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Optimization of Material Input in Induction Furnace for Casting

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Abstract – Foundry, especially casting is one of the most Energy exhaustive metallurgical industriy. The major part of the energy consumed in Foundry is in the melting energy consumed per melt of molten metal. Energy in the form of electricity also contributes to the major cost input to the production of metallic components as castings. Besides foundries, high energy consumption is upbringing the threat to climate change and also has effect on global warming. Therefore it becomes very much necessary to look into various mea ns by which energy consumed in melting units can be brought down considerably. Many of the works have being done by many Foundry men to reduce specific energy consumed in liquid metal generation. Operational uncertainties create disincentive for use of recycled metals in production. One that greatly influences on the remelting and batch optimization variation in the raw material and additional composition, particularly for materials which are secondary. Currently, to accommodate variation in composition, firms commonly set production target s well inside the window of compositional requirement required for performance reasons. The present work deals with some of the steps taken in an industry. The Foundry are required to reduce material consumption particularly in standard frequency furnace that contain improved, scrap charging order, furnace, sampling, changes in metal composition etc. This has resulted in drop of specific material input and significantly money savings.

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1. INTRODUCTION

Foundry is one of the power consuming metal casting industries. The major part of the energy consumed in Foundry is in the melting energy consumed per melt of molten metal. Energy in the form of electricity also contributes to the major cost input to the production of metallic components as castings. Besides foundries, high energy consumption is upbringing the threat to climate change and also has effect on global warming. Therefore it becomes very much necessary to look into various mea ns by which energy consumed in melting units can be brought down considerably. Many of the works have being done by many Foundry men to reduce specific energy consumed in liquid metal generation.

Variation in operation create problems for use of materials hich are being recycled in metal production. One that greatly influences is melting in batches optimize the variation in the raw material composition, mostly for materials which are secondary. Currently, to cope up composition variation, industries commonly set production targets well inside the specific limit required for performance reasons and quality is one among them.

In the casting process a pattern is produced in the shape of the required part. This pattern is produced out of wood, metal or plastic. Simple and small designs can be made in a single piece of solid. More complex designed components are made in two components, called split patterns. A split pattern has a top or upper part, called a cope, and a bottom or lower part called a drag. Both solid and split patterns can have cores inserted to complete the end part shape. Where the cope and drag separates is called the parting line where both components meet. When making a pattern edges are tapered so that the pattern can be removed without breaking or distorting the mould.

2. INDUCTION FURNACE METAL CONSUMPTION

Variety of compositions are used in one melt of induction furnace, which an approximate of 500kgs. Different composition of metal can be used with its additives to get different characteristics of metal. In this context industry produces mainly three grades of metal, those are SG iron, pulley grade and also ordinary grade, which are based on customer and requirements based on use.

The table 1 shows different composition of metal to form the required grade. The actual process varies slightly, for the two components considered for the experiment, the quontity of metal melted is approximately 485kg , as the quantity of metal required for the above mentioned components is approximate of 406 kg. The extra amount of metal is melted due to loss of metal while pouring, melting and handling.

The figure 1 elaborates the component. There are some experiments conducted prior to manufacturing of the prescribed component.

Fig 1 Component

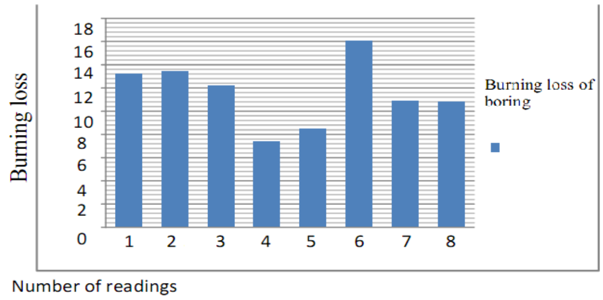
Table 1 Grade wise metallic mix for 500 kg

Sl no	Components	SG iron	Cast iron	
			Pulley grade	Ordinary grade
1	Pig iron	160 kg	100 kg	80 kg
2	MS scrap		140 kg	70 kg
3	Returns	160 kg	100 kg	150 kg
4	Boring		160 kg	200 kg
5	CRC (punching scrap)	180 kg		
6	CPC (Graphite fines)	7 kg	5.7 kg	3.8 kg
7	Silicon		3.6 to 3.8 kg	2 kg
8	Manganese		1.5 kg	0.8 kg
9	Chromium		1.8 kg	
10	Magnesium	3.4kg /250 kg		
11	Copper			
12	Inoculation	0.2%		0.15 to 0.2 %

Table 2 Metal consumption with boring

Sl no	1	2	3	4	5	6	7	8
Units	250	256	254	252	255	258	254	258
MS scrap	140	140	140	140	140	140	140	140
Pig iron	60	60	60	60	60	60	60	60
Boring	200	200	200	200	200	200	200	200
Returns	70	71.5	60	70	70	70	70	70
Additives	13.72	13.72	13.72	13.72	12.32	13.72	12.32	12.32
Total wt	483.72	485.2	473.72	483.7	482.3	483.7	482.3	482.3
Return wt	13.8	14	10	42	35.5	0	23.9	24
Metal wasted	63.92	65.22	57.72	35.72	40.82	77.72	52.42	52.32
Bunch wt	406	406	406	406	406	406	406	406
Burning loss	13.214	13.44	12.184	7.384	8.463	16.07	10.87	10.85

The burning loss is tabulated by using below mentioned formula shows the variation in the metal consumption. Higher the burning loss results in more melting losses. These losses also effect the energy consumption and effect the production costs of the induction furnace. The graph 1 shows eight set of readings generated from various composition change per reading, from which shows variation in burning can be tabulated.



Graph 1 – Burning losses of present process

2.1 Calculations

- Total weight tabulated as - MS scrap + pig iron + boring + returns + additives
- Bunch weight tabulated as - the bunch weight of each 620 or 637 component is 203 kg
- Metal wasted tabulated as - Total weight – bunch weight – return metal weight
- Burning losses tabulated as - metal wasted / total weight of metal* 100
- Standard deviation(s or σ) tabulated below

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2} \qquad (1)$$

$$X = (x_1 + x_2 + \ldots .xn) / (n-1) \qquad (2)$$

From equation 2, mean can be tabulated which shows the middle value of the deviation. All the values of burning loss are considered from Table 2 considered as x1, x2----xn where xn is last value. By this the value of X is given below;

$$X = 11.56\ \%$$

Therefore from the above X (mean) value, average of 11.56 % of burning loss was produced by sampling of eight readings.

$$\sigma = 2.8\ \%$$

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The above value (σ) shows the deviation of the burning loss from its mean value, which also denotes the uncertainty of variation

That is, from the mean value of 11.56%, there is a ± variation of 2.8 %.

2.2 Improvement in Metal Consumption

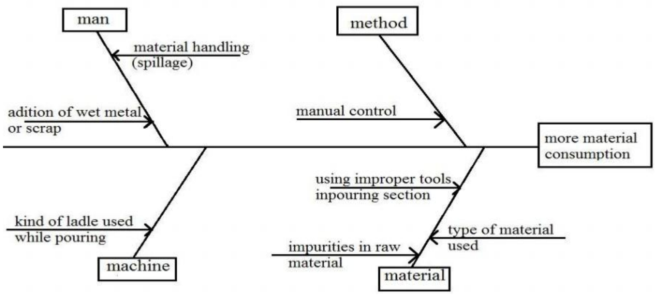

Fig 2 Fish bone diagram (Cause and effect diagram) for material consumption

3. FIRST EXPERIMENT CONDUCTED ON METAL CONSUMPTION

The process which was carried out previously, it was observed and noted that the burning loss of metal melting was comparatively high. In that process MS scrap, returns and boring were acting main constituent of the charge to be melted for casting. Some changes were made in the ingredients of the metal melted. Boring was terminated, and returns from previous casting were added around 270 kg for every batch of melt. This change was produced because, boring contained many unwanted impurities like mud, oil etc. It is difficult to remove or separate mud and other impurities from boring, which also consumes much of labour hours. The presence of unwanted material like oil and mud in boring also increases the melting loss of the induction furnace. Though the melting of boring is faster than the other metals, presence of impurities in boring drastically increases the time required for one melt.

Fig 3 Boring

Figure 3 shows the picture of boring, in the above experiment all compositions are kept exactly the same except that the boring has been completely eliminated which is compensated by adding extra returns got by green sand process.

Returns are the metal extracted from the remains of runner, riser and other elements of gating systems; these cannot be used directly for melting, as the return metal contains sand particles adhering or included in it. The returns got from the mould are shot blasted, by using blasting machine. The blasting machine will be set for forcing a small diametric shots along with high pressured air, which hits the metal at high velocity, and removes sand and other inclusions, which are present outside of the component. But the inclusions present inside cannot be removed by this method.

Fig 4 Return metal

Table 3 First composition change

Sl no	1	2	3	4	5	6	7	8
Units	253	254	252	256	251	250	256	258
Ms scrap	140	140	140	140	140	140	140	140
Pig iron	60	60	60	60	60	60	60	60
Returns	270	270	270	270	270	270	270	270
Additives	12	13.82	13.82	13.82	13.82	13.82	13.72	12.32
Total wt	482	483.82	483.82	483.82	483.82	483.82	483.72	482.32
Return wt	46	53.6	55	53.7	45.8	56.6	42.7	46.2
Metal wasted	30	24.22	22.82	24.12	32.02	21.22	35.02	30.12
Bunch wt	406	406	406	406	406	406	406	406
Burning loss	6.2241	5.006	4.7166	4.9853	6.6182	4.3859	7.2397	6.2448

3.1 Calculation

- Total weight tabulated is - MS scrap + pig iron + returns + additives
- Bunch weight tabulated is - the bunch weight of each 620 or 637 component is 203 kg
- Metal wasted tabulated is - Total weight – bunch weight – return metal weight
- Burning losses tabulated is - metal wasted / total weight of metal* 100
- Standard deviation(s or σ) =

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$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2} \quad (1)$$

X = (x1 + x2 + ...xn) / (n-1)

(2) Therefore from equation 1 and 2

X = 5.677 %

From the above mean value, average of 5.677 % of burning loss is developed for a sample of eight readings, when this is compared with the mean got from previous set of readings, considerable amount of variation can be noted.

σ = 1.03 %

The above value elaborates the deviation of the burning loss from its mean value, which is less when compared to previous standard deviation.

This denotes for the mean value of 5.677 %, there is a ± variation of 1.03 %

By the above mentioned experiment, it can is evident that there is reduction in % of burning losses drastically.

4. SECOND EXPERIMENT CONDUCTED ON METAL CONSUMPTION

In the first experiment, though the burning losses were minimized to an amount, but still burning losses were more. In the below figure it can be seen that there are sand inclusion in the metal, as the sand has high melting temperature and metal has lower melting point than sand, the sand doesn't melt in the induction furnace and consumes unnecessary electrical energy

Fig 5 showing sand inclusion in return metal

Shot blasting process cannot use in removing these sand inclusions. This type of sand inclusion can be abridged by while preparing mould, mould paint is useful for healthier surface finish, this mould paint can be applied at the riser section of the mould, so that molten metal is away from mould surface this can reduce sand inclusions in metal. The riser portion is rough and irregular. The irregularity of the riser portion of the mould should be avoided before the application of mould paint.

Fig 6 Shell return metal

In this experiment as an alternative of normal returns, shell returns were used. The shell return is almost pure metal with no or very less sand inclusions.

Table 4 Second composition change

Sl no	1	2	3	4	5	6	7	8
Units	249	255	253	257	259	253	255	254
MS scrap	140	140	140	140	140	140	140	140
Pig iron	60	60	60	60	60	60	60	60
Shell returns	270	270	270	270	270	270	270	270
Additives	13.72	12.32	12.32	13.72	13.72	13.72	12.32	13.72
Total wt	483.72	482.32	482.32	483.72	483.72	483.72	482.32	483.72
Return wt	55.2	59.2	58.5	58.1	50.2	53.8	60	56.9
Metal wasted	22.52	17.12	17.82	19.62	27.52	23.92	16.32	20.82
Bunch wt	406	406	406	406	406	406	406	406
Burning loss	4.6556	3.5495	3.6946	4.0561	5.6892	4.945	3.3836	4.3041

The table 4 shows the composition of the experiment conducted in order to minimize the burning losses to as minimum as possible. Shell returns are taken from shell casting process, and sand engaged in this process is Green sand. As the packing density of the green sand is high compared to CO2 sand, the casting and returns got from this process are of much superior surface finish. Producing castings by using green sand process is slow process; therefore CO2 process is mainly employed for quicker production.

4.1 Calculation

- Total weight = MS scrap + pig iron + shell returns + additives
- Bunch weight = the bunch weight of each 620 or 637 component is 203 kg
- Metal wasted = Total weight – bunch weight – return metal weight
- Burning losses = metal wasted / total weight of metal * 100
- Standard deviation(σ) =

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2} \quad (1)$$

$$x = (x1 + x2 + \ldots . xn) / (n-1) \quad (2)$$

There from equation 1 and 2

x = 4.284 %

From the above mean value, average of 4.284 % of burning loss is developed by sample of eight readings.

σ = 0.78 %

The above value shows the deviation of the burning loss from its mean value

That is, from the mean value of 4.284 %, there is a ± variation of 0.78 %

By this experiment, it can be seen that the percentage of burning loss has been comparatively abridged.

5. SUMMARY OF METAL CONSUMPTION

Table 5 Summary of metal consumption

	with boring	without boring	with shell RR
Average burning loss	11.56%	5.68%	4.28%
Standard deviation	2.80%	1.03%	0.78%

Table 4 and graph 3 shows the relative reduction in burning loss. By the experiments conducted it is possible to reduce the burning losses from an average of 11.56 % to an average of 4.2 %.

The limit of burning loss set in JPF Metacast is around 3 %.

There are other unaccounted loss of metal such as spillage of metal while pouring in to mould and ladle, the wetness of Metal and many other factors.

6. CONCLUSIONS

- The original composition of metal was high. The average burning loss earlier was 11.56%. In the next experiment, the burning loss was reduced to the average of 5.68%. In the second experiment the burning loss was reduced to 4.28%.

- Dissimilar composition of metals can be used without varying the grade of metal, so as to reduce burning losses to smallest as possible.

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