wear and other external factors. Taguchi process an off-line strategy improvement in place of attempt to inspect quality into a product on the production line. He observes that poor quality can not be improved by the process of inspection, screening and salvaging. No amount of inspection can put quality back into the product, it is merely treats a symptom .Therefore, quality concepts based upon and developed around the philosophy of prevention. Taguchi experimental design a suitable for a wide range of application but his techniques have commonly been applied to what he classifies as "Off Line Control". He distinguishes three phase of off-line quality control as system design, parameter design and tolerance design. However, parameter design is the primarily key stage in improving product or process quality. Parameter design is using to dampen the effect of noise (reduced variation) by choosing the proper level for control factors. Parameter design is used to improve quality without controlling or removing the cause of variation, to make the product robust against noise factors.

ANOVA (Analysis of Variance) was developed by Sir Ronald Fisher in the 1930s as a way to interpret the results from agricultural experiments. It is not a complicated method and has a lot of mathematical beauty associated with it and is a statistically based, objective decision-making tool for detecting any differences in average performance of groups of items tested. The decision, rather than using pure judgment, takes variation into account. In statistics, analysis of variance is a collection of statistical models, and their associated procedures, in which the observed variance is partitioned into components due to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether or not the means of several groups are all equal. The discussion of ANOVA will start with a very simple case, no-way ANOVA, and build up to more comprehensive situations such as three-way ANOVA. ANOVA can also be applied to experimental situations utilizing orthogonal arrays, although this analysis method can be used with any set of data that has some structure. The experimental designs and subsequent analyses are intrinsically tied to one another. In the experimental two-way ANOVA there are two controlled parameters in the experimental situation. In two-way ANOVA total variation may be decomposed into: variation due to factor A, Variation due to factor B, variation due to the interaction of factors A and B and variation due to error. After calculating the total variation from the above, number of degrees of freedom are calculated. F-test for variance comparison is carried out which provides a decision at some confidence level as to whether these estimates are significantly different.

2 LITERATURE REVIEW

Rasik Upadhye[1] discussed to optimize the sand casting process parameters of the castings manufactured in iron foundry by maximizing the signal to noise ratios and minimizing the noise factors using Taguchi method. The process parameters considered are moisture, sand particle size, green compression strength, mould hardness, permeability, pouring temperature, pouring time and pressure test. The results indicated that the selected process parameters significantly affect the casting defects in the foundry. The improvement expected in reduction of casting defects is found to be 37.66 percent. The optimum conditions for the factors computed are:

Moisture (%) – Level 1 – Minimum 3.5
Green compression strength (g/cm^2) – Level 1 – Minimum 900
Permeability – Level 2 – Minimum 185
Pouring temperature (deg. Celsius) – Level 3 – Maximum 1420

The improvement expected in minimizing the variation is 37.66 percent which means reduction of casting defects from present 6.16 percent to 3.84 percent of the total castings produced in the foundry.

Lakshmanan Singaram[2] applied Taguchi method by considering parameters like Green strength, moisture content, permeability and mould hardness. The outcome of his research is the optimized process parameters of the green sand casting process which leads to improved process performance, reduced process variability and thus minimum casting defects. **Uday A. Dabade and Rahul C. Bhedasgaonkar [4]** analyzed the optimized levels of selected process parameters obtained by Taguchi method are: moisture content (A): 4.7 %, green compression strength (B): 1400gm/cm2, permeability number (C): 140 and mould hardness number (D): 85. With Taguchi optimization method the % rejection of castings due to sand related defects is reduced from 10 % to a maximum upto 3.59 %. 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.

B. Senthilkumara, S.G. Ponnambalamb, N. Jawaharc[3] optimized pull down defects in iron casting by identifying parameters like pouring temperature, carbon equivalent and gating system are more significant. The identified factors were analyzed using 'Design of Experiments' approach. 'Signal-to-noise' ratio was estimated. Robust design factor values were estimated from the 'signal-to-noise' calculations. ANOVA analysis was done for robust design factor values. It was identified that the optimized values had improved the acceptance percentage from 86.22% to 96.17%.The improved acceptance percentage had enhanced productivity of the foundry.**G.P.Syrcos[5]** analyzes various significant process parameter of the die casting method of AlSi9Cu13 aluminium alloy. An attempt has been made to obtain optimal setting of the die casting parameter,in order to yield the optimal casting desity of the AlSi9Cu13 aluminium alloy casting.The process parameters considered were: piston velocity (first and second stage), metal temperature, filling time and hydraulic pressure.The result indicated that the selected parameter significantly affect the density of AlSi9Cu13 aluminium alloy casting.**Satish Kumar, Arun Kumar Gupta, Pankaj Chandna[10]** analyses different parameters of pressure die casting to minimize the casting defects. Pressure diecasting is usually applied for casting of aluminium alloys. Good surface finish with required tolerances and dimensional accuracy can be achieved by optimization of controllable process parameters such as solidification time, molten temperature, filling time, and injection pressure and plunger velocity. Overall 2.352% reduction in defects has been observed with the help of suggested optimum process parameters.

G.O. Verrana, R.P.K. Mendesb, L.V.O. Dalla Valentinaa[15] discusses the application of a design of experiments (DOEs) experimental method for analysing the influence of three injection parameters (slow shot, fast shot and up set pressure) on the internal quality of die casting SAE 305 alloy parts. The quality assessment of the die casting parts was based on density measurements and qualitative image analysis. Results were evaluated by means of variance analysis, which assessed how the variation in the three different injection parameters influenced the integrity of the components

3 TAGUCHI APPROACH

The Taguchi method is a well-known technique that provides a systematic and efficient methodology for process optimization. It has been widely used for product design and process optimization worldwide. This is due to the advantages of the design of experiment using Taguchi's technique, which includes simplification of experimental plan and feasibility of study of interaction between different parameters. Lesser number of experiments is required in this method. As a consequence, time as well as cost is reduced considerably. Taguchi proposes experimental plan in terms of orthogonal array that gives different combinations of parameters and their levels for each experiment. According to this technique, the entire parameter space is studied with minimal number of necessary experiments only. Based on the average output value of the quality characteristic at each parameter level, main effect analysis is performed. Analysis of variance (ANOVA) is then used to determine which process parameter is statistically significant and the contribution of each process parameter towards the output characteristic. With the main effect and ANOVA analyses, possible combination of optimum parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the process parameter design.

4 TAGUCHI METHODOLOGY

The Taguchi method can be applied by using eight experimental steps that can be grouped into three major categories as follows:

• Planning the experiment: (1) Identify the main function of casting process. (2) Identify the quality characteristic to be observed and the objective function to be optimized. (3) Identify the control factors and their alternate levels. (4) Identify noise factors and the testing conditions of the process. (5) Design the matrix experiment and define the data analysis procedure.

• Performing the experiment: (6) conduct the matrix experiment.

• Analyzing and verifying the experimental results: • (7) Analyzing the data, determining the

Optimum levels for the control factors, and predicting performance under these levels: • (8) Conducting the verification (also called confirmation) experiment and planning future actions.

The basic steps for achieving the above target are summarized below

1. Improving the quality of green sand casting through process control, keeping the effects of uncontrolled parameters at a minimum level.
2. Analyze and select the most significant parameters that affect quality characteristics (Casting Defects)
3. Select an appropriate orthogonal array and suitable levels of parameters. Collect related experimental data.
4. Analyze the data using DOE software and generate ANOVA table, interaction graphs and response graphs.
5. Predict the result of new parameter at their new optimum level.
6. Verify the result in the predicted improvement in the casting defect.

5 CONCLUSIONS

From the above review, it is clear that in green sand casting process, the fundamental principle of the Taguchi method helps to improve the quality of a product by minimizing the effect of the causes of variation without eliminating them. Taguchi method has proved its success in prediction the optimum casting parameters to reach the best properties green sand. In this methodology, the design desired is finalized by selecting the best performance under conditions that produce a consistent performance. The Taguchi approach provides systematic, simple an efficient methodology for the optimization of near optimum design parameters with only a few well-defined experimental sets and determines the main factors affecting the process.

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