Analysis of the Effect of Using Ceramic Filters in Steel Castings

Course: ME-428 Casting

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ABSTRACT

This project involves discovering the influence of using ceramic filters in the manufacture of steel parts. The objective is to show that the use of ceramic filters as an alternative to the traditional casting system of steel parts. Fundamentally, this traditional system consists in that the control of the slag was done in the feeding system (in the channels or in the feeder); However, we want to show that this control of the slag can be done in a more effective way using ceramic filters, in this case, we will say that the metal that enters the mold is much cleaner compared to the other control system, this brings Consequently the reduction of defects in our piece and a notable improvement in the surface finish of the same. Finally, a cost - benefit analysis is done to demonstrate the feasibility of this alternative method.

INTRODUCTION

The present project is a work, that is part of the training of future metallurgical engineers, since it must have a solid knowledge in how to carry out the process of manufacturing a piece of any metal or alloy.

The importance of the process of the casting of a piece reflects in all the process of the pieces of the series production, it is necessary to analyze which factors intervene at the moment of its manufacture, in order to be able to carry out this process more efficiently. One way to obtain a piece in a more efficient way, is by adding ceramic filters in the feed channel. Ceramic filters are a cost-effective and efficient way to reduce defects in castings.
What are filters?

Use of filters

The advantages of foam filtration are seen throughout the casting. According to the alloy and the application, many of the following advantages can be achieved:

<u>Control of slag</u>

- Low levels of slag produced.
- Improved ability to diagnose slag problems due to clearer separation of mold and metal factors.
- Reduction of costly rejection in mechanization.
- Filling and filling systems fill up gradually and remain full, which reduces the risk of gas bubbles entering the mold cavity.

<u>Productivity Improvements</u>

- Higher tonnage sent compared to cast tonnes (yield) due to the elimination of long casting systems.
- Simplified filling systems since the filter itself will reduce the speed and make the flow of the liquid metal more homogeneous.
- Simpler models allow casting to reduce mold size or increase number of pieces per mold.
- Higher yield means more molds per melted ton.
- It is often possible to reduce casting temperatures.
- Reduction of fixed assets for work in progress.

<u>Improvements in the quality of the pieces</u>

- Greater regularity in cleaning parts.
- Reduction in the variability of the metal flow of castings by hand, which leads to greater regularity of parts.
- Improvement in mechanical properties due to metallurgical characteristics.

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DESCRIPTION OF THE PROBLEM

Casting is the metallurgical process where metals and alloys at elevated temperatures are emptied into a mold containing the geometry of the product to be manufactured where it is allowed to solidify and cool.

There are seven basic stages in the process of casting that are: Design, Molding, Fabrication of Souls, Fusing, Casting, Demoulding, Finishing and Heat Treatment. The success of the final product falls in those stages.

Although the engineer responsible performs each stage of the casting process properly, it is difficult to obtain a metal piece without defects, since these are typical of the same process.

However, there are methods of being able to minimize such defects, such as inclusions, porosities, etc., one of which is applied by the use of ceramic filters, these ceramic filters help to retain the impurities that accompany the liquid metal, such as slags , Sand drag, etc.

OBJETIVES

GENERAL OBJECTIVE:

[1]. Verify the advantages ceramic filters give in the manufacturing of steel pieces in comparison with the traditional method.

SPECIFIC OBJECTIVES:

[1].Notice the defects without using ceramic filters.
[2].Learn the correct way to mold the metal piece.
[3].Recognize the factors involved in the casting process.
[4].Learn the right pouring technique to get the best fluidity.

DESCRIPTION OF THE SOLUTION

In every foundry process, the first thing to do is to calculate the dimensions of our piece to be melted then we can define and calculate the gating system. In this research, we worked with two methods for the calculation of the pouring system and risers: The modulus method (Wlodawer) and the method of the inscribed circumference.

<u>First Method: Modulus method (Wlodawer)</u>

Modulus is defined as the ratio of the volume to the cooling surface of the casting (or a part of the casting) or the feeder.

$$\mathrm{M(piece)} = \frac{V(piece)}{A(cooling)}$$

Where:

M_{piece}: Solidification module

V_{piece}: Volume of Casting

$A_{cooling}$: Cooling surface area

We calculate the area that will be in contact with sand:

$A_{cooling} = (27.36\ \mathrm{cm} * 15.8\ \mathrm{cm}) + (30\ \mathrm{cm} * 15.8\ \mathrm{cm}) + 2(15.8\mathrm{c\ m} * 3.635\ \mathrm{cm}) + 2\ (\frac{(30\ cm+27.36\ cm)}{2} * 3.58\ \mathrm{cm})$

$A_{cooling} = 1226.5028\ \mathrm{cm}^2$

$V_{piece} = (\frac{30+27.36}{2}) * 15.8 * 3.58 = 1359.432\ \mathrm{cm}^3$

With these parameters, we continue to calculate the module of steel pieces:

$M_{piece} = \frac{1359.432\ cm^3}{1226.5028\ cm^2} = 1.108380674\ cm$

This method of Wlodawer tell us that $M_{feeder} = 1.2\ M_{piece}$, so we replace the value of M_{piece} to obtain the value of M_{feeder}:

$M_{feeder} = 1.2 * (1.108380674\ \mathrm{cm})$

$M_{feeder} = 1.330056809\ \mathrm{cm}$

Now, to find the diameter and height of the feeder, the first thing to do is to consider the shape of it. In this case we will consider the shape of the feeder to be that of a cylinder with a dimensional ratio of H / D = 1. (Where "H" is the height of the feeder and "D" the feeder diameter)

For this type of feeder to be considered, the module is defined as "r / 3", where "r" is the feeder radio, then we calculate this with M_{feeder}.

We have: $M_{feeder} = \frac{r}{3} = 1.330056809$ cm.

So the value of “r” will be r = 3.990170426 cm.

We proceed to calculate the diameter and height of the feeder, using the ratio of“H/D = 1“

D = 2r = 2 (3.990170426 cm), so D = 7.980340852 cm.

The ratio of “H/D = 1”, so H = 7.980340852 cm.

After having done the calculation of the feeder, we will calculate the efficiency of the same, for that we need the weight of the piece (P_{piece}), the weight of the channels (Taking 10% of the weight of the piece) and the weight of the feeder. (P_{feeder}, it should be mentioned that all these weights have to be expressed in kg)

$P_{piece} = V_{piece} * \rho$, where the volume of the piece we had already calculated when making the module of the piece so now we only have to replace this value and we also know that the density of a common steel is 7.8 gr / cm^3.

$P_{piece} = 1359.432\ cm^3 * 7.8\ gr/cm^3 * 1kg / 10^3\ gr$

$P_{piece} = 10.6035696$ kg

After calculating the weight of the piece (P_{piece}), we calculate the weight of the runners ($P_{runners}$) assuming that it is worth 10% of the Piece, then:

$P_{runners} = 10\%\ P_{piece}$

We replaced to obtain that $P_{runners}$ = 10% (10.6035696 kg) = 1.06035696 kg

After calculating the weight of the part and the runners, we calculate the weight of the feeder, for that we need to calculate the volume of the feeder using the dimensions we have calculated, both the Diameter "D" and the Height "H" of the feeder.

$P_{feeder} = V_{feeder} * \rho$

$P_{feeder} = (\frac{pi*D^2}{4} * h) * \rho$

$P_{feeder} = (\frac{\pi*(7.980340852cm\text{^}2)^2}{4} * 7.980340852cm) * 7.8$ gr/cm^3 * 1kg/10^3 gr

$P_{feeder} = 3.11349955$ kg

Now, with all the weights calculated, we can calculate the efficiency, knowing that it is defined as:

$$\mathrm{n} = \frac{\mathrm{P(piece)}}{\mathrm{P(feeder) + P(piece) + P(runners)}}$$

Replace to obtain that:

$$\mathrm{n} = \frac{10.603569\ \mathrm{kg}}{3.1134995\ \mathrm{kg} + 10.603569\ \mathrm{kg} + 1.0603569\ \mathrm{kg}}$$

Resolving:

$$\mathrm{n} = 71.7551863\ \%$$

We see that the efficiency that is obtained is advisable for the steels that we will be melting. (Such efficiency range is 60% - 72%)

We will begin to calculate other parameters such as the time of emptying (t) and the area of shock (Ac), for that it is necessary to remember the relations that define these two important parameters. These are:

$$t = k * \sqrt[3]{eP}$$

Where:

k: Constant that depends on where the metal was emptied to the piece.

e: Thickness of the Piece (in mm)

P: Total weight of the casting ($P = P_{feederr} + P_{piece} + P_{runners}$)

We calculate the casting time (t) for the piece to be cast, taking into account that the thickness of the piece is 35.8mm (e = 35.8mm), the total weight of the casting is 21.792588435 kg (P = 10.6035696 kg + 1.06035696 kg + 3.11349955 kg = 14.77742611 kg). Because it is going to be molded by the medium, that is, it is going to be cast by the partition line of the box, so we have k = 1.4, so we can calculate the emptying time by replacing each of these values in The equation we have:

$$t = 1.4 * \sqrt[3]{35.8mm * 14.77742611\ kg}$$

$$t = 11.32283842\ s$$

Obtain a drainage time of approximately 11 s, with possible to calculate the area of shock (Ac) which is another important parameter when designing the feed system and what it defines as:

$$\mathrm{Ac} = \frac{22.6\ P}{t * \rho * c * \sqrt{\mathrm{H}}}$$

Where:

Ac: Choke area, in cm^2

P: Total weight of casting, kg

t: Dump time, in s

ρ: Metal density, in gr/cm^3

c: Constant that depends on the place where the metal is poured into the box

H: effective height, in cm

For this case, we have as data that P = 14.77742611 kg, ρ = 7.8 gr / cm3, t = 11.32283842 s, the value of constant "c" is 0.35 because it will collapse by means and effective height, Half the height of the piece plus the height of the feeder

We replace all these data in the equation shown to obtain the Ac:

$$\mathrm{Ac} = \frac{22.6 * 14.77742611}{11.32283842 * 7.8 * 0.35 * \sqrt{19.746}}$$

$$\mathrm{Ac} = 2.43136249\ \mathrm{cm2}$$

Applying the scaling of areas, considering a pressure system

$$S_{sprue} : S_{runner} : S_{ingate} = 1:2:1$$

We have our area of shock that would come Ac, so it is enough to replace this in the scaling areas. We get that:

$S_{sprue} = 2.4316249\ cm2$
$S_{runner} = 4.86272498\ cm2$
$S_{ingate} = 2.4316249\ cm2$

This gating system will be use

<u>Second Method: Method of the inscribed circumference</u>

This method tells us that the diameter of the feeder is in function of the maximum circumference that can be inscribed in the thickness of the piece.

$$Dfeeder = (1.4 - 1.6)Dc.inscribed\ , for\ bars$$

$$Dfeeder = (1.6 - 2.5)Dc.inscribed, para\ plates$$

Where:

D = Diameter (in mm), either of the feeder or of the inscribed circumference that can be drawn in the part.

In the model of the piece, we realize that the maximum circumference that we can inscribe in its thickness is one of diameter 35.8 mm (corresponding to the thickness of the piece itself), then we apply the second relation because this piece has the shape Of a plate, we will take a value within the range indicated in the second equation, in this case, a factor of 2.4 will be used. We substitute in the equation to obtain that:

$$Dfeeder = 2.0 * (35.8\ mm)$$

$$Dfeeder = 71.6\ mm$$

Using a exotermic cuffs board supplied by the company MERCURIO S.A, we see that the dimensions of our feeder (and in addition to the handle) will approximate the exothermic cuff available by this company.

D_{feeder} = 80 mm

P_{feeder} = 3.25 kg

H_{feeder} = 120 mm

For this case, we will also calculate the efficiency (n), knowing that we have already defined it, then:

$$n = \frac{10.6035696\ \mathrm{kg}}{3.25\ \mathrm{kg} + 10.6035696\ \mathrm{kg} + 1.06035696\ \mathrm{kg}}$$

Calculating:

$$n = 71.09844317\ \%$$

<u>NOTE</u>: The diameter of the feeder that is obtained is relatively similar to that calculated by the first method (Wlodawer method), thus avoiding the calculations of the emptying time and the area of shock.

<u>Calculation using Ceramic Filters</u>

To calculate the dimensions of the filter, the following area ratio is used. (Note that the weight of the part has already been calculated)

We are going to use a filter of dimensions 50mm * 50mm (As the total weight of our piece, considering feeders and channels is approximately 15 kg).

Another fundamental aspect in the filters are the "ppi" or also called "Pore per inch2", this quantity depends on which material the piece will be fused, we attach a table that relates the "ppi" to the different alloys to be fused.

Alloy		Filter porosity (ppi)
Cast iron:	grey iron	20 – 30
	ductile iron	10
	malleable iron	30
Steel:	low-carbon	10
	high – carbon	10 – 20
	stainless	10
Aluminium alloys		20 – 40
Magnesium alloys		10 – 20
Copper alloys		10 – 20

Table 1. Ratio between alloy to melt and ppi in filters

Due we are casting steel to the Cr-Mo, we will use a 10 ppi filter and we have already said that the dimensions of the steel were 50mm * 50mm. This filter will be placed in the feeder and the laundry will be made directly to it. Only desfogues will be used so that the gases can escape by them and not be retained in the piece to avoid porosities.

RESULT

We will show the finishes obtained for the same piece, in this case, a grinding wheel of laboratory jaw crusher, using ceramic filter (Direct casting by the feeder) and without using a ceramic filter (cast by the traditional feed system)

<u>WITHOUT FILTER</u>

In this piece where no filter was used, porosities, inclusions, and a poor surface finish are observed, these pieces will have to be soldered to fill the porosities and imperfections that were obtained in the casting. While it is true that our food system worked because most of the slag remained in the distribution channel, another small amount passed to the piece and that can be seen in the points in it.

Drawn 1. Piece where didn´t used filter

<u>WITH FILTER</u>

In this piece that was used ceramic filter, you see a better surface finish. In addition, a smaller amount of inclusions is seen because the metal that has entered is cleaner because our filter has retained the slag. We can say that it is not necessary to repair the part with a weld. Also, In addition, we will compare the prices that are obtained in both casting. (Both using filter and without using it)

Drawn 2. Pieces obtained with the use of ceramic filters

Cost Without Filter			
Area	Unit Cost	Units	Cost ($)
Pattern Making ($/mould)	50	0.1	5
Mould ($/min)	1	30	30
Core ($/min)	0	1	0
Furnace ($/kg)	0.05	14.7	0.74
C. Metal ($/kg)	0.7	14.7	14.56
Casting Cleaning ($/min)	0.3	20	6
H. Treatment ($/kg)	0.15	14.7	2.22
Machining ($/piece)	0	1	0
	TOTAL COST		58.52

Table 2. Cost of Casting without Filter

Cost with Filter			
Area	Unit Cost	Units	Cost ($)
Pattern Making ($/mould)	50	0.1	5
Mould ($/min)	1	30	30
Core ($/min)	0	1	0
Furnace ($/kg)	0.05	13.85	0.69
C. Metal ($/kg)	0.7	13.85	12.76
Casting Cleaning ($/min)	0.3	15	4.5
H. Treatment ($/kg)	0.15	13.85	2.08
Filter ($/piece)	3	1	3
	TOTAL COST		58.03

Table 3. Cost of Casting with Filter

CONCLUSIONS

[1]. Ceramic filters are a cost-effective and efficient way to reduce defects in castings.

[2]. The use of ceramic filters allows a clean piece to be obtained (both internally and externally), which means that the mechanical properties of the part improve because there are fewer defects.

[3]. The use of ceramic filters improves the productivity of the piece because my piece is of much better quality and thus, the rejection to it is minimized, increasing the productivity because we avoid losses by rejection, welding, etc. In addition, our customer service will be the best due to the quality of the delivered piece

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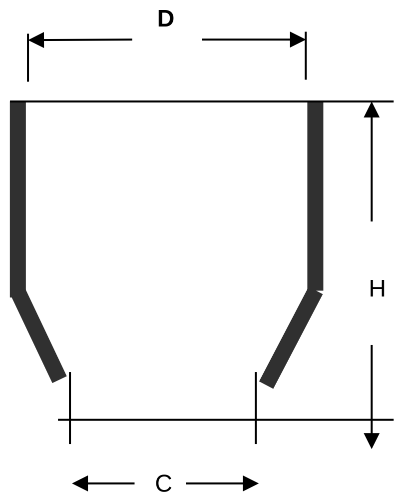
ANEXXES

EXOTHERMICAL CUFFS WITH "UL" CONSTRICTION



Highly insulating exothermic cuffs with bottleneck in the base to facilitate cutting and better finishing of the casting.

Exothermical Cuff UL	D (mm)	C (mm)	H (mm)	Modulus (cm)	Feeder Weight in Kg.	Maximum weight in kg To be fed in function of contraction					Exo-Dust E-23 Add
						5%	6%	7%	8%	9%	
50 UL	50	30.0	75	1.80	0.93	6.2	5.1	4.4	3.8	3.4	0.03
60 UL	60	36.0	90	1.95	1.60	10.0	8.8	7.5	6.6	6.0	0.04
70 UL	70	54.0	116	2.00	2.70	13	11	9	7	6	0.05
80 UL	80	59.2	120	2.30	3.25	21	18	15	12	11	0.07
90 UL	90	66.6	135	2.70	5.40	38	32	27	23	20	0.09
100 UL	100	74.0	150	3.00	8.05	54	45	39	34	31	0.12
110 UL	110	81.4	165	3.35	11.00	77	64	55	49	43	0.14
120 UL	120	88.8	180	3.60	13.00	88	74	63	56	50	0.17
130 UL	130	96.2	195	3.90	15.40	104	87	75	66	58	0.21
140 UL	140	103.6	210	4.30	20.50	141	117	101	88	78	0.26
150 UL	150	111.0	225	4.65	26.00	179	150	129	113	102	0.32
160 UL	160	118.4	240	4.90	31.00	208	173	149	131	116	0.38
170 UL	170	125.8	255	5.20	38.75	262	219	188	166	147	0.45
180 UL	180	133.2	270	5.45	42.70	287	240	207	181	161	0.54
190 UL	190	140.6	285	5.75	48.10	323	271	233	202	180	0.62
200 UL	200	148.0	300	6.05	53.00	367	307	263	231	206	0.72
210 UL	210	155.4	315	6.40	70.30	465	389	333	292	259	0.83
220 UL	220	162.8	330	6.75	81.90	553	460	394	345	307	0.95
230 UL	230	170.2	345	7.05	92.00	589	511	437	382	340	1.00

The shape, material and size of the exothermical cuff are not limiting. The client can consult us to see the possibility of attending to specific need.

Note: Guaranteed performance when Exo-Dust E-23 expansive exothermic powder is used.