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Calculation of Shrinkage of Sand Cast Aluminium Alloys

Dr Samavedam Santhi
Assistant Professor, MGIT, Hyderabad, Telangana, India.

Abstract

Shrinkage is a major concern for foundry industry which is to be addressed to reduce the in-process rejections in castings. Present study mainly focuses on envisaging the shrinkage in aluminium alloy castings which help the foundry industry in predicting and controlling the shrinkage. Affect of mould coat and pouring temperature on shrinkage of US 413 and US A356 alloys is studied.

Key Words**:** Shrinkage, pouring temperature, mould coat, Al-Si alloys

INTRODUCTION

The greatest percentage of castings produced is by sand casting route and is the most economical with optimum efficiency and reclaimability [1]. In sand moulds the temperature distribution in the molten metal is uniform and the temperature of the inside surface of the mould is equal to the temperature of the liquid metal, because the heat conductivity of the sand is very low compared to molten metal [2]. Al-Si eutectic alloy, in as cast condition contains Silicon as needles or platelets in the matrix. To add to the mechanical properties and the feeding capacity of the alloy, silicon has been refined which reduces the surface energy of Aluminium – Silicon interface [3]. The cast Al-Si alloys are the true workhorses of the aluminum alloy casting industry because of their excellent casting characteristics and fine strength [4].

Most of the liquid metals shrink when they start solidifying. Solidification shrinkage is in the range of 3 to 8% for pure metals [5]. This shrinkage results in the form of voids like micro and macro shrinkage during solidification. Thermal contraction of solid during subsequent freezing also increases the risk of shrinkage if proper care is not taken in casting as observed by J. A. Eady [6]. Macroporosity or macro shrinkage occurs due to entrapped liquid metal surrounded by solid. Y. Li states that the tendency for formation of shrinkage porosity is related to liquid to solid volume fraction at the time of final solidification and solidification temperature range of alloy [64]. In order to predict shrinkage and porosity the thermal properties are defined as a function of the temperature [7].Generally macro cavity takes the conical shape and is the last portion to be solidified in the casting. Shrinkage cavity occurs in thick wall portions at an area where wall thickness varies largely [8]. Modulus of elasticity value of casting having macro shrinkage is seen to be lesser than theoretical value of the alloy [9]. Figure 1 shows the shrinkage pipe or piping which is a smooth conical funnel or long 'tail' formed inside the ingot.

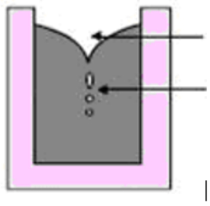

Figure 1. Macro cavities

The parameters that influence the macro cavities formation are the temperature range of solidification of the liquid metal (long freezing range or short freezing range alloy), thermophysical properties of the alloy, cooling conditions during solidification, gas content, atmospheric pressure above liquid metal during solidification of alloy. Internal porosity or micro porosity is a defect due to amalgamation of shrinkage and liberation of gases during solidification. Porosity results as a series of interconnected holes created by a lack of feed liquid metal at the end of solidification. This type of shrinkage is confined to thermal center of a section, which can extend to the casting surface. According to W.Laorchan the microporosity forms due to poor mass feeding, difficulties in interdendritic feeding, low pore nucleation energy, low atmospheric pressure and high gas content or low gas solubility in the solid [10].

When the temperature gradients during freezing are directed towards riser, the possibility of occurrence of microporosity is reduced in case of long freezing alloys. Directional solidification alone is sufficient for short freezing or skin forming alloys to reduce internal porosity. The feeding requirements are dependent to a large extent on the freezing range of the alloy being cast for cast aluminium alloys [11,12,13,14] as shown in Table 1.

Table 1. Freezing range of cast aluminium alloys

S.No	Alloy	Composition	Approximate Freezing range (ºC)		
1	LM0	Al 99.5	657-650	7^0	Short freezing range
2	LM 6	Al –Si 12	575-565	10^0	
3	LM 20	Al-Si 12 Cu	575-565	10^0	
4	LM 4	Al-Si5Cu3	580-520	60^0	Long freezing range
5	LM 25	Al-Si7 Mg	615-550	65^0	

EXPERIMENTAL STUDIES

For the present study the process parameters considered are **pouring temperature** and mould coat for calculating the shrinkage of the US 413 (Al-12Si) and US A356 alloys.

Mould coat provides smooth surface, improves the quality and reduces the mould erosion. Pouring temperature [15] influences fluidity, porosity, strength and structure of the casting. Pouring temperature with 50^0C of super heat is considered [11,15]. 8 experiments have been conducted for the present study and details are presented in Table 2. Diagram for the shrinkage experiment for cube shape casting is given in Figure 2.

The overflow core is placed over the mould in order to ensure that a fixed quantity of metal only is poured each time into the mould. The assembled mould, overflow core, pouring basin and other details for this experiment are shown in Figure. 3.

Table 2. Experimental plan for Shrinkage

Exp No.	Alloy	Pouring temperature (^{0}C)	Mould coat
1.	US A356	T+50	Graphite
2.	US A356	T	Graphite
3.	US A356	T+50	No coating
4.	US A356	T	No coating
5.	US 413	T+50	Graphite
6.	US 413	T	Graphite
7.	US 413	T+50	No coating
8.	US 413	T	No coating

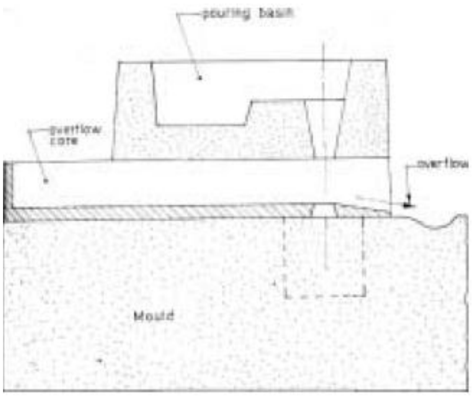

Figure 2. Diagram for the volume deficit experiment for cube shape casting

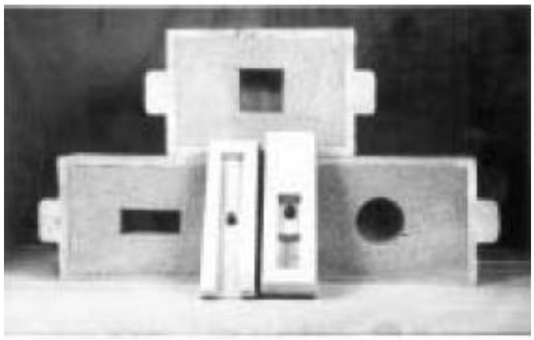

Figure 3. Details for experiment for volume deficit experiment

The moulds are provided with dowel pins for perfect matching of cope and drag. Moulds are prepared with slight ramming. The patterns have been stripped after 3 hours. Moulds are prepared using green sand process consisting of Bentonite (5%-6% of sand weight) and water (5%-8% of sand weight). The moisture level is adjusted in such a way that compatibility is maintained between 45% and 50%, permeability is maintained between 400 and 500 and green compression strength is in the range of 700-900g/cm^2. The mould hardness is in the range of 75-80 on B scale. The alloys are melted in an electric resistance furnace of capacity 20Kg provided with mild steel crucible. Temperature is measured with the help of a thermocouple. The furnace is put off and the crucible is lifted and put in a tilting device. The metal is tapped into a smaller crucible for pouring into the mould. The pouring height is maintained constant to avoid turbulence and difference in surface oxidation and oxide pick-up. Figure 4 shows the cube-shaped solidified casting of the experimental studies.

RESULTS

The transformation from liquid to solid state is accompanied by a decrease in volume in most of the metals. Though metal casting process has greatly advanced, porosity, shrinkage and gas bubbles remain occurs during the casting process.

To minimise the casting defects information regarding the shrinkage and its distribution is critical. Test castings have been analysed to determine the shrinkage and its distribution by using the following procedure. The % shrinkage for 8 experiments has been given at table 3 and in figure 5

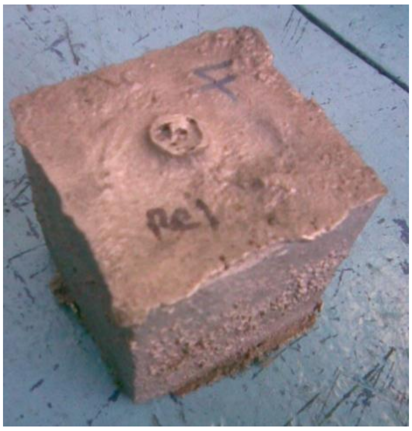

Figure 4. Solidified Casting

1. The test casting is taken out of the mould and the cone portion is cut off. The volume of the pipe is measured by keeping the casting under a burette and distilled water with wetting agent is dropped into the cavity till it is completely filled. The titration volume V_{titr} is read from the burette. The macrocavity, V_m is given by

$V_m = V_{cone} + V_{titr}$

2. The weight of casting in air and while immersed in water are determined using a sensitive balance of accuracy 0.001gm

V = (weight in air – weight in water)

3. The theoretical volume, V theoretical is obtained as follows:

Vtheor = Weight in air / (Theoretical maximum density)

The internal porosity Vint is computed as follows :

Vint = V – Vtheor, Shrinkage porosity is given by

= (Vm+Vint)/Vmould

Solidifying mechanism of casting can be categorized as liquid feeding, mass feeding, burst feeding and solid feeding [16]. Inadequate liquid metal feeding leads to macro cavities. Liquid metal feeding is the focal feeding mechanism in short freezing range alloys. Mass feeding is the association of a fluid mass of solid crystals and residual liquid metal. The burst feeding is due to puncturing of the skin of the casting during last stages of solidification when external pressure exceeds the pressure in the casting. Solid feeding is through surface sinks of solidifying casting surface by movement between two opposite surfaces.

Table 3. % shrinkage for 8 experiments

Exp No.	Alloy	Pouring temperature (^{0}C)	Mould coat	% Shrinkage
1.	US A356	T+50	Graphite	2.4
2.	US A356	T	Graphite	2.65
3.	US A356	T+50	No coating	2.628
4.	US A356	T	No coating	2.84
5.	US 413	T+50	Graphite	1.9
6.	US 413	T	Graphite	2
7.	US 413	T+50	No coating	2.07
8.	US 413	T	No coating	2.108

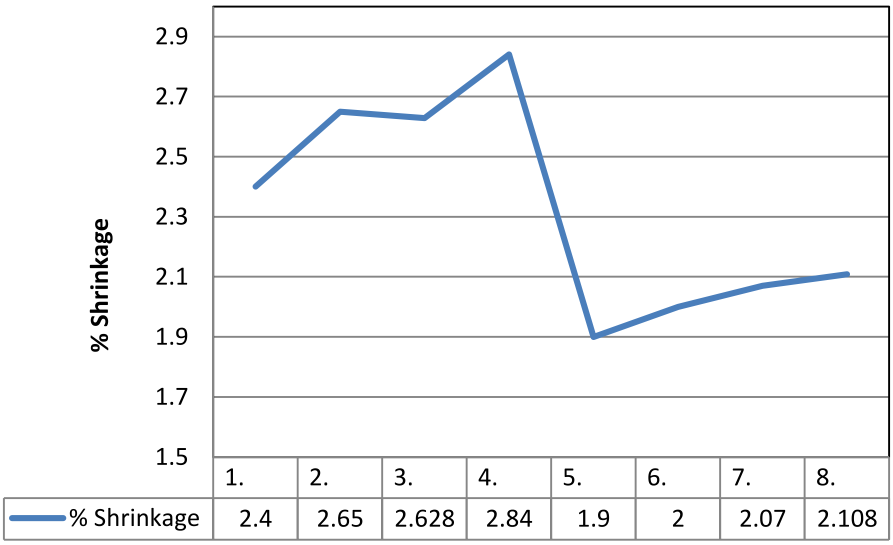

Figure 5. % Shrinkage for 8 experiments

Feeding is a transport mechanism of movement of liquid or solid metal to the exact location of shrinkage during solidification. Cavity in the casting is formed when shrinkage cannot mobilize the liquid or solid metal. The basis and sources of porosity or shrinkage are described in Table 4[11, 15]

Presence of gases in the pouring liquid metal enhances the formation of cavities in the casting. Defect free castings can be developed by considering either the shrinkage or porosity controlled by directional solidification as complete shrinkage occurs in the feeder or the shrinkage completely / partly occurs in a non critical area of the casting. Some of the significant factors that influence shrinkage in cast products are thermal cooling conditions, casting temperature, mould coat and alloy content.

Table 4. Sources of porosity / Shrinkage [11,15]

Parameter	Cause of failure	Freezing range	
		Short	Long
Macro porosity	Liquid feeding	Smooth shrinkage pipe	Shrinkage sponge
Micro porosity	Interdendritic feeding	micro shrinkage dispersion	micro shrinkage dispersion

Influence of pouring temperature

The pouring temperature is a vital tool in foundry industry in the manufacture of quality castings. The influence of degree of superheat on the shrinkage and its distribution is studied for pouring temperatures T and T+50ºC. Pouring temperature is an important parameter in foundry for manufacturing quality castings. Superheat is (additional heat) essential for melting. Additional pouring temperature or super heat increases the fluidity and considers the allowance for heat losses before they are in their final position in the mould. Increase in pouring temperature results in lower rate of heat extraction by the mould. Higher pouring temperature leads to decreased porosity as shown in the Figure 5.

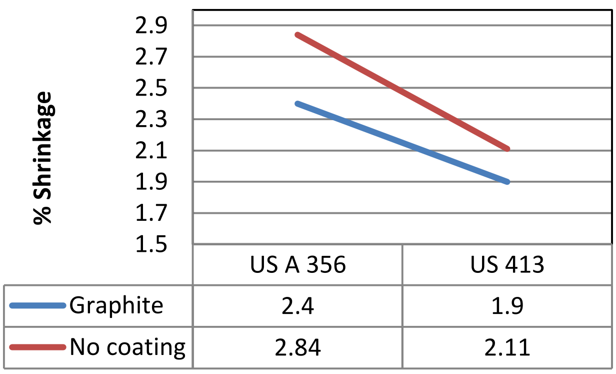

Figure. 6. Influence of pouring temperature

Influence of Mould Coat

In order to study the affect of mould coating on shrinkage porosity, mould with and without graphite coat are considered. Mould coat provides smooth casting surface. Mould coat influences the thermal gradient by promoting the directional solidification.

Mould coat allows a passageway for feed metal to flow into the solidifying structure and compensates for normal metal shrinkage during solidification. There is decrease in shrinkage porosity for graphite coated mould as shown in Figure 6

CONCLUSIONS

Additional pouring temperature or super heat increases the fluidity and considers the allowance for heat losses before they are in their final position in the mould, thereby decreasing the shrinkage. Mould coat allows a passageway for feed metal to flow into the solidifying structure and compensates for normal metal shrinkage during solidification.

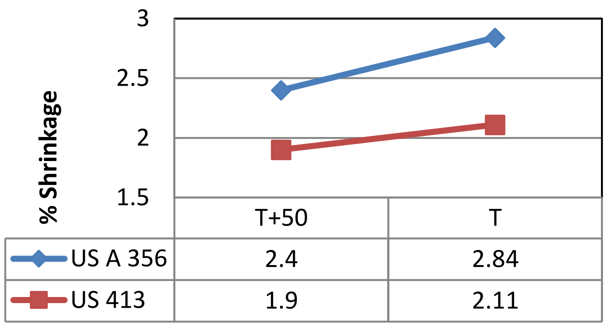

Figure. 7. Influence of mould coat

REFERENCES

[1] P. J. Tikalsky, H. U. Bahia, A. Deng and T. Snyder, Excess foundry sand characterization and experimental Investigation in controlled Low-strength material and Hot-mixing asphalt, Contract No. De-fc36-01id13974, October 2004, U.S. department of energy, pp.13-161

[2] Mollard, F:R, Flemmings M.C., and Nyama E.F.; Understanding aluminium fluidity: the key to advanced cast products, AFS Trans (1987), vol. 95, pp. 647-652

[3] Ashok Sharma, High strength cast Al-12%Si-0.3%Mg alloy through grain refinement, modification and heat treatment, Indian Foundry Journal, Vol.51,No.1,January 2005

[4] Vankateswaran S, Mallya R.M., Seshadri M.R.; Effect of trace elements on the fluidity of eutectic Al-Si alloy using the vacuum suction technique, AFS Transaction pp.67, 1986

[5] Timothy L. Donohue and Dr. Helmut F. Frye, Characterization and Correction of Casting Defects,

TechForm - Advanced Casting Technology, L.L.C. 1999

[6] J. A. Eady and D. M. Smith, The Effect of Porosity on The Tensile Properties of Al-Alloy Castings",Mat.Forum, 9(4), 1986,pp 217-223

[7] Arno Louvo and Matti Sirviö, Use of Simulated Porosity for Avoidance of Casting Defects, VTT Manufacturing Technology, Finland, World Foundry Conference 1994 in Düsseldorf, Germany

[8] A Reis, Zhian Xu, Rob Van Tol, A.D.Santos, A. Barbedo Magalhães, Modeling of The Underpressure Occurring During The Shrink Porosity Formation, FEUP – Faculdade de Engenharia da Universidade do Porto, R.Dr.Roberto Frias s/n, 4200-110 Porto, Portugal,2005

[9] Shuyong Dongy, Shoumei Xiong and Baicheng Liu, Numerical Simulation of Microporosity Evolution of Aluminum Alloy Castings, J. Mater. Sci. Technol., Vol.20 No.1, 2004, pp.23-26

[10] W.Laorchan, JEGruzleski, Grain refinement, Modification & melt hydrogen–their effects on microporosity, shrinkage and impact properties in A356 alloy, AFS Transactions,1992-39,pp. 415-424

[11] ASM Metals Handbook Volume 15, Casting, ASM International, The Materials Information Company, 2004

[12] J. M. Kim, C. R. Loper Jr., AFS Trans. vol, 103, 1995 pp.521-529.

[13] J.L. Davies, V.Kondic, Mechanism of formation of shrinkage cavities in castings, The British Foundryman, Vol.69, p.39, 1976

[14] J.L. Davies, V.Kondic, Mechanism of formation of shrinkage cavities in castings, The British Foundryman, Vol.69, p.39, 1976\

[15] S.Sundarrajan, H.Md. Roshan, E.G. Ramachandran, Studies on shrinkage characteristics of binary Mg-Al alloys, Transactions of The Indian Institute of Metals, Vol.37, No.4, August 1984

[16] Dr. R. L. Naro, Porosity Defects in Iron Castings from Mold Metal Interface Reactions, Silver Anniversary Paper (99-206), Presented at the 1999 St. Louis, Missouri AFS Casting Congress