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Defects analysis, minimize metal wastages and yield improvement for grey cast iron casting: A case study

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ABSTRACT

Proper selection and maintenance of melting and holding equipment, molten metal wastages, moulding methods and casting defects influence metal losses in foundry. Casting yield mainly depends on runner and riser weight, pouring practices and casting defects. In this study all castings were grouped into three categories namely light, medium and heavy weight castings. After implementing new runners and risers and remedial measures for defects in castings, weights of runners and risers have reduced by 2.1%, 5.7% and 3.1% respectively for the three categories. Weights of defects in castings have been reduced by 1.6%, 6% and 1% and as a result casting yield has increased by 3.5%, 7.7% and 4.2% from products of light, medium and heavy respectively.

KEYWORDS

Casting;
Foundry;
Moulding;
Riser;
Runner.

INTRODUCTION

Foundry is the most basic input in most of the manufacturing industries and stringent demands of quality and quantity are being placed on it with rapid industrialization and growth in other fields of production. Up to date knowledge of materials and processes for casting is necessary in order to produce economically sound castings[8]. Nearly all mass produced discrete parts are manufactured by dies and moulds during the production process such as forging, stamping, casting and injection moulding[1]. Generally, dies and moulds are designed to have the capacity for mass production. With modern hard materials and proper mould design, an injection mould is capable of producing one hundred thousand parts or more. According to Klobcar and Tusek[3] and Klobcar et al.[4], the production capacity of a die casting die can reach up to three hundred thousand castings.

Casting traceability is an unsolved problem for large quantity, green sand foundries. The principle of green sand mould castings makes it hard to efficiently trace individual castings. Rinsing the sand from the castings, after the castings have cooled, often involves a process that shuffles the castings. Flawed castings cannot be backtracked precisely or efficiently. Thus, casting traceability requires a marking of the castings themselves, before the rinsing process is initiated;hence, the mark itself must be cast. Today, cast marking is made by identifiers on the pattern plate or by mould inserts. Two pattern plates are used to mould a sand mould, into which the melt is poured[6].

Compared with other countries foundry industry in Sri Lanka is far behind. The basic method used in Sri Lanka to produce various types of products is sand casting and most of the time grey cast iron is used as the casting material. Molten metal is wasted due to bad handling of molten metal in casting industry when producing the products by using sand casting in grey cast iron. In Sri Lanka, casting industry has so many problems such as low casting yield, defects in casting, and bad attitudes towards this industry due to dusty and hot environment[9].

Sri Lanka Government Railway, Government Factory in Kolonnawa, and Industrial Development Board are the major state owned organizations that use sand casting methods in production. In addition to these organizations, there are some private organizations running foundries such as Ceylon Heavy Machinery Industries Company Limited, Solex Industries Private Limited and Jinasena Casting Company Limited[9].

The increasing globalization of demand for castings and the constant presence of alternative methods and materials are recognized as the most important area in foundry industry in the 21st century. The manufacturing is empowered by utilizing highly skilled workers in order to compete in the new global market, trends toward accepting more supply chain responsibility and the need for speed. Foundries will have entirely different workforce requirements, including people as well as the entire business that is managed. Operators have to take a hard look at said process and the role in component supply, with critical future decisions[2].

The proper selection and maintenance of melting and holding equipment are clearly important factors in minimizing wastages in casting operations. In addition to wastages of molten metal, methods of moulding and defects in casting are also influence metal loss. Other important factors influencing casting yield are geographic location, alloys, starting form of alloy, overall process, scrap rate, cycle times, number of shifts per day, days of operation per month, type and size of casting of alloy and size of the casting machine, related equipment and downstream processing. Each of these factors also influences the casting quality, productivity and yield of casting enterprise[5,10].

There are three kinds of losses that reduce yield: crap castings due to defects, metal devoted to excessive runner and riser systems in order to deliver metal to the mould cavity and provide a reservoir as necessary to feed solidification shrinkage are losses. This is only valid for certain items which are having larger gating systems than normal sizes and compose the amount of molten metal in the pouring process[7].

When a defective casting is produced, it is necessary to analyze the defect or defects and observe or determine the causes for the occurrence of the defect, so as to arrive at appropriate remedial measures. Following are few methods to minimize the defects occurring when the pouring system is used[11].

- Fill the mould rapidly, without laps or else requires excessively high pouring temperature
- Reduce or prevent formation of slag in the mould
- Prevent slag and eroded sand entering the casting by way of the gating system
- Prevent aspiration of air into the molten metal stream
- Avoid erosion of mould and cores
- Obtain suitable thermal gradient to attain directional solidification and minimize distortion in castings
- Obtain maximum casting yield and minimum grinding cost
- Provide handling equipment for ease of pouring and utilizing of melt on ladle.

In this research main objective was to improve the casting yield by minimizing the wastages of molten metal, such as excessive weight of runner, riser systems, poor pouring practices and defects in casting products.

DATA AND METHODOLOGY

All the necessary data were collected from the selected well stabilized Casting Factory in Colombo, Sri Lanka by interviewing the Factory Manager, Senior Metallurgist, Junior Metallurgists, Supervisors and Foundry men. For the purpose of analysis of data, past data such as weight of melt, weight of good casting, weight of risers and runners, weight of defected products and weight of loss in melt were collected.

After grouping all castings into three categories namely light, medium and heavy weight castings, they were analyzed. Three items were selected, one from each category, such as N110 Volute from light weight casting, T400 pump body from medium weight casting and diffuser 2CA 500/3 from heavy weight casting.

Category method was based on product weight and shape and size of product.

New sizes for existing runners and risers were introduced using past research results[2,5]. Proposed sizes of runners and risers were implanted with the identified root causes affecting to the mismatch and misrun for the aforesaid items. The company has introduced remedial measures for the above defects. All these defects are tabulated separately and the percentages of defects were calculated and the sizes of runner in-gates and time taken for the filling of moulds were measured.

Analysis of root causes for the elements of gating system such as pouring time, runner in-gate, sprue taper, sprue base design and designing of runner, In-gates and number of risers are mostly effecting to the casting yield. For this purpose, weight of each and every item has to be taken into consideration. Basic gating design for gravity-fed vertically parted sand mould castings has little changes in this factory. Current designed yield is less than optimal results. Improvements in gating designs can significantly reduce casting defects and increase casting yield.

RESULTS AND DISCUSSION

As an average of casting yield 70% to 75% is maintained. Casting yield is mainly depends upon, conventional methods. Casting practices are very important when the yield is going to be minimized. Normally, temperature of first melt is low and fluidity of that melt is also very low. This melt is used as scrap for the next cycle. In addition to these defects, some defected items are coming from the machine shop.

Gray cast iron was used to produce water pumps. Hence cupola furnace is used for melting operation. There are two types of cupola furnaces: conventional type 61 cm (2ft) diameter cold blast cupola, capacity is 1.8T/h. It consists of four tuyeres in a layer and divided type 61 cm (2ft) diameter cold blast cupola, capacity is 2.2 T/h. It consists of 6 tuyeres in each layer and temperature can reach up to 1550^{0}C. Following raw materials were charged into cupola furnace to obtain required melt; Cast iron scraps (local)100 kg, Pig iron (imported)10 kg, Re-generated scrap 40 kg, Coke (92% carbon imported)15 kg and Lime stone 12 kg.

The following data were collected without any changes to the existing casting practices at the selected factory.

Lightweight castings

Weight of product of N 110.and weight of defect in kg measured on 12th of September 2006 is given in TABLES 1 and 2 respectively.

The defects in light weight product of N 110 were as follows

A usage of molten metal of product of N 110 measured on 12th of September 2006 is presented in Figure 1.

Medium weight castings

The following TABLES 3 and 4 are the usage of melt in above date and defects in medium weight product of Volute of T 400 Pump Body.

A usage of molten metal of product Volute of T 400 Pump Body measured on 12th of September 2006 is presented in Figures 2.

Heavy weight castings

The defects in heavy weight product of Diffuser 2

TABLE 1 : Usages of molten metal - Production chart of product N 110 on 12th of September 2006

Melt used (kg)	Good Casting (kg)	Runner & Risers (kg)	Defects (kg)	Yield (%)	Defects (%)	Runner & Riser (%)	Time taken for filling (second)
912	617	197	98	67.8	10.7	21.6	145

TABLE 2 : Defects in casting - Production chart of product N 110 on 12th of September 2006

Item	Misrun	Mismatch	Blow Holes	Cracks	Damaged	Sand Wash	Slag Incl.
kg.	34	29	14	9	5	4	3

TABLE 3 : Usages of molten metal of product volute of T 400 PumpBody - Production chart on 12th of September 2006

Melt used (kg)	Good casting (kg)	Head &Risers (kg)	Defects (kg)	Yield (%)	Defects (%)	Runner & Riser (%)	Time taken for filling (second)
1909	1221	465	223	63.9	11.7	24.4	280

TABLE 4 : Defects in casting of product volute of T 400 Pump Body- Production chart on 12th of September 2006

Item	Mismatch	Misrun	Sand Wash	Cracks	Slag Incl.	Blow Holes	Damaged	Inner Surface Damaged
kg.	93	63	17	16	9	9	7	7

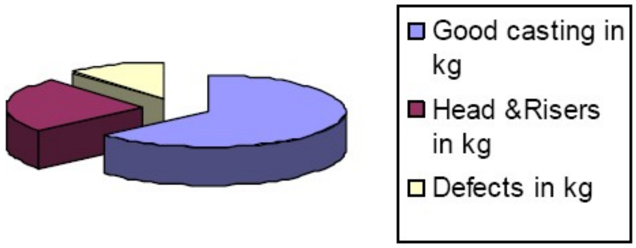

Figure 1 : Usages of molten metal of product N 110

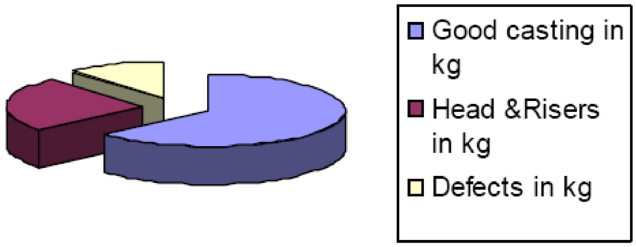

Figure 2 : Usages of molten metal product volute of T 400

CA 500/3 are as tabulated in the following TABLES 5 and 6 respectively.

According to the analysis, about 10% to 20% molten metal was wasted for the defects in casting. Root causes that affected for the defects in casting were identified and remedial actions were implemented to minimize the defects in castings. In addition to defects in castings 20% to 25% of molten metal was used for the weight of runner and risers. These two types have to be considered at once.

Root causes for defects (mismatch and misrun) were identified as follows: Mismatching of moulds due to quick assembling; Low pouring temperature (only taping temperature was measured); Low fluidity due to low temperature; Inadequate venting of moulds; Faulty pouring practice and core shift and Uneven sizes of runner in-gate and due to this some items were broken when removing of in-gates in fettling section.

TABLE 5 : Defects in casting of Diffuser 2 CA 500/3 - Production chart on 12th of September 2006

Melt used (kg)	Good casting (kg)	Head &Risers (kg)	Defects (kg)	Yield (%)	Defects (%)	Runner & Riser (%)	Time taken for filling (second)
1524	1048	304	172	68.7	11.3	20.4	387

TABLE 6 : Defects in casting of Diffuser 2 CA 500/3 - Production chart on 12th of September 2006

Item	Mismatch	Misrun	Sand Wash	Slag Incl.	Blow Holes	Damaged	Inner Surface Damaged	Cracks
kg.	65	48	19	14	9	7	5	3

TABLE 7 : Production chart of product N110 after modifications

Melt used (kg)	Good casting (kg)	Runner &Risers (kg)	Defects (kg)	Yield (%)	Defects (%)	Runner & Riser (%)
786	560	154	72	71.3	9.2	19.6

Therefore, following practices were introduced as a remedial action to minimize the above defects: Reduce the time of vibration when the moulds are made; Increase silica sand quantity by 1% to the moulding sand; Keep runner full of molten metal during the pouring process; Fix the guide pins tightly when assembling the parts of the mould such as drag and cope; Fix the core with core prints and match these core prints properly; Remove all slag from molten metal before pouring and Conduct the fluidity test before pouring.

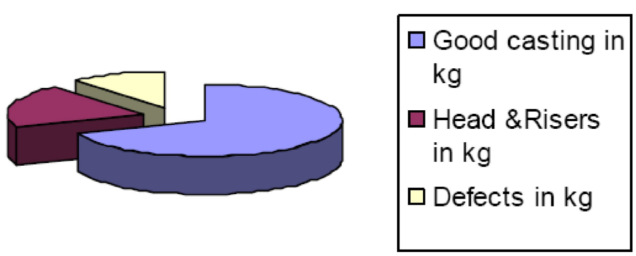

Figure 3 : Usages of molten metal of Diffuser 2 CA 500/3

Light-weight casting

TABLES 7 and 8 are show the casting yield of product N110 and weight of defects in kg observed on 20th of October 2006 respectively after implementing new runner, risers and remove the root causes affected

TABLE 8 : Defects in casting of product N110

	Misrun	Mismatch	Blow Holes	Sand Wash	Cracks
Kg	31	19	11	9	1

TABLE 9 : Casting yield comparison production chart of product N110

Previous casting yield %	New casting yield %	Previous defects in casting % by weight	New defects in casting % by weight	Previous runner & riser % by weight	New runner & riser % by weight
67.8	71.3	10.7	9.1	21.6	19.5

TABLE 10 : Usages of molten metal after modifications of product T400 pump body production chart

Melt used (kg)	Good casting (kg)	Runner &Risers (kg)	Defects (kg)	Yield (%)	Defects (%)	Runner & Riser (%)
1348	965	252	131	71.6	9.8	18.7

TABLE 11 : Defects in casting f product of T400 pump body production chart

	Misrun	Mismatch	Blow Holes	Sand wash	Slag Incl.	Cracks	Damaged
kg	44	37	20	13	7	6	2

to the main defects such as misrun and mismatch.

TABLE 9 shows the casting yield comparison production chart between new and previous casting methods. According to the TABLE 9, casting yield has increased by 3.5% after implementing above modifications, weight of defects rate has reduced by 1.6% and weight of runner and risers has reduced by 2.1% for the product N110.

Medium- weight casting

TABLES 10 and 11 show the casting yield of product T400 Pump body and weight of defects in kg observed on 12th of September 2006 respectively after implementing the modified runner, risers and root causes affected to the main defects.

TABLE 12 shows the casting yield comparison production chart between new and previous casting methods of product T400 Pump body. According to the TABLE 12, casting yield has increased by 7.7% after implementing above modifications, Weight of runner, risers has reduced by 5.7% and weight of the defects has reduced by 6% for the product T400 Pump Body.

Heavy- weight casting

TABLES 13 and 14show the casting yield of product of diffuser 2CA 500/3 and weight of defects in kg observed on 12th of September 2006 respectively after implementing the proposed runner, risers and root causes affected to the main defects such as misrun and mismatch and time taken for the filling of moulds.

TABLE 15 shows the casting yield comparison production chart between new and previous casting meth-

TABLE 12 : Casting yield comparison production chart of product T400

Previous casting yield %	New casting yield %	Previous defects in casting % by weight	New defects in casting % by weight	Previous runner & riser % by weight	New runner & riser % by weight
63.9	71.6	11.6	5.6	24.4	18.7

TABLE 13 : Usages of molten metal after modifications of diffuser 2CA 500/3 production chart

Melt used (kg)	Good casting (kg)	Runner &Risers (kg)	Defects (kg)	Yield (%)	Defects (%)	Runner & Riser (%)
2431	1772	408	251	72.9	10.3	16.8

TABLE 14 : Defects after modifications of product of Diffuser 2CA 500/3 production chart

	Mismatch	Misrun	Sand Wash	Sand wash	Slag Incl	Inner Surface Damaged
kg	88	79	31	21	18	15

TABLE 15 : Casting yield comparison of product 2CA 500/3 - production chart

Previous casting yield %	New casting yield %	Previous defects in casting % by weight	New defects in casting % by weight	Previous runner & riser % by weight	New runner & riser % by weight
68.7	72.9	11.3	10.3	19.9	16.8

ods of product diffuser 2CA 500/3. According to the TABLE 15, casting yield has increased by 4.2% after implementing above modifications, Weight of runner, risers has reduced by 1.0% and weight of the defects has reduced by 3.1% for the product 2CA 500/3.

After changing the method of mould filling, time has reduced by certain level and there is uniformity of time taken for the filling of any mould such as light, medium and heavy weight castings. This is indicated in TABLE 16. Only three items were taken to measure the time taken for the filling of moulds with two foundry men with controlled pouring.

As per the results indicated in TABLE 16, casting yield has increased by 4.2% after implementing above modifications, Weight of runner, risers has reduced by 3.1% and weight of defected items has reduced by 1% for the product, Diffuser 2 CA 500/3.When removing unnecessary parts from the casting products in fettling section, some defects occurred previously but now there are no braking of items when removing of gating systems.

TABLE 16 : New runner in-gate sizes and time taken for the filling of moulds

Item	Width (mm)	Depth (mm)	Time taken for filling (second)
Product N 110.	12	10	118
Volute of T 400 Pump Body	18	16	216
Diffuser 2 CA 500/3	34	32	330

CONCLUSION AND RECOMMENDATIONS

Casting yield depends upon all the activities in the foundry from pattern design stage to marketing of the final products. Production yield depends on all the activities done by the workers on the shop floor. Casting yield mainly depends on the weight of runner, risers, pouring practices and defects in casting. Runner and risers are introduced in the mould making stage by using trial and error methods. Due to this, sizes of runner and risers increased to large sizes.

The weights of existing runner and risers have high values comparing with weights of runner and risers after implementing the new runner and risers and remedial measures for root causes. The weights of runner and risers have reduced by 2.1%, 5.7% and 3.1% from the products of light, medium and heavy respectively after implementing the new runner and risers.

In addition to the above, defects in castings such as misrun and mismatch are also directly affected to the casting yield. Further, waste of molten metal with low temperature and poor pouring methodology is also directly affected to the casting yields. Therefore, root causes affected the defects were identified and implemented to minimize of defects in casting with above new runner and risers.

The previous weights of defects in castings have high values comparing with weight of defects after implementing the remedial measures with new runner and risers. Appearance of the defected products indicated many holes in the thin sections of the castings, smooth and well rounded edges and round holes on the surface of the metal. Therefore, the remedial measures are based on these defects such as misrun and mismatch and the root causes affected to the main defects. The weights of defects in castings have reduced by 1.6%, 6% and 1% from the products of light, medium and heavy respectively after implementing new runner and risers and remedial measures for defects in castings.

By implementing the new runner and risers and remedial measures for gray cast iron castings, the casting yield has increased by 3.5%, 7.7% and 4.2% from light, medium and heavy weight castings respectively.

When increasing the casting yield and production yield, the attitudes of the foundry men have to be changed by introducing proper training systems. For this purpose need survey has to be carried out by the organization to find the training needs and by considering the objectives of the company proper training programs have to be designed.

Following recommendations have to be implemented for minimizing of defects in casting; avoid excessive ramming of mould, increase vent holes by means of a wire or adding silica sand to the mixture sand, keep runner full of molten metal during the pouring process, fix the guide pins tightly when assembling the parts of the mould such as drag and cope, fix the core with core prints and match these core prints properly and remove all slag from molten metal before pouring.

Further, following recommendations have to be implemented for minimizing the weight of excessive runner and risers; redesign the runner and risers at the pattern designing stage and take extra care when making the runner in-gates manually.

Following recommendations have to be implemented for minimizing the waste of molten metal, with low temperature and poor pouring methodology; to use correct composition and temperature of the melt for the thin sectioned moulds. Chill-wedge test and fluidity test should be done and take the correct decisions to pour the molten metal into the moulds, to use the correct pouring sequence, molten metal in first tapping can be used for the non machinable products such as gutters, weights and molten metal in second and third tapping can be used for less machinable products such as pump housings or machinable products subsequently introducing suitable heat treatment process.

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