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Optimization of Gating System for Sand Casting Using Sequential Quadratic Programming

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Abstract: Lower rate of filling of metal in sand casting is a common and avoidable problem in the production unit. This often leads to increase in expenses as well as time taken. By optimizing the gating system design, we can reduce the inferiority in the products and hence reduce the cost and time taken.

I. INTRODUCTION

Sand casting is an important and widely used casting technique used in industries today. The problem of lower rate of metal filling remains intact even after several advances across industries. There cannot be a perfect rate of filling but it can be optimized to meet the almost perfect mark. And for this, sequential quadratic programming comes into picture with a potential solution. Design parameters are given as input and SQP optimization can be done based on that to reduce the time taken and reduce the overall cost for a firm.

II. OBJECTIVE

The goal is to develop a systematic methodology to optimize the gating system design to maximize the rate of filling of molten metal in sand casting. Sequential Quadratic Programming is one such way to optimize the design by using inputs and optimizing it to the required optimum level. The objective is to maximize the filling rate using the algorithm implemented using MATLAB. The previously published research work has not focused on the optimization of the gate design based on the maximizing filling rate, which is more important in thin and long casting because the quickly loses heat.

III. METHODOLOGY

First of all, we start with identifying important parameters in the gating design that affect the mould filling process, including controllable or design factors, and make gating design and therefore factors that affect the final castings are uncontrollable. Then, we select an SQP optimization algorithm using the design parameters. This algorithm is applied using MATLAB programming for optimizing process parameters. Finally, we come up with a design of the gating system using the customized value of the design variable. We can speed up this experiment by using a repeated approach to solution, considering all the products which affect the cost quality of the product. High filling rate is also useful for meeting the customer requirements by completing the job before the due date.

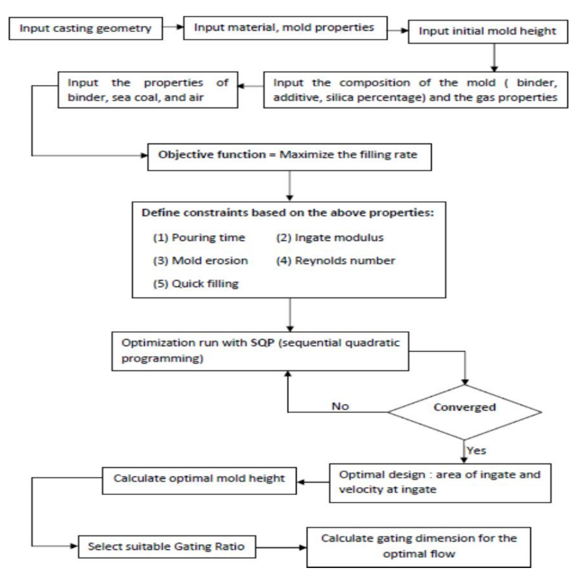

Fig. 1. Methodology

IV. PROBLEM STATEMENT

The objective function proposed is to maximize the filling rate of molten metal for sand casting.
Mathematically,

$$\text{Filling rate} = \rho\, m \times A\, g \times Vg$$

Where,
ρ m = density of molten metal
A g = cross sectional area of ingate
Vg = Velocity of molten metal at ingate

Hence, mathematically, objective function is given by: maximize ρ m× A g × V g which is filling rate. As the variation of density of metal above melting point temperature is very small, we can assume constant density of molten metal in our analysis. Therefore, there are only two design variables (cross sectional area of ingate and velocity of molten metal at the ingate), which are taken into consideration for gating optimization.

V. SOLUTION

To achieve the above objectives, the work has been divided into three phases:

1) In the first phase, literature and knowledge are acquired in connection with the design of the gate, and it is shown in a variety of methods. Information is obtained from metal moulding, research papers, and consultants and academic from standard hand books.
2) In the second phase, different optimization techniques are studied and the best optimization technique is implemented. The optimization technique implemented to maximize the filling rate is SQP (Sequential Quadratic Programming). Simultaneously, there are formulas of obstacles affecting the process of filling.
3) In the final stage, new barriers affecting the filling process are prepared. Programming (coding) is also done to optimize the fill rate. Finally, the SQP algorithm is implemented in coding to optimize the rate of filling the obstacles prepared in the second and third stages.

A. *Specifying Attribute Values*

This step involves the input to be given for the process. To initialize optimization process, the casting geometry related dimensions are given as input. The other inputs like material, mould and binder properties are tabulated below.

ATTRIBUTE	VALUE
Casting Dimensions	300 mm x 250 mm x 150 mm
Material	Aluminum grade 6061
Minimum mold thickness	20 mm
Pouring to solidification time	15 sec
Minimum layer thickness	5 mm
Liquid density of metal	2380 kg/m^3
Dynamic viscosity of metal	0.012 $N\text{-}s/m^2$
Pouring height	30 mm
Effective thickness	2 mm
Density of sea coal	5600 kg/m^3
Pouring Temperature	948 K
Initial pressure of air in mold cavity	1.013 KPa
Mold compressive strength	117.198 KPa
Sand permeability	90
Gating ratio	1: 2: 1.5

Table 1. Input attributes data

B. Calculation Of Constraints

Calculation of the various design constraints values based on the mathematical formulation is done using MATLAB software. Based on the input attribute values, the design constraints limiting the filling rate are computed by the program as follows:

1) Pouring time constraint: $0.002 - Ag \leq 0$
2) Modulus constraint: $Ag - 0.065 \leq 0$
3) Mould erosion constraint: $Vg - 28.704 \leq 0$
4) Reynolds number constraint: $Vg \times \sqrt{(Ag)} - 0.1 \leq 0$
5) Quick filling constraint: $16692.2 - 0.632 \times Ag \times Vg \leq 0$

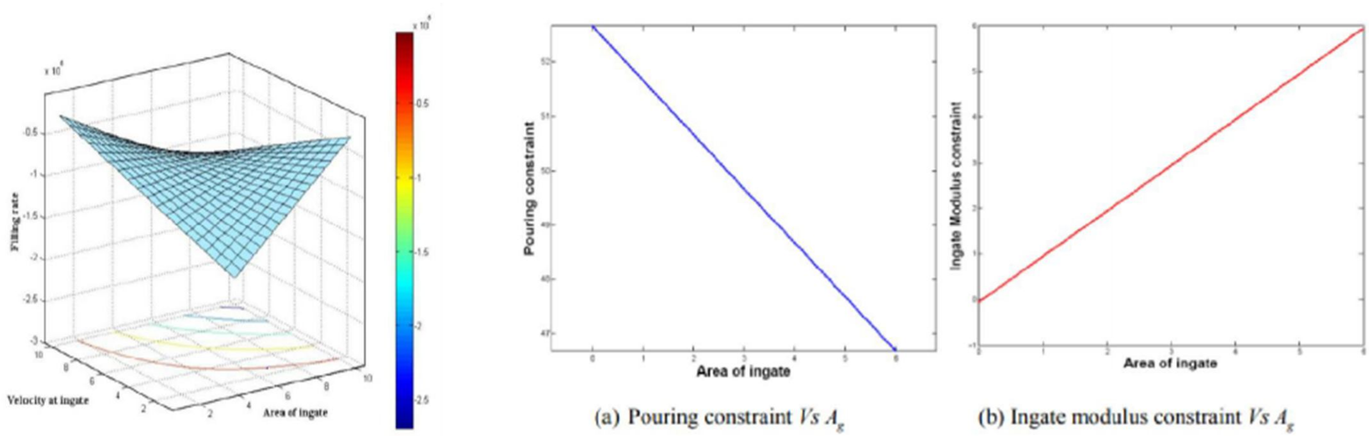

Fig. 2. Results obtained using MATLAB software

C. Results Obtained

ITERATION NUMBER	AREA OF INGATE (m^2)	VELOCITY AT INGATE (m^2/sec)
1	0.00583	6.58
2	0.00272	5.36
3	0.00489	3.29
4	0.00135	1.87

Table 1. Final results after iterations

Following results were obtained from the iterations:
Area of ingate (A g) = 0.00135 m^2
Velocity at the ingate (Vg) = 1.876 m/sec
Area of sprue exit = 0.0009011 m^2
Runner cross sectional area = 0.001800 m^2

VI. RESULTS

A customized gating design that meets the requirement is achieved by experimenting and error methods for a given cast geometry. However, this method takes a long time to get the optimum dimension of getting channels and adds the cost to the company as well. The proposed mathematical model here represents the actual mould filling process, so that we can guess the result before producing actual castings. This mathematical model can be applied in a suitable adaptation algorithm which satisfies the process parameters, as well as satisfy all the process constraints. Therefore, physical experiment is replaced by numerical experiment by this method.

VII. CONCLUSION

To maximize the rate of filling, a method for customizing the gating design for sand casting process has been described. It avoids premature cold in these castings in long and thin segmental defects. This method raises the production rate of casting to meet the customer's order within the due date. This process is applicable only for sand casting. Further studies can be done to extend this SQL programming technique to other casting like die casting, investment casting, centrifugal casting and other mould preparation processes. The proposed work assumes that the location of ingate is fixed and hence only requires to reduce the gating dimensions. Although there is a need to add an in-place location barrier, so that the layout of the gating system can be adapted to both the gating dimension.

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