Modeling of Cement-Bonded Sand Mould System: An Artificial Intelligence Approach

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ABSTRACT

The present paper deals with the forward mapping problem of cement bonded sand mould system using fuzzy logic (FL)-based approaches. It is important to note that the performance of an FL-based approach depends on its knowledge base (KB) that is, rule base and data base. Here, three approaches have been proposed to solve the said problem. The first Approach deals with the development of manually constructed Mamdani-based FL system, and the second Approach deals with the optimization of the rule base and data base of the FL system constructed in Approach 1, whereas the third Approach deals with automatic evolution of the FL system, in which the consequent part has also been optimized. A binary coded genetic algorithm (GA) has been used for the said purpose. The performances of the developed approaches are tested in forward mapping of a cement bonded sand mould system. It is to be noted that all the approaches can be effectively used to model the cement-bonded moulding sand system.

Keywords: Artificial Approach, Cement Bonded Sand Mould, Forward Mapping, Fuzzy Logic, Genetic Algorithm

INTRODUCTION

By using the cement as binder, moulds/cores of excellent strength and castings of high dimensional accuracy can be produced. These moulds/cores do not produce any toxic gases during moulding sand preparation and on metal pouring. In the cement bonded sand moulding system, silica sand, cement and water are the important ingredients. The major constituents of cement are tricalcium silicate (3CaO.SiO₂), dicalcium silicate (2CaO.SiO₂), tricalcium aluminate (3CaO.Al₂O₃) and tetracalcium aluminoferrite (4CaO.Al₂O₃.Fe₂O₃). The major drawback associated with these moulds is that, they need considerably long time to attain the required strength. As a result, it will increase the total time of making casting. However, the said problem can be resolved by using accelerator. The use of accelerator increases the rate of hydration and thereby reduces the time required to obtain the strength. In the present study, calcium formate (Ca[OOOCH]₂) is used as an accelerator. It is to be noted that this ac-
cement was already used in the construction of civil works. Moreover, hydration leads to the formation of thin film of hydrated cement for the cement, and prevents further chemical reaction (Sleicher & Providence, 1943). This helps in preventing any gas generation, when the molten metal comes in contact with the cement.

Limited work had been reported on the cement bonded sand moulding system. This might be due to the drawbacks associated with cement-bonded moulding sand system, and availability of other bonding materials. It is to be noted that, the study of input-output relationship will help to increase the commercial use of cement as a binder in cement-bonded moulding sand system. Moreover, there are a number of independent variables, such as the amount of Portland cement, amount of accelerator, water quantity and setting time etc., which influences the properties of sand mix. However, the past investigations were helpful in identifying the variables, affecting cement-bonded moulding sand system and operating range. In Schleede and Ill (1944), the authors had identified the uses of Gypsum cements in pattern and mould making. A classical approach was presented by Uchikawa and Uchida (1976) to study the effects of amount of jet cement, testing time, presence of an accelerator and the amount of water on compression strength. They varied one variable at a time, keeping the others fixed. In addition to these, statistical design of experiments were used by some of the researchers, and proved to be an effective tool for studying the effects of number of independent variables on various responses. Both the linear as well as non-linear regression models based on design of experiments (Chakraborty & Dhindaw, 1977; Cochran & Cox, 1963) and response surface methodology were used to establish accurate input-output relationships in different moulding sand systems. Moreover, Parappagoudar, Pratihar, and Datta (2008a) used full factorial and central composite designs to model cement bonded sand moulding system. It is to be noted that the amount of Portland cement, accelerator, water and testing time were treated as inputs, and compression strength and hardness were considered as outputs.

It is important to note that, the computational models had also been tried out to model the casting process with simulation software. Starobin et al. (2009), developed a computational model was developed to predict the generation of decomposed binder gas in sand cores. The amount of gas that enters the liquid metal was predicted after considering true molding geometry and core venting positions. Moreover, the effect of casting parameters on microstructure and casting quality for Si-Al alloy had been investigated by Hong et al. (2009). The practical casting results were compared with that of the results of simulation obtained using flow-3D software. In addition to this, the same software could also be used for the assessment of casting filling (Reilly et al., 2009) by modeling surface entrainment events. The developed algorithms allowed for the prediction of entrainment and detection of defect motion. It is important to note that the computational models require more complex and complicated mathematical equations to represent the system, whereas the regression models were developed response-wise with the help of experimental data. With this computational modeling, the dependency among the responses of a process (if any) may not be possible to capture. More recently, soft computing (Pratihar, 2008) had been tried to model input-output relationships of different manufacturing processes. It consists of neural networks (NN), fuzzy logic (FL), genetic algorithms (GA), etc and their different combinations used to establish the input-output relationships in complex and non-linear systems.

In Babu, Ohdar, and Pushp (2006), the green compression strength of the clay bonded sand moulding system was evaluated by utilizing NN and NN-FL approaches. Moreover, Karunakar and Datta (2007) had used NN and Genetic Algorithms (GA) to model the green sand moulding system. Jakubski and Dobosz
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