IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 6, June 2016
ISSN (Online) 2348 – 7968 | Impact Factor (2015) - 4.332
www.ijiset.com

An Experimental Investigation and Optimization of Casting by Elimination of Blowholes in Steel Casting

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Abstract

The purpose of this project is an experimental investigation and optimization by elimination of blowholes in steel casting. It describes various methods for eliminating blowholes defects in steel casting and provides remedial action on defect in casting. Blowholes are one of the major casting defects caused due to evolution and entrapment of gases during casting process. This project aims to develop a systematic approach for blowhole elimination in steel casting based on available knowledge, experience of experts in this area and mathematical modeling of physical phenomenon taking place during mould filling.

The focus is on large size blowholes occurring in sand casting. Mathematical equations were derived for gas pressure developed during mold filling and for temperature drop of metal during mold filling (considered layer-by-layer). This enables the industry to experiment with parameters like pouring height, vent dimensions, number of vents and number of in gates and sand volume to minimize the occurrence of blowholes in casting

Keywords: *Blowholes, casting defects prediction, mathematical modeling.*

1. Introduction

The Casting is a manufacturing process by which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. A casting defect is an irregularity in the metal casting process that is undesired. Some defect can be tolerated while others can be repaired otherwise they must be eliminated. The main defects in a casting are gas porosity, shrinkage, mold material defect, pouring material defect and metallurgical defects.

1.1 NDT for defect s identification.

ASTM’s nondestructive testing standards provide guides for the appropriate methods and techniques used to detect and evaluate flaws in materials and objects without destroying the specimen at hand.

- Liquid Penetrant Test (DP)
- Radiographic Testing (RT)
- Ultrasonic Testing (UT)
- Magnetic Particle inspection(MPI)

2. Scope of the project work

The main focus of the project was on large size blowholes. The project aimed at studying principle, causes and remedies of blowhole formation. Literature review on principle of blowhole formation, causes of gas generation and different ways of reducing their generation in mold cavity was carried out. Mold filling phenomenon and solidification phenomenon taking place inside the mold cavity are studied.

- Getting thermal and physical properties for binders and additives is very difficult. It is necessary to collect values of these properties for all types of binders and additives used in sand casting, so that any sand casting can be analyzed easily.
- It is necessary to calculate the time required to fill considering back pressure of gases acting on metal front.
- We are using approximate approach for temperature drop during mold filling. A neat approach is necessary in order to get the actual temperature drop

2.1 Objectives of the project work

The purpose of this project is an experimental investigation and optimization by prediction of blowholes in steel casting. It describes various methods for eliminating blowholes defects in steel casting and provides remedial action on defect in casting. The main defects in a casting are macro blowholes, shrinkage, mould material defect, pouring material defect and metallurgical defects.

- To identify various causes of occurrence of blowhole and put them together
- To identify corresponding remedies and put them together
- To develop a mathematical model for blowhole
- To develop a knowledge base related to blowhole.
- To use fluid mechanics techniques for solving mathematical model

3. Modelling and Experimental analysis

To analyze these blowholes, we are considering layer by layer filling of the mold cavity by hot metal. If the pressure of the gas inside mold cavity (Pmold) is more than the metallostaic pressure (Pmetallostatic) of the liquid metal, then the gas generated inside the mold will enter the liquid metal and result in formation of large size blowholes (of radius 5 to 10 mm). Our focus is on large size blowholes formed in sand casting, due to entrapment of gas in solidifying metal.

There are three types of gating system: top gating, bottom gating and parting line gating. First consider the bottom gating system as shown in figure1. Consider a simple rectangular mold cavity of length L, width w, thickness t cavity and cross sectional area A as shown in figure1below. We divide this cavity into n number of layers of equal thickness dl along length L.

When pouring of the metal is started inside mold, initially layer dl gets filled at position 1 as shown in figure1. As soon as metal takes position 1, sand in contact with this metal gets heated and gas formation takes place due to heating of sand contents (moisture, binder and additives).

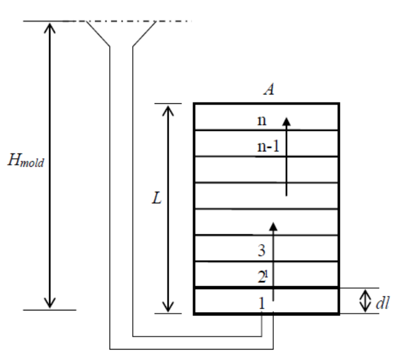

Fig. 1 Layer by Layer filling in mold cavity

Further, metal releases some gas during solidification, which is dissolved in hot liquid metal during melting. As pouring continues, the layer dl moves to position2 from position 1 and position 1 is captured by fresh hot metal. Again gas releasing phenomenon takes place due to heating of sand surrounded by hot metal at position 2. This phenomenon continues till the metal reaches to position n.

Before beginning to derive equations, some assumptions have been made to simplify the problem. Assumptions made are listed below.

- The layer by layer filling of the mold cavity is considered
- The hot metal is poured at constant rate
- Assume incompressible flow of the liquid metal inside the mold cavity
- All the gases formed during mold filling are ideal gases
- Whole volume of moisture, binder and additives in effective thickness of mold
  Wall gets converted to gaseous state
- Thermal and physical properties of gaseous state of moisture
- Once pouring of hot metal starts, all the gases formed are at pouring temperature
- Properties of air are considered as properties of mixture of gases
- The sand mold is preheated to certain mold temperature
- Conduction heat transfer between two consecutive metal layers is ignored

Each individual pressure can be expressed as,

$$P_i = \frac{m \times R \times T}{Vi} = \frac{m \times R \times T}{(L-li) \times Ai} \quad (1)$$

In order to calculate pressure drop due to gas escaping through mold walls because of sand permeability, we use permeability equation.

$$P_{gas_{perm_i}} = \frac{V_{gas\_i} \times t_{mold}}{V_{sand} \times f \times \tau_i} \quad (2)$$

- In order to calculate the pressure drop due to escape of gases through vents

$$n \times A_1 \times V_2 = A_2 \times V_2 \quad (3)$$

Loss of head H_1

$$H_1 = k_1 \frac{V_1^2}{2g} + k_2 \frac{V_2^2}{2g} \quad (4)$$

- Pressure drop due to venting is given as,

$$\Delta P = \rho \times g \times H_1 \quad (5)$$

Thus, we can calculate the total pressure drop due to escape of gases through mold walls and through vent by following equation.

ΔP escape _i= ΔPpermeability+ ΔPventing (6)

- Now, the metallostatic pressure developed due to pouring of the liquid metal from certain height is given by

Pmetallostatic = H×ρ×g (7)

Thus, if Pmold_i > Pmetallostatic

Then, blowhole will occur. As pressure due to gases is more than the metallostatic pressure, gas will enter the liquid metal and may get entrapped in solidifying metal.

- Time Required for Metal Layer to Fill

$$t = \frac{Vlayer-i}{Vb} \quad (8)$$

$$v_B = c_f \times \sqrt{2 \times g \times (H_{mold})} \quad (9)$$

4. Experimental details and result analysis

Table 1: Relation between defect occurring and pouring rate

Heat no	Pouring temperature (0c)	Pouring time (sec)	Liquid weight (kg)	Pouring rate (kg/sec)	Weight of welding rod used after (MPI(Kg)	Defect found in UT	Defect found in RT
H12600	1562	96	5900	61.46	25	Two level 3	Two level 3
H12806	1554	74	5900	79.73	28	One level 3	Two level 3
H12795	1558	69	5900	85.5	31	One level 3	NIL

Test result

Fig. 2 Defect found in Grade: ASTMA 352 LCB casting using Ultrasonic Testing

Table 2: Defects, Causes and Precautions

Defects	Causes	Precautions
Blow hole	Insufficient permeability of moulding or core sand	Increase permeability by use of vent wire or open sand with additions of a coarser silica sand.
	Hard ramming	Avoid excess ramming
	High moisture content	Reduce moisture to minimum consistent with workability
	Rusty or damp chaplets	Reduce oil in sand. Ensure vents are clear. Bake until cores are hard. Thoroughly dry all pouring ladles

4.1 Conclusions

- The main focus of the project was on large size blowholes.
- The project aimed at studying principle, causes and remedies of blowhole formation
- Literature review on principle of blowhole formation, causes of gas generation and different ways of reducing their generation in mould cavity was carried out.
- mould filling phenomenon and solidification phenomenon taking place inside the mould cavity are studied
- We considered layer by layer filling of the mould cavity. Equations are derived for calculating gas pressure during mould filling using Bernoulli's equation.
- The gas pressure developed inside the mould cavity is compared with metallostatic pressure in order to predict blowhole formation.

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