STUDY OF SAND COMPOSITION ON MOULD PROPERTIES AND SELECTION OF TAGUCHI ORTHOGONAL ARRAY FOR DESIGN OF EXPERIMENTS

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ABSTRACT

The quality of castings in green sand mould is influenced by its properties such as green compression strength, green shear strength, permeability etc. The relations of these properties with the input parameters like sand grains size, shape, binder, clay is complex in nature. Binders play a vital role on green sand mould to enhance specific mould properties. The mould properties such as compression strength, permeability, hardness & shear strength have been studied & comparison have made with different binders. As per the study, for steel casting, we require 3% to 5% moisture content and 7% to 9% clay content respectively. Cause and effect diagram has been used to identify the different caused for casting defects. For optimizing the mould properties, Taguchi parametric design is studied and L9 orthogonal array is selected to find out optimal solution.

Key words: Permeability, Green compression strength, Taguchi parametric design, Cause and effect diagram

1. INTRODUCTION

Casting is one of the important and versatile processes of manufacturing. Its prime purpose is to form solid or hollow objects, parts, etc. of desired shapes, sizes, etc. Incorrect sand condition result in the production of scrap. It is for this reason that majority of foundries today require costly laboratories for controlling existing foundry sands and for testing new sands to discover their foundry suitability. Foundry sand control can only by testing of all the raw materials; sands, binders, and additives prior to the preparation of the sand mix. Sands found in different locations can have wide variations in surface, physical, and chemical characteristics due to environmental, ecological, climatic and geological factors. Different sands have different foundry properties. One cannot therefore be sure of the suitability of a sand for casting a given metal until standard necessary laboratory tests are properly carried out on it.

Permeability is defined by the AFS as the physical property of molded sand, which allows the gases to pass through it. It is determined by measuring the rate of flow of air (2000 cm^3)

through the metric standard rammed specimen (Ø50 mm×50 mm in height) under a standard pressure (10 g/cm^2). The amount of clay and moisture content has a significant role in improving the strength and permeability of green sand mould and it should be controlled to get defect free castings. For example, green sand properties for a mould prepared by using a jolt /squeeze machine are water (3-4%), live clay (5.5%) and permeability (80-110) while for the mould prepared by using a high pressure are water (2.5-3.2%), live clay (6-10%) and permeability (80-100) .

Clay (Bentonite) act as a binder, mixes with water to bind the sand particles and can be maintained in the range 5-7% to produce mould with better refractoriness and higher permeability If the clay content is higher in the sand mixture, the permeability is lowered due to fine clay particles occupied in the available spaces between the sand grains.

Water content in the mixture of 1.5% to 8%, activates the clay in the sand, causes the aggregate to develop plasticity and mold strength. Without water addition, no strength would be achieved, as the sand and clay would be just two different dry materials Too little water fails to develop adequate strength and plasticity where sands and clays grains are combined together apart thus the permeability is very poor. The clay adsorbs the water up to a limiting amount. Only the water rigidly held (adsorb) by the clay appears to be effective in developing strength and permeability. The development of bond strength between the grains depends upon on the hydration of clay. The green strength and permeability of a moulding mixture increases with water content up to an optimum value determined by the proportion of clay. Above this value, an additional % of water causes the permeability to diminish due to the increasing of the thickness of the water films. So, the clay becomes soft, lose its bonding power and less stiff and the sand grains are held further apart thus decrease the strength. Therefore, excess moisture must be avoided since it lowers the permeability and increases the chance of a blown casting. At the same time, plasticity and deformation of the mould will occur. Low permeability and green compression strength encourage the entrapment of gases and the washing away of sand by molten metal.

Figure 1 shows the effect of increasing the water content and the comparison between the sand mixtures bonded with 4% and 6% clay on the permeability of the moulding sand.

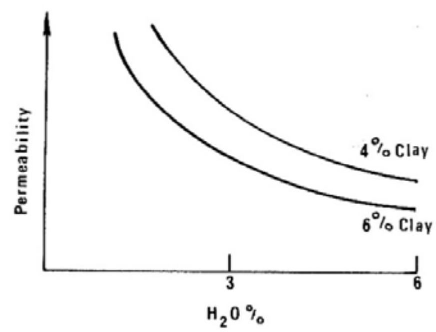

Figure 1: Effect of moisture content and clay on permeability

2. TAGUCHI METHODOLOGY

The Taguchi method involves reducing the variation in a process through robust design of experiments. The Taguchi method was developed by Dr. Genichi Taguchi of Japan who maintained that variation. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varies. This allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources.

2.1 The Taguchi process

- Problem identification
- Brainstorming Session (identify: factors, factor settings, possible interactions, objectives)

- Experimental Design (Choose orthogonal arrays, design experiment)
- Run Experiment-Analyze Results
- Confirmation Runs

2.2 Parameters and level selection:

Cause and effect diagram is constructed as shown in Fig. 2 to identify the casting process parameters that may influence green sand casting defects. The process parameters can be listed in five categories as follows:

- Mould-machine related parameters
- Cast-metal related parameters
- Green-sand-related parameters
- Mould-related parameters
- Shake-out-related parameters

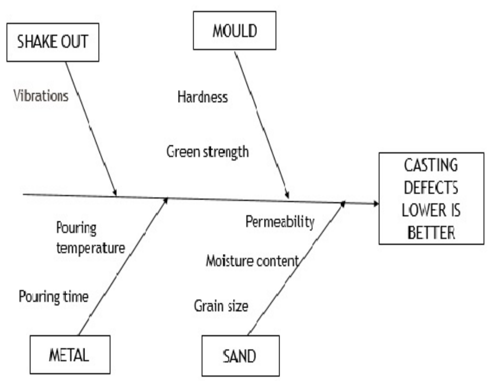

Figure 2: Cause and effect diagram for casting defect

From Fig. 2, we observe that sand related and mould related parameters are selected because, they have major impact on occurrence of selected casting defects. The selected casting process parameters, along with their ranges, are presented in Table 1.

Table 1: Parameters and their levels

Parameters	**Level 1**	**Level 2**	**Level 3**
Silica grains	Type 1	Type 2	Type 3
Clay %	7	8	9
Moisture %	3	4	5

Cause and effect diagram is a quality control tool that enables one to a systematic listing of causes (factors) that may lead to performance deviation or poor quality (effect). It is also called as fish bone diagram because of its appearance. This approach defines the problem clearly and lists all the possible factors contributing to the problem. It must be prepared after a brainstorming session and after gathering the opinion of as many people as possible in order to identify all the relevant factors (or causes). From Figure 2 it is clear that for this case the Signal to Noise ratio required is lower is better.

For lower-is-better characteristic, we use following equation:

$$\frac{S}{N} = -10log10 \sum_i \frac{y_i^2}{n} \tag{1}$$

2.3 Selection of orthogonal array

Once the problem is identified and the factors contributing to the problems are listed in the form of Cause and effect diagram, the next step is to identify the appropriate number of variables and the range (treatment levels) over which these variables would be tested. A design matrix is then constructed between the number of variables and the range over which they are tested. This type of specially designed matrix is called Orthogonal Array (OA).

Table 2: Rules for selecting orthogonal array

(When level and parameters are same)		(When level and parameters are not same)	
Number of Factors	**OA to be Used**	**Number of Factors**	**OA to be Used**
2-4	L_9	2-3	L_4
5-7	L_{27}	4-7	L_8
		8-11	L_{12}
		12-15	L_{16}

A Taguchi OA is denoted by $L_N(S^m)$, where ‘N’ is the number of experiments/test to be conducted, ‘S’ is the levels at which these experiments is to be conducted, ‘m’ is the number of variables/factors chosen in an N×m matrix, whose columns are mutually orthogonal. That is, for any pair of column, all possible combinations of factor levels appear equal number of times. For example, if a process is identified which consists of three variables and each variable has to be run at three different levels, then the actual number of experiments to be conducted will be 27 experiments have to be performed for optimizing a process. This design is called full factorial design. However, in many practical situations it is sufficient to run only a fraction of these full factorial experiments. This helps conserve both time and other valuable resources; therefore, for three factors running at three levels, one may obtain much information by conducting only 9 experiments using L9 (3^3) OA of 9×3 matrix (as given by Taguchi's standard OA) rather than conducting 27 full factorial experiments as shown in Table 3. The various OAs can be obtained from Taguchi's standard catalogue which is widely used.

Table 3: L_9 Orthogonal array

Experiment run	Level 1	Level 2	Level 3
1	1	1	3
2	1	2	2
3	1	3	1
4	2	1	2
5	2	2	1
6	2	3	3
7	3	1	1
8	3	2	3
9	3	3	2

CONCLUSION:

For improving the quality of casting we have to select the sand properties in appropriate range. For this we have to optimize the process parameters like silica grains, moisture and clay content. For this the knowledge of sand properties and effects should be known. The authors have investigated the desired ranges of process parameter for improving the quality by Taguchi. The L_9 orthogonal array was selected to carry out the further experimentation.

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