CHAPTER I

INTRODUCTION

Huge quantities of various types of sand systems as basic materials for moulding and core making are being used in the metal casting industries. But a considerable loss is incurred by the casting manufacturers for rejections due to improper sand control. Most of the sand systems are highly complex in nature due to the large number of variable factors encountered at different stages of operations. Thus it is necessary to obtain the proper combinations of the variable factors that would yield the optimum properties of the sand systems. It is also necessary to understand the effects and interactions of the variable factors on the properties and behaviour of the sand systems for an effective control.

A survey of the past work shows that exhaustive investigations have been carried out in most of the sand systems now in use in the metal casting industries, but mainly by classical methods of single-factor experiments, so as to understand the underlying phenomena in each of them and various recommendations have been made for sand control. The synthesis of such investigations is done by trial and error principle and theory is taken into account for explaining the results obtained. Further, as a consequence of such investigations the optimum sand mixtures developed, if any, is only a matter of chance. Again such optimal conditions frequently demand changes as the characteristics of the basic raw materials and environmental conditions keep on changing from time to time and hence the investigations must be repeated in line with the recommended methods. Naturally, the classical method of single-factor experiment involves a large number of trials over a prolonged period of research with consequent demand on effort and money and yet the interactions between the variable factors cannot be brought out clearly. Thus a methodology is desired whereby the results of investigations are easy to process for the search of optimal conditions and to secure maximum amount of information about a sand system in a short period by spending least amount of money, materials and efforts.

The process of optimization can be made easier, if a mathematical relationship between the measurable properties of a sand system and the variable factors involved can be established. Since the properties and behaviour of a sand system are controlled by the variable factors, the former may conveniently be expressed as a function of the latter as below.

$$Y_i = F(X_1, X_2, \ldots X_i, \ldots X_n) \qquad \ldots \quad (1.1.1)$$

where Y_i represents any of the measurable properties of a sand mixture and X_i represents the variable factors involved. Here, the function 'F' may be called the response surface. This function can be presented in the form of a polynom (in a limiting case),

$$Y_i = \beta_o + \sum_{i=1}^{n} \beta_i X_i + \sum_{i \neq j=1}^{n} \beta_{ij} X_i X_j + \ldots \qquad \ldots \quad (1.1.2)$$

where $\beta_o, \beta_i, \beta_{ij}$ .... are called the regression coefficients and equation (1.1.2) is called a regression equation. The equation may also be compared with the Taylor's series,

$$Y_i = F_o + \sum_{i=1}^{n} \frac{\partial F}{\partial X_i} X_i + \sum_{i\neq j=1}^{n} \frac{\partial^2 F}{\partial X_i \partial X_j} X_i X_j + \dots \quad \dots \qquad (1.1.3)$$

From comparison, $F_o = \beta_o$, $\frac{\partial F}{\partial X_i} = \beta_i$, $\frac{\partial^2 F}{\partial X_i \partial X_j} = \beta_{ij}$

Now, if an equation like (1.1.2) can be developed for each of the properties (response variables) of a sand system, the process of optimization becomes much easier. At the same time, the regression coefficients (β_i, β_{ij}) of such equations can be exploited to throw some light on the physical or physico-chemical phenomena occurring in the sand system being investigated. Hence, what is necessary is a method of investigation by which the data on the properties (response variables) of a sand system can be collected in such a way that these can easily be processed to develop the relationships as illustrated by equation (1.1.2).

One of the efficient ways[1-8] of data collection seems to be by application of statistical design of experiments, which help in developing the above mentioned regression equations. The concept of this technique had originated mainly in connection with agricultural research. But the honour of discovering this idea goes to the British statistician Sir Ronald Fisher[1] (the end of twenties), who was the first to show the expediency of simultaneously varying all the factors in contrast to the widespread single-factor experiments. The data collected by application of this technique are amenable to statistical treatments and mathematical methods can be used to develop the formal relationships, like equation (1.1.2), between the properties of a system and the variable factors involved. It is further suggested[1-8] that the most efficient way of examining the effects and interactions of the variable factors is by means of a factorial experiment where all possible combinations of each level of every factor are realized. In fact, the application of factorial experiment allows carrying out a minimum number of trials in order to develop the regression equations as above, resulting in the savings of materials and time devoted to the investigations. Once such equations are developed, these can be used to construct nomograms by drawing iso-property curves from which the optimum regions can be found out for selecting the proper combinations of the variable factors. But when the number of factors are more than two or even three, the equations help to the process of optimization with the aid of a computer which is now a recognised tool for efficient management and technological control.

Over the past years, considerable advances have been made in this branch of statistics and various types of experimental designs are available in the standard text books on the subject. It is claimed[4,6,7] that any system can be investigated by the Box-Wilson method for the purpose of optimization and also for an understanding of the roles of various factors and their interactions in deciding the properties and behaviour of the system. But if a system is already investigated by classical methods, the prior information may be gainfully utilized for further research by application of statistical design of experiments. An added advantage of this technique is that the experimental and personal errors get minimised and the accuracy with which the regression coefficients are determined is higher than those determined by classical statistical methods like multiple correlation and regression analysis[1,2,4-7].

The application of this statistical technique provides more information at less cost than can be obtained from classical methods and hence is highly suitable for investigations in the metal casting technology. It will be shown later (Chapter IV) that the existing data of other workers can also be utilized for developing regression equations by application of this technique. But all the data collected by other workers are not necessary for the above purpose. In other words, the same conclusion could be arrived at by collecting less number of observations, if the importance was given to the proper planning and designing of the experiments, before collecting and analysing the data.

The work done[8-15] so far by application of statistical design of experiments in the field of metal casting technology has not been adequate enough and so its utility is not appreciated fully. Some work in this field have already been initiated, but in a scanty way either in metallic systems[8,10,11,14] or in sand systems[13,15]. The past work[13,15] has only been partially successful in pointing out the application of this concept in sand control by constructing nomograms, which is but one aspect of its use. In short, the subject has only been introduced to those working in the metal casting industries and the amount of work done by this technique is far from adequate in the field of sand investigations.

1.1 OBJECTIVE OF THE PRESENT WORK

The present work was undertaken in order to investigate in detail the utility of statistical design of experiments in the study of sand systems, used in the metal casting industries, considering the growing demands for methodology in fast and economic sand control. Since various types of sand systems are in use, it is necessary to study a number of sand systems by this technique to serve the above purpose. Here, three sand systems have been chosen for investigations by application of factorial design of experiments and regression equations have been developed in each of them. Apart from demonstrating the utility of these equations for constructing nomograms and also for optimization with the aid of a computer, attempts have been made here to exploit the regression coefficients to secure an insight into the physical or physico-chemical phenomena operating behind the strengthening of the sand mixtures or occurring in the different stages of operations. Also the help of existing knowledge or theories have been taken into account, wherever available, for the above purpose.

The three basic sand systems chosen in this study are