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Research Article

Comparing two Pouring System Processes of Sand Mold Design for Casting Recycled Aluminum Pots

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ABSTRACT

The artisanal molding of recycled aluminum pots with green sand is a molding process based on the founder's personal experience. Our study consists in proposing two alternative casting systems to the craftsmen of aluminum pots molding. This activity, based on the craftsman's subjective experience in sizing, affects the solidity and molding cost without a valid explanation. We illustrate two complete casting system processes using a pot shape to opt for one or the other casting system. The mold's sizing mainly constitutes the pouring system (Pouring basin, sprue section, channel section, gating system section) and the feeding system (riser) elements. It appears that the casting from above is economically more viable than the bottom for small and regular section pots. However, it does not guarantee rigid pots and good qualities of mechanical properties, especially for irregularly shaped pots.

Keywords: Casting System, Mold Design, Recycled Aluminum, Green Sand

Introduction

The mold is a set of appropriate elements, delimiting the molded print and receiving the liquid metal, which after solidification gives the blank.[1] In Central Africa, craftsmen have used this aluminum foundry technology for the artisanal casting of aluminum pots with green sand. To make their kettles successful, workers use many subjective skills to control many process variables. Still, they often end up with castings that are faulty or scrapped due to possible incorrect factors. This lack of control of in-depth techniques on molding variables, particularly the design of the mold, the measurement of the aluminum filling rate in the cavity, and the cooling rate control and the formulation of the sand mixture despite their commendable practical competence.

Therefore, successful sand casting requires meticulous control of a large number of metallurgical and mold design variables. Correct mold design with the flow and cooling rate controls of the molten metal in the mold cavities is the basic for successful casting and reducing the labor involved. Mold design requires establishing requisite specifications of the pouring basin, sprue, sprue well, runner, gating system, product cavity, and cooling means to achieve satisfactory products of various types and sizes. Improper mold design can cause oxidation of molten metal, mold erosion, and failure with attendant costs. In foundries, more significant engineering skills and creativity help to control many process variables to eliminate or minimize defects in castings and achieve higher production rates with less labor compared to artisanal casting practices.[2,3,4]

The mold is made up of two halves-the copes (upper half) and the drag (bottom half), which meet along a parting line.

Both mold halves are contained inside a box called a flask divided along the parting line. The two halves of the mold are placed together by using pins called dowel pins. The mold cavity is formed by packing sand around the pattern in each half of the flask. When Sand load and pattern are removed, a hole that forms the external shape of the casting remains. Cores may create some internal surfaces of the casting. Sand casting involves the use of green or dry sand molds. Cores are additional pieces that include the inner holes and passages of the casting. Cores are typically made of sand to be shaken out of the casting.[2] Figure 1, shows a typical mold arrangement for sand casting.

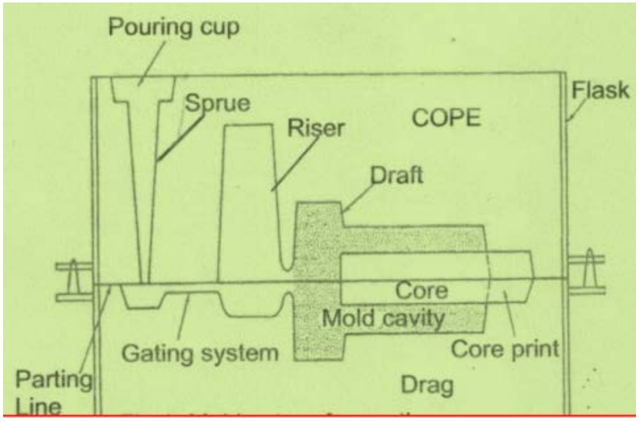

Figure 1.Mold set-up for casting[2]

The sand used for molding is transformed into a malleable paste made up of excellent grains of moistened silica. It meets the following requirements: having a smooth surface as far as possible, reproducing faithfully the pattern of the part, resisting the high casting temperature of the metal (have a softening temperature higher than the melting temperature of the alloy), resisting the erosion of liquid metal, and do not oppose the passage of gases produced at the time of casting. The composition of the green sand is generally:[5] 70 to 80% silica (support), 5 to 15% clay (binder), 7 to 10% water, 3 to 5% impurities (iron oxide, organic matter, etc.).

The design of the casting cluster consists in modifying the geometry of the part to adapt it to the process, then adding the appendages necessary for filling and solidifying the impression; each step must prevent the generation of defects during casting.

A molding defect is an undesirable irregularity in a part obtained by molding and characteristic of the production process and the cast metal. Some faults can be repaired, but they can also lead to a scrap of the part. We can distinguish five categories of defects, based on their mechanisms of formation, namely:[5] the defects formed during shrinkage related to solidification (shrinkage, cracks, and tapures), the gas faults (blowholes), the defects related to the mold's material (penetrations), the defects formed during mold filling (filling defects) and the production defects (defects in the parting line).

The artisanal casting process of aluminum pots follows an exceedingly complex chain of operations that requires prior skill and mastery. The manufacture of a cooking pot requires a succession of technical gestures that must carry out with great skill and precision given the small thickness of the object's walls. Depending on the technological resources available, the metals and alloys used, the number of things to be produced, and the desired degree of roughness, there are several molding methods.[6,7] Our study consists in proposing two pouring systems to allow workers of choosing the best alternative during casting. Thus, this starts with a brief review of sand casting, follows by the methods used, the sizing model of the two casting systems, and finally, the comparative study of these two alternative pouring systems.

Recycled Aluminum Kettle Molding Methods

Material Used

Artisans produce several shapes of pots using green sand in a mold whose filling boxes are made of wood, made from aluminum melted in a traditional oven made from refractory clay. After investigations into artisanal molding, the most used pot is of a particular shape pot "does everything" (Figure 2). The core print is defined by sand, and the crate is made of wood. The sand used is "green sand." Greensand is made up of clay, silica, a black mineral, and water. It hardens when strongly compressed and becomes refractory. The aluminum used is collecting spare parts from auto garages and other recyclable aluminum waste collected across the city. The furnace used to smelt the latter is constructed with fireclay and fueled by coal.

Figure 2.Type of pot shapes "does everything."

Casting Aluminum Pot Methodology

The methodology for molding pots follows logic of steps in chronological order, the non-observance of which inevitably leads to failure of molding (defective pot). It is divided into 04 main stages, as indicated in Figure 3.

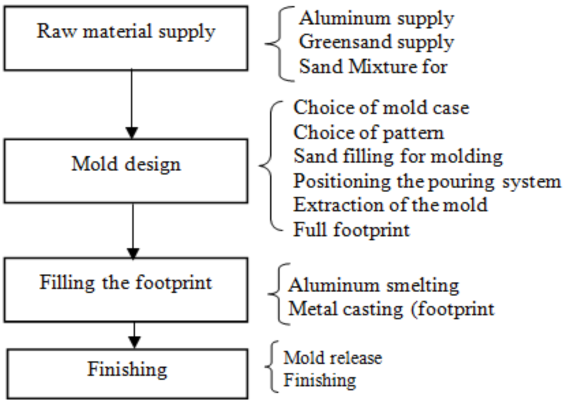

Figure 3.Methodology for molding aluminum pots

Casting Cluster Construction Methodology

Sizing a complete mold consists of obtaining finally the casting cluster, which defines the total mold footprint of the blank's model. This part consists of starting from the dimensions of the initial blank to obtain the dimensions of the model and taking into account the modifications, which are the sizing of pouring and feeding systems as indicated in Figure 4, below.

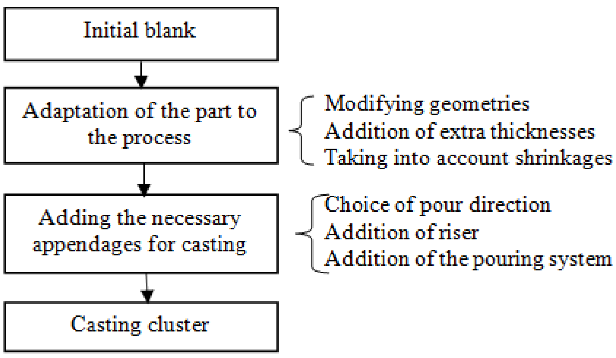

Figure 4.Casting cluster construction process[8]

Design Method

This method allows us to apply the casting cluster construction method by following the foundry logic for a proposed pot shape. For this pot "*does everything*," Figure 5 illustrates the pot to be obtained and that of the associated wooden pattern with extra thicknesses, and Tables 1, and 2 present parametric characteristics.

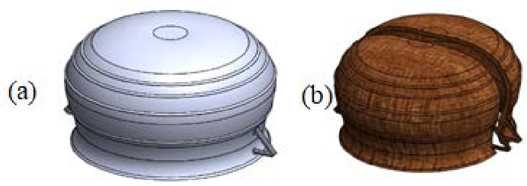

Figure 5.The shape of the "do everything" pots to obtain(a)and the mahogany wood pattern(b)

Table 1.Nominal dimensions of the pot

Nominal dimensions of the pot's body		
Dimensions	**Designations**	**Relationship**
Thickness	e	Given value
Internal diameter	D_i	Given value
External diameter	D_e	$D_e = D_i + 2e$
Internal depth	H_i	Given value
Volume	V_m	$V_m = \frac{\pi}{4}[(D_e^2 - D_i^2)H_i + e.D_e^2]$
Nominal dimensions of handling lugs		
Radius	r	Given value
Thickness	t	Given value
Volume	V_{em}	$V_{em} = \pi\frac{t^2}{2}[2r + t]$

- Design of the pattern (adaptation of the part to the process)

To obtain the desired part with its exact dimensions, the design of the pattern must take into account the metal shrinkage allowance, machining allowance, and undercuts.

Shrinkage and Machining Allowance

the allowances must be added to respect the dimensional tolerances of the pot. The plot is scaled to take into account the concrete shrinkage of the metal during cooling. So the dimensions of the pattern are greater than those of the part to be molded. Suppose a shrinkage allowance of 1.5% = 0.015mm for aluminum and its alloys (see appendix 2) and the machining allowance (MRA) is chosen according to the largest dimension of the part (see appendix 5). The calculation of the dimensions of the pattern must take into account the formula for allowance and shrinkage. The drafts depend on the sharp angles and the choice of molding direction (parting line).

Table 3, Summarizes the volume and mass of the alloy required for the molding of the pot.

Adding Appendages to the Casting

Solidification orientation method: Solidification is at the heart of metallurgy and the foundry principle. Good solidification leads to healthy parts with a respected dimension. Failure to follow the orientation leads to the sinkhole and crack.

Pouring System Sizing (Riser):[9] The risers are liquid metal reserves intended to feed the part during its cooling and compensate for the volume shrinkage that the metal undergoes. It is added during the design of the foundry cluster cooling after the part to displace shrinkage defects. Chvorinov formula governed the sizing.[8]

Table 2.Nominal dimensions of the pattern cooking pot

Nominal dimensions of the Pattern of Pot's body		
Dimensions	**Designations**	**Relationship**
Thickness	e_m	$e_m = (e + 2MRA)(1+S_r)$
Internal diameter	D_{im}	$D_{im} = D_i - 2MRA$
Outside diameter	D_{em}	$D_{em} = D_{im} + 2e_m$
Interior depth	H_{im}	$H_{im} = (H_i + 2MRA)(1+S_r)$
Volume	$V_{pattern}$	$V_{pattern} = \frac{\pi}{4}[(D_{em}^2 - D_{im}^2)H_{im} + e_m . D_{em}^2]$
Nominal Dimensions of the handling lugs pattern		
Ray	r_m	$r_m = r\text{-}MRA$
Thickness	t_m	$t_m = (t + 2MRA)(1+S_r)$
Volume	$V_{em\_pattern}$	$V_{em_{pattern}} = \pi \frac{t^2}{2}[2r_m + t_m]$

Table 3.Raw materials needed for molding

Parameters	Computation formulas of Raw material needed for molding
Footprint volume	$V_{T\_pattern} = V_{m\_pattern} + V_{c\_pattern} + V_{em\_pattern}$
Aluminum mass	$M_{a\_shrinkage} = \rho_a V_{T\_model}$
Cost of aluminum	$C = M_{a\_shrinkage} \times$ price 1 *kg*
Mass of sand	$M_{sand} = (V_{frame} - V_{footprint})\rho_{sand}$
Water for sand dosing	$V_{water} = M_{sand} \times$ % water

- The cooling module

$$M_r = \frac{V_{pc}}{A_{pc}} = \frac{volume\ of\ one\ part\ of\ the\ part}{cooling\ surface\ of\ that\ part\ of\ the\ part}$$

- Solidification time

According to Chvorinov's law, the solidification time is:

$$T_s = \beta\left(\frac{V_{pc}}{A_{pc}}\right)^n = (M_r)^n \begin{cases} T_s\text{: solidification time in seconds} \\ M_r\text{: cooling module} \\ n \text{ is between 1.5 and 2} \\ \beta \text{ is a constant depending on the alloy and the mold temperature} \end{cases}$$

- Verification conditions

Riser volume: $V_{riser} \geq r.V_{part.k}$

With r, the volumetric shrinkage and k a coefficient depend on the type of weight.

Riser module: $M_{riser} \geq 1.2M_r$

- Sizing of the pouring system

The role of the pouring system is to direct the metal from the ladle to the part. Obtaining a compact part needs necessary to establish a pouring while keeping the same pressure in the gating system (short conduits, generally of reduced section and flat shape connecting the channels to the footprint of the part) as the temperature.

- Bernoulli's Law and Choice of Staggering

Bernoulli's law makes it possible to determine the filling and outlet speeds of each section, and the staggering makes it possible to decide on the different sections of the filling system: Sprue section (S_d), Channel section (S_c); gating system section (S_a).

An abacus gives the scale according to the materials cast (See appendix 4). It determines the channel and attacks sections according to the sprue section. The presentation of the staggering is given according to the casting sprue section as follows:

$\frac{S_d}{S_d} \rightarrow$ selected value of the appendix 4 chart.

$\frac{S_c}{S_d} \rightarrow$ determined the value of the appendix 4 chart.

$\frac{S_a}{S_d} \rightarrow$ chosen the value of the appendix 4 chart.

On average, the shrinkage is 1.5% = 0.015mm for aluminum and its alloys.

The molding range is all the different operations carried out according to specifications.

Application of the Sizing of the two Casting Systems

Sizing of the Bottom Casting

The dimensions of the model are obtained, taking into account the machining and shrinkage allowance. According to annexes 1 and 3, we have because the broadest dimension is and the machining allowance is; the pattern (Figure 6) obtained is as follows:

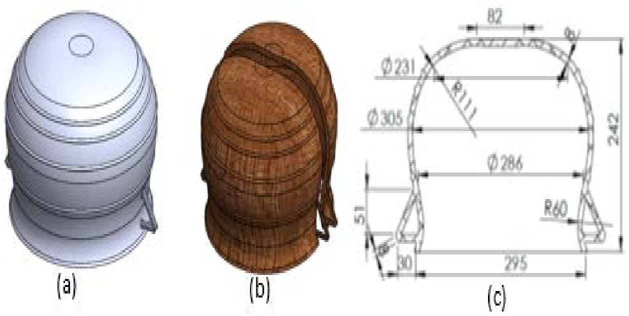

Figure 6.(a) Pot to obtain (b) Wooden pot pattern (c) 2D drawing of pattern pot dimensions

Sizing of the Pouring and Feeding System

The volume of the pot and the Surface area:

Mass and the Volume of the pattern:

- **Feeding System**

Cooling module $M_r = \frac{V_T}{A} = \frac{2106905.38}{534310.51} = 0.394cm$

Solidification time:[10,11] $T_s = \left(\frac{V_T}{A}\right)^2 = M_r^2 = 3.94^2 = 15.5\ seconds$

- Riser module: M_{riser} = 1.2(0.364) = 0.4728cm
- Riser volume: V_{riser} = 5.5(0.01)(6)2106905.38 = 695278.77mm^3

Dimensions of the riser:

- Riser diameter: $D_{mas} = 5.M_{mas}$ D_{mas} = 5(6.2) = 37.5*mm*
- Riser height = 75*mm* $H_{mas} = 2D_{mas}$

- **Pouring System**

Volume to be filled: $V_{fill} = V_{model} + V_{maselotte}$ = 4211456.5*mm*^{3}

Drop height: $H = 320 - \frac{248}{2} = 196mm$

Charging time: T_r = 5.4 secondes

Sprue section: $S_d = \frac{\eta.V_{remplir}}{T_r\sqrt{2gH}} = \frac{0.4(4211456.5)}{2\sqrt{2(9.81\times1000)(196)}} = 172mm^2$

Hence, $d = 2\sqrt{\frac{S_d}{\pi}} = 2\sqrt{\frac{172}{\pi}} = 14.7mm$

Channel Section: $S_c = 3S_d$ = 516mm²

Section of a Channel: S_c = 258mm²

Channel Dimension c = 16mm

Gating system section: $S_a = 3S_d$ = 516mm²

Dimension of a Gating System or a Channel

Section of a gating system S_a = 258mm² hence *h* = 8mm and the length *l* = 32mm

Supply of Raw Materials Needed for Molding

Sand: Volume of sand = 400 × 450 × 350 = 63dm³

Mass of sand M = 63×1.6 = 100.8kg

Amount of water needed for the mixture=100.8 × 4/100 = 4.032 liters

Aluminum: 4211456.5 × 2700/10⁹ = 11.37kg

Controlling the amount of water for mixing the sand is important because the sand that is too wet can be the source of risks: false tightening, gluing, risk of metal backflow, splashing, faults due to excess gas such as bites and blowholes.

Mold Details

Figures 7 and 8, show the pouring cluster that will define the complete pot footprint to be obtained and the isometric model of the mold.

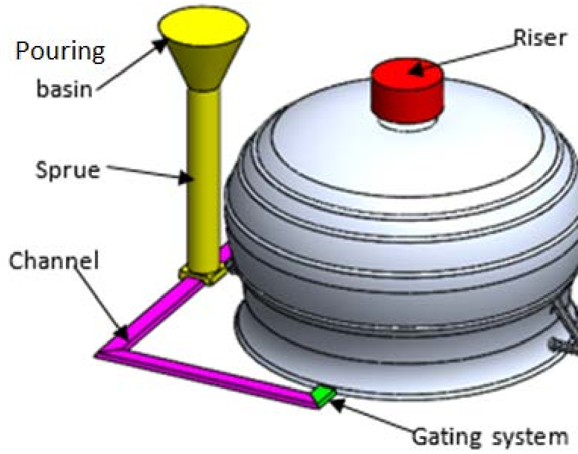

Figure 7.Casting cluster

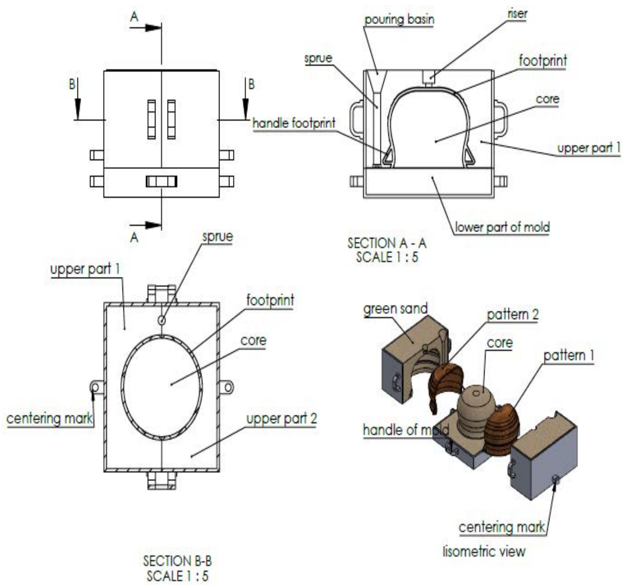

Figure 8.Details 2D drawing and isometric view of the mold

Sizing of the Casting From Above

Sizing of the Filling and Feeding System

- Filling System[2]

Volume to be filled: $V_{fill} = V_{Pattern} = 3516177.72mm^3$

Drop height: $H = h = 108mm$

Pouring time: $T_r = 4.9$ *secondes*

Sprue section: $S_d = \frac{\eta . V_{fill}}{T_r\sqrt{2gH}} = \frac{0.7(3516177.72)}{5\sqrt{2(9.81\times1000)(108)}} = 338mm^2$

Hence, $d = 2\sqrt{\frac{S_d}{\pi}} = 2\sqrt{\frac{172}{\pi}} = 20.7mm$

Supply of Raw Materials Needed for Molding

- **Sand:**

The volume of sand in the two copes = 400 × 400 × 350 = $56dm^3$

The volume of sand in the drag = 400 × 400 × 125 = $20dm^3$

Amount of water needed for the mixture = 121.6 × 4/ 100 = 4.8 liters

Aluminium: Quantity of aluminium = 3516177.72 × 2700/10^9 = 9.5kg

Mold Details

Figures 9 and 10 show the pouring cluster, which will define the complete footprint of the pot and the isometric model of the mold.

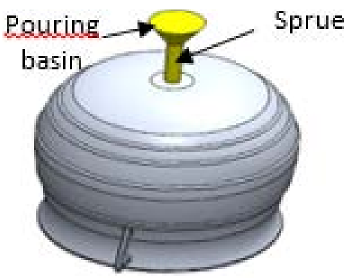

Figure 9.Casting cluster

Analysis of the Two Casting Methods: Top Casting and Bottom Casting

Casting from above is a direct casting through the crater opening directly into the footprint of the part itself. The pouring system, which consists of the filling core and the sprue section, performs both the filling channel and riser pouring, while the casting from below is a casting that uses a more complex pouring system than that of the casting from the top. The filling system comprises 03 sections (sprue section, channel section, and gating system section), allowing the filling of the molded print from the bottom to the top. This imposes a sense of solidification from top to bottom. This type of casting requires a feeding system that considers the usage of the riser.

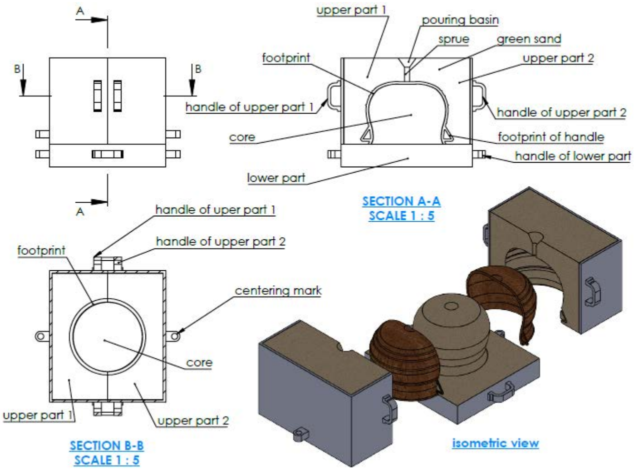

Figure 10.Details 2D and isometric view of the mold for top casting

To highlight the aspects of each type of casting, we will use the following procedure: the complexity of the geometry of the casting cluster, model production time, loss or gain in raw material (metering), and quality of the pot obtained.

The Complexity of the Casting Cluster Geometry

The casting cluster defines the complete footprint of the pot to be obtained and the pouring system and supplying molten metal. So, the complexity of the bunch makes it possible to get a pot of complex geometry. Our comparative study shows the casting clusters of the different pouring for the identical shape of the pot (Figure 11).

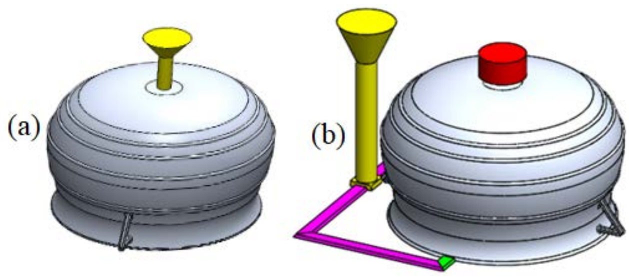

Figure 11.Sprue (a) from the top (b) from the bottom

Comparatively, the pouring system for bottom casting is more complex than top casting. Likewise, the footprint to be filled by the molten metal is greater than that of the casting from above.

Model Realization Time

No matter the geometry complexity of the pot, it is obvious to say that the realization of the footprint for the casting from the top is more uncomplicated than that of the casting from the bottom. Because the more the cluster has appendages, the more complex the realization is; therefore, the realization time is essential.

Loss or Gain in Raw Material

To bring out the comparison in terms of minimizing the loss of raw material, we will calculate the metering of each pouring.

Let M_1 be the milling of the casting from the bottom and M_2 casting from the top.

Reminder: the metering is the mass ratio of the part before the release by the mass of the final part (obtained part).

$$M_1 = \frac{11.37}{5.7} = 1.9$$

$$M_2 = \frac{9.5}{5.7} = 1.6$$

The goal of metering is to minimize the loss of raw material, and the objective is to tend towards 1, which is the excellent value (without losing raw material).

It observed that more raw material (aluminum) is loosened in casting from the bottom than that from the top; hence, $M_1 > M_2$.

Table 4.Comparative study of the two casting systems according to the design parameters

Characteristics	Bottom casting	Top Casting
Riser	Obligatory	Possible, very small (if it exists)
Events	Yes	No (except where necessary)
Sprue section	Yes	Sprue section only
Channel section	Yes	
Gating system section	Yes	
Focus	High	Scaled-down
Completion time	High	Scaled-down
Cost	Expensive	Cheaper
Pot quality	Better	Less good
Precision	More precision	Less precision
Turbulence	Scaled-down	High
Solidification direction	Up down	Down up
Weld fault	High	Scaled-down
Risk of penetration	Scaled-down	High
Blowing Defects	Scaled-down	High
Irregular thickness shape pot	Yes	Not recommended
Regular thick-ness shape pot	No	Recommended

Quality of the Pot Obtained

The quality of the resulting pot is a crucial issue to the faithful customer. To evaluate the quality of the pot, we will proceed in a simple way which consists in assessing the physical properties. The mechanical properties of the pot obtained depend on the orientation of the solidification provided by the riser (when the pot thicknesses are irregular) and the pouring system. The absence of defects also assesses the quality of a pot. The minimization of the defects is ensured by the vents, riser, and formulation of mixing sand.

About the casting from above, the quality of the pot obtained is good because the pouring system ensures the orientation of the solidification (from the bottom to the top), making it possible to avoid shrinkage defects. The molding sand mix formulation allows the sand to evacuate gas to prevent blister defects. On the other hand, concerning the geometry and the dimensioning of the casting cluster from the bottom, it is evident that the quality of the pot obtained is better because the riser provides the metal gaps during solidification. Trapped gases are vented and gunk. Impurities are retained by the height offset between the channel and gating sections.

From the above studies on the two types of casting that are the casting from the top and the bottom, we can bring out the comparison in table 4 below:

Conclusion

Based on the different sizing and study of the two types of casting, the casting from the top and the bottom, it emerges that the two kinds of casting make it possible to obtain two identical pots. The difference arises at the level of the mechanical properties, quantity of raw material used, production time, and cost. From the study carried out above, we can conclude that:

Casting from the top is simpler, faster, and less expensive, more economical than raw material quantity. It is generally used for parts of small thickness and of a constant cross-section of which the cooling is rapid. So it is an ideal method for small pots or large pots (in this case, it is necessary to size the pouring system because it ensures the faith, the filling, and the function of the riser).

Pouring from the top is much more complex and expensive but offers a better quality of the pot. The raw material is loosened due to the presence of the risers and the different filling sections. The completion time is essential. Despite all these factors, it remains the casting capable of responding to the expected results due to the maximum minimization of molding defects and responds to the molding of a pot of various sections.

References

1. Bensaada Said, Foundry and Welding: The basic principles of foundry and welding. 2010. https://www.edition-ue.com, P143.

2. Thomas GN, Uche LO. Sand Mold Design for Casting an Aluminum Pot-A Basic Procedure of Supplementing Artisanal Practices. *European Journal of Engineering Research and Science EJERS* 2019; 4(4).
3. Jain RK. Production Technology Delhi. India 16th Edn. Khanna Publishers. 2005; 138-254.
4. Avalon B, Baumeister T. Standard Handbook for Mechanical Engineers, London, Mcgraw-Hill Company, ch. 13. 1998; 1-6.
5. GARA Souhir. 2017. https://www.technologuepro.com/cours-genie-mecanique/cours-30-procedes-mise-forme-moulage/
6. Gilotte P. Étude numérique du remplissage 3D en fonderie. Mécanique [physicsmed-ph]. École Nationale Supérieure des Mines de Paris, Français. 2003.
7. Saez E. Étude numérique du remplissage 3D en fonderie. Mécanique [physicsmed-ph]. École Nationale Supérieure des Mines de Paris, Français. 2003.
8. Antonin S. Eude expérimentale et numérique de la coulée basse pression de l'alliage de magnésium RZ5 dans des moules imprimés en 3D, l'École Nationale Supérieure d'Arts et Métiers Spécialité "Génie mécanique – procédés de fabrication. 2017.
9. Dietrich R, Facy G, Hugonnaud E et al. Précis de construction mécanique : Méthode, fabrication et normalisation, Nathan, Afnor. 1976; 242.
10. Collectif CTIF, *Masselottage en moulage sable*. Editions techniques des industries de la fonderie. 1994.
11. Collectif CTIF, *Le remplissage des empreintes de moules en sable*. Editions techniques des industries de la fonderie. 1984; 10.

Appendix

Appendix 1.Choice of value for (volumetric shrinkage of the riser)

Alloy		Values are taken into account to produce liquid alloy supply systems in %
Aluminum alloys	Copper	7 to 8
	Magnesium	7 to 8
	Silicon	3.5 to 5
	Zinc	8
Copper alloys	Cupro-aluminum	4
	Bronzes	4.5
	Brass	6.5
	High strength brass	7.5
Ferrous alloys	Unalloyed cast steels	5 to 7
	Cast alloy steels	7 to 10
	GL cast iron	0.5 to 3
	GS cast iron	3 to 6
	Allied cast iron	6 to 8
Magnesium alloys		4
Zinc alloys		5

Appendix 2.Metal Shrinkage Allowance

Alloy		Values are taken into account to produce the mold tooling (%)
Aluminum alloys	and copper	1.2 to 1.4
	and Magnesium	1.2 to 1.4
	and Silicon	1.1 to 1.3
	and Zinc	1.5
Copper alloys	Cupro-aluminum	1.8
	Bronzes	1.2 to 1.4
	Brass	1.5
	High strength brass	1.7
Ferrous alloys	Unalloyed cast steels	2 to 2.4
	Cast alloy steels	2.2 to 2.4
	GL cast iron	0.5 to 1.2
	GS cast iron	1 to 1.7
	Allied cast iron	1.5 to 2
Magnesium alloys		5
Zinc alloys		0.4 to 0.5

Appendix 3.Pressure Drop Depending on the Type of Casting

Cast from above	0.7
Casting from the side	0.4
Bottom casting	0.4
The casting of flat parts	0.25

Appendix 4.Phasing table for the calculation of the different filling sections

	S_d/S_d	S_c/S_d	S_a/S_d
Aluminum	1	2	1
	1	1.2	2
	1	2	4
	1	3	3
	1	4	4
	1	6	6
Aluminum bronze	1	2.88	4.8
Brass	1	1	1
	1	1	3
	1.6	1.3	1
Copper	2	8	1
	3	9	1
Ductile iron	1.15	1.1	1
	1.25	1.13	1
	1.33	2.67	1
Grey cast iron	1	1.3	1.1
	1	4	4
	1.4	1.2	1
	2	1.5	1
	2	1.8	1
	2	3	1
	4	3	1
Magnesium	1	2	2
	1	4	4
Malleable iron	1	2	9.5
	1.5	1	2.5
	2	1	4.9
	1	1	7
Steels	1	2	1
	1	2	1.5
	1	2	2
	1	3	3
	1.6	1.3	1

Appendix 5. ISO 8062 standard dated 01-04-1994

Table A1.Tolerance class

Type of molding	Tolerance class								
	Casting metals and alloys								
	Steel	**Grey font**	**Spheroidal graphite cast iron**	**Malleable cast iron**	**Copper alloy**	**Zinc alloy**	**Alloys light metals**	**Nickel base alloys**	**Cobalt-based alloys**
Hand sand casting	11 to 14	11 to 14	11 to 14	11 to 14	10 to 13	10 to 13	9 to 12	11 to 14	11 to 14
Sand casting Mechanical and shell casing	8 to 12	8 to 12	8 to 12	8 to 12	8 to 10	8 to 10	7 to 9	8 to 12	8 to 12
Shell molding by gravity/ low pressure	Work is in progress to refine the appropriate values. Consultations should take place between the modeler and the client to agree on the data to be used.								
Die-casting die-casting									
Precision casting									

Table A2.Typical class of specified machining allowance

Type of molding			Class of specified machining allowance						
			Casting metals and alloys						
	Steel	**Grey font**	**Spheroidal graphite cast iron**	**Malleable cast iron**	**Copper alloy**	**Zinc alloy**	**Alloys light metals**	**Nickel base alloys**	**Cobalt-based alloys**
Hand sand casting	G to K	F to H	F to H	F to H	F to H	F to H	F to H	G to K	G to K
Sand casting Mechanical and shell molding	F to H	E to G	E to G	E to G	E to G	E to G	E to G	F to H	F to H
Gravity/ low-pressure shell molding	-	D à F	D à F	D à F	D à F	D à F	D à F	-	-
In pressure die-casting	-	-	-	-	B à D	B à D	B à D	-	-
Precision casting	E	E	E	-	E	-	E	E	E

Table A2.Typical class of specified machining allowance

Machining allowance											
Largest Dimension (mm)		Class of specified machining allowances									
Above	**Up to and including**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**J**	**K**
-	40	0,1	0,1	0,2	0,3	0,4	0,5	0,5	0,7	1	1,4
40	63	0,1	0,2	0,3	0,3	0,4	0,5	0,7	1	1,4	2
63	100	0,2	0,3	0,4	0,5	0,7	1	1,4	2	2,8	4
100	160	0,3	0,4	0,5	0,8	1,1	1,5	2,2	3	4	6
160	250	0,3	0,5	0,7	1	1,4	2	2,8	4	5,5	8
250	400	0,4	0,7	0,9	1,3	1,8	2,5	3,5	5	7	10
400	630	0,5	0,8	1,1	1,5	2,2	3	4	6	9	12
630	1000	0,6	0,9	1,2	1,8	2,5	3,5	5	7	10	14
1000	1600	0,7	1	1,4	2	2,8	4	5,5	8	11	16
1600	2500	0,8	1,1	1,6	2,2	3,2	4,5	6	9	13	18
2500	4000	0,9	1,3	1,8	2,5	3,5	5	7	10	14	20
4000	6300	1	1,4	2	2,8	4	5,5	8	11	16	22
6300	10000	1,1	1,5	2,2	3	4,5	6	9	12	17	24
The largest dimension is that of the machined blank.											

Appendix 6. A mixture of moulding sand

Casting sand	Composition %				Properties		
	Sand unchecked	**Quartz sand**	**Sand (bentonite)**	**Addictions**	**Moisture %**	**Permeability**	**Resistance to compression in wet conditions (Kgf/cm²)**
Single sand	85-90	Molding from 10-5	Cast iron 3 (1-0.5)	1-sulfuric detergent 0.5-Coal	4-5	70-80	0.4-0.6
Sand contact	50-60	40-30	6.5-5.0 (2-1.5)	2-sulfuric detergent 3-Coal	4.5-5.5	80-100	0.5-0.6
Sable de remplissage	96-98	3-45	1.0-0.5	----------	5-5.5	60	0.3-0.4
unique high resistance sand (for the automatic machine)	93-96	3.5-2	--------- (2-1.5)	1-Coal 0.5-starch	3-3.4	120-150	1.5-1.7
unique sand for aluminum alloys	82-87	10-5	10-8	---------	4.5-5.5	20	0.3-0.5
Unique sand for bronze	80-85	10-5	12-8	1.5-Coal	4.5-5.5	30	0.3-0.5