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IMPROVEMENT IN PRODUCTIVITY OF CASTINGS BY SWITCHING FROM GREEN SAND MOULD PROCESS TO SHELL MOULD PROCESS

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ABSTRACT

The creation and application of technology to monitor and control the production and delivery of products and service in casting foundries has gained importance and are necessary to sustain in competitive market conditions. Setup of the industries as applied to casting foundries need timely setup and changes to cope up with the increasing demand from the customers as foundries have great demand for the products produced, in numerous fields. In this work various parameters of importance are improved by employing shell mould process for the production of the castings which were previously produced by green sand mould process. Parameters considered in this work are to achieve overall productivity of castings. In this regard delivery of castings, reducing rate of rejection, improving the yield, methods to improve quality etc, plays an important role. Accordingly work to achieve all these, without forgetting cost and economical considerations to get greater profit is done. Apart from these, to sustain in the market, customer is required to be satisfied with the product produced. In this regard work has been carried out which is towards getting more demand for the product. And also manual work is reduced by employing the machineries, which brings many changes in foundry and hence towards automation.

Keywords: Castings; Shell mould process; Green sand mould process; Improvement; Productivity:

INTRODUCTION

Casting is one of the oldest manufacturing processes [01] from which simple and complicated shapes can be made from any metal that can be melted. Around 6.5million kg of casting are produced every year. The most common materials used for casting are grey iron, ductile iron, aluminum alloys and copper alloys. Applications of castings ranges from agriculture to railroad equipments, automobiles and aircraft equipments, heating and cooling equipment sand many more. The cast component has a shape, size, chemical composition and metallurgical microstructure which is determined by engineering decisions arrived by design engineers, pattern makers, casting engineers and manufacturing engineers along with technically well versed team who work together as a team to manufacture castings in intended time and in a cost effective manner. Castings produced may be small part of useful device or it may be the entire device. Foundry [02] is a casting factory which equipped for making moulds, melting and handling molten metal, performing the casting process, cleaning and finishing the castings. Foundries need improvisation in every step to increase the productivity, necessary changes are done, and Keeping cost constraints under consideration.

Significant amount of work has been done in the field of castings and their types. According to S. Jones, C.Yuan [03] the investment casting technique has tremendous advantages in the production of quality components and the key benefits of accuracy, versatility and integrity. In this work incorporating organic fibres into the binder improved performance and reduced shell production time and also shell thickness is improved. S. Amira, D Dube, R Tremblay [04] identified the new improved method to evaluate both the strength and the permeability of ceramic shell specimens under high temperature conditions. According to R.Yang, Y.Y.Cui, L.M. Dong, Q.Jia [05]t he properties and shell mould casting of gamma TiAl-based alloys are discussed in this work. The advantage of gamma TiAl based alloys in specific modulus, specific high temperature strength, and oxidation resistance makes them attractive materials for use in turbine engines. Likewise many related works are done on castings, present work concentrates on overall productivity improvement considering various parameters which are discussed below.

CASTING

In the casting process [06], the material is given the desired shape by melting it. The molten material is poured into a cavity of the desired shape and size of the product to be produced, allowing it to solidify. The cavity is made in a suitable material held in a box called mould. After solidification, the end product is extracted from the mould. Using this process, very intricate shapes can be manufactured. In addition, the range of size of the products that can be manufactured by the casting process is unlimited. Casting processes are used to manufacture a wide variety of products. Typical examples of the products that are manufactured by the casting process are frying pans, machine bases, automobiles engines, carburetors, gun barrels etc. There are many situations where casting processes are essential or even inevitable. For example, manufacturing the cylinder block of an internal combustion engine by any process other than the casting would be very difficult and time consuming. Similarly, the production rate to produce an intricate shape or profile by any other process will be much lower than that of the casting process.

A. *Types of Casting Process*

1. Expandable mould process: This uses a mould which is destroyed to remove casting. Mould materials used are sand, plaster and other similar materials. More complex shapes can be produced but production rates often limited by time to make mould rather than casting itself.

2. Permanent mould process: This uses a mould which can be used again and again. Mould materials usually will be ceramic refractory materials. This process has high production rates but geometries are limited.

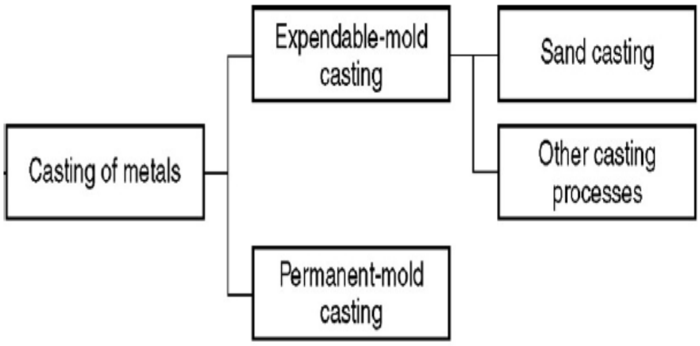

Figure 1. Types of Castings.

The two main processes upon which the present work is based on are green sand mould process and shell mould process. Green sand mould process utilizes a mould made of compressed or compacted moist sand packed around a wood or a metal pattern [07]. Whereas shell mould process is an expendable mould casting process that uses a resin covered sand to form the mould. Sand used in both the processes has different characteristics which has impact on final mould as well as finishing. Sand used in green sand mould process contains high moisture content whereas shell mould process uses fine-grained high purity sand along with resin. Accordingly the castings taken out will be less smoothly finished bearing rough surfaces in green sand mould process and fine finished castings in shell mould process. To match with the increasing demand, industry concentrated on changing the process and accordingly the machinery setups which routed towards shell mould process from green sand mould process. In this paper, we describe analysis and experimentation of the system for the production of castings which improves yield, quality and delivery of castings and also reduction in rate of rejection, raw materials and manual work. Analysis and experimentation will be performed and results will be compared.

PROCEDURE

As per customer requirements, foundries will manufacture different grade of castings. Present work has been carried out for SG 700/2 Grade. Every casting involves chemical composition shape, size and metallurgical microstructure which is determined by engineering decisions arrived at by, Design Engineers (Mechanical Engineers), Pattern Makers (Skilled craftsman, CAD), Casting Engineers (Metallurgical Engineers), Manufacturing Engineers (Mechanical, Metallurgical Engineers).The engineering professionals that carry out this process work together, sharing information so that the casting will perform as intended in a timely and cost effective manner. Providing allowances, risers runners etc drawing according to the customer requirement is done.

A. *Preparation of Moulds*

AFS 75/78/80 Sand mixed with 4-6% resin is weighed as per requirement and required pattern is kept in the shell mould machine. Sand is filled properly in the pattern and it is heated to required temperature (usually 175-370°C).using compressed air shell moulds are cleaned and inspected for damages [06].Moulds are heated to 180-200°C for 30-45° C in core oven to cure them to dark brown colour and cope over the drag matching locating pins is placed.

Figure 2. Shell Mould Manufacturing Machine.

Figure 3. Mould Produced.

B. *Preparation of Molten Metal*

Molten metal is prepared using CRCA scrap, copper, Ferro manganese, Ferro silicon, inoculants, calcium carbide, and Carbocoke as basic raw materials. First charge 40 –50 Kilograms of Cast Iron is fed to the bottom of the crucible. Switch ON the induction furnace & charge the Solid Scrap like foundry Returns, Steel Scrap in orderly manner. Give full Power and keep on poking the Charge with tarsteel & pig iron for faster melting and for optimum Power utilization. Continue to charge till furnace is 85% to its total capacity. Required Carburizer, Ferro alloys to be charged as per calculation. Once the molten metal bath attains approx.1350°C take the sample to check the chemistry. Get the Spectro lab report if composition achieved ok top up the furnace by adding returns, otherwise dilute or add Ferro alloy/carburizer to make up the composition, remove the slag using slagger and release the metal for Magnesium treatment.

Magnesium treatment: Take-required percentage of magnesium alloy and inoculation on the quantity of molten metal in the alloy pit of treatment ladle place the tundish cover. Pour the metal from the furnace to the treatment ladle to get react to the magnesium alloy to convert in to S.G.Iron molten metal. Take the molten metal after treatment for pouring in the same ladle or transferring to T spout ladle. Do post stream inoculation while pouring & complete the pouring within the stipulated time to avoid fading of magnesium. Take a sample for microstructure and final chill sample for Spectro analysis.

Figure 4. Induction Furnace.

C. *Shakeout and Degating*

The solidified metal component is removed from the mould. This process frees the casting from sand if attached. Degating is the removal of the heads, gates and risers from the casting. Gates and risers can be removed using cutting torches, bandsaws or ceramic cut-off blades.

D. *Inspection and Fettling*

1. First stage inspection: After knocking the castings from the moulds, the moulds are inspected for mismatch, blow hole, shrinkage, short pour, mould leak, sand drop, casting bulge, cold shuts, under cut etc. on observation of the following defects the castings are identified and reject/reworked. Now days automatic detectors are developed for this purpose [08].

2. Second Stage Inspection: After 1st stage inspection, Removal of riser neck, ingrate area, flow of area and other extra material on the casting is done using hammer & cutting wheel. The knockout foundry returns shall be moved to respective bin / locations. Second stage inspection will be conducted and defective castings will be reject/reworked.

3. Fettling: Inspected castings are ground smoothly to match the casting surface. Grind the parting line completely. Remove defects concerned to shrinkages [09], fins, sticky materials, sand and scaling. Use proper equipments and tools to reduce fettling cost. Under cuts shall be avoided.

4. Finishing: Finishing of castings is done using three types of CNC machines. 3 main CNC machines used are horizontal, vertical and Turning CNC. According to the need, castings are allowed to any one machine and finished.

Figure 5. Finished Castings.

COMPARISON BETWEEN SG 700/2 AND 400/18 GRADE CASTINGS

As stated earlier this work has been carried out considering SG 700/2 grade. Comparison of this with other grade is done in order to study the difference between different grades. For this study another grade considered is 400/18 grade which shows much more deviation from the grade considered.

A. *Chemical Composition*

Chemical composition of SG 700/2 Grade is graphically represented as below. Minimum and maximum values of copper, manganese, phosphor, silicon, copper and magnesium is shown. In the same way chemical composition of SG 400/ 18 grade is also shown graphically

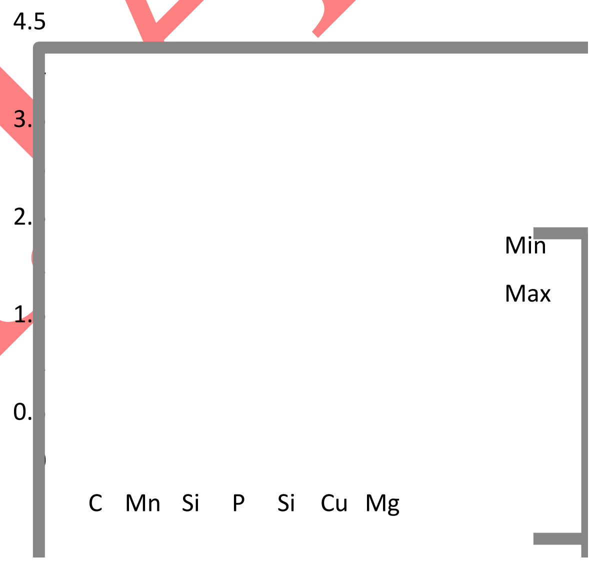

Figure 6. Graphical Representation of Chemical Composition of SG 700/2Grade.

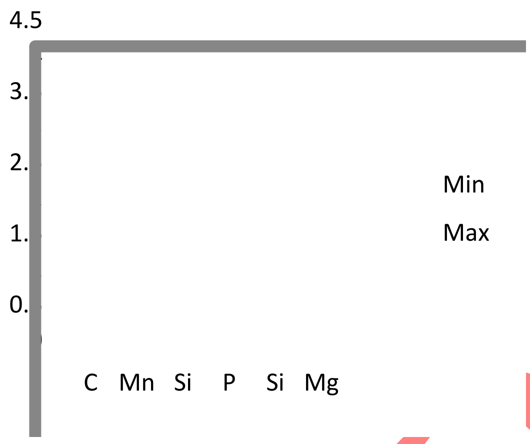

Figure 7. Graphical Representation of Chemical Composition SG 400/18Grade.

B. ***Mechanical Properties***

Mechanical properties [6] greatly affect the strength and hardness of castings and hence the applications where they can be used. Below two tables shows how mechanical properties differ from grade to grade.

Table I. Mechanical Properties of SG 700/2.

Properties	*Yield Strength*	*Tensile Strength(Kgf/mm^2)*	*Elongation %*	*Reduction %*	*Hardness(BHN)*
MIN	*42.84*	*71.40*	*2*	-	*225*
MAX	-	-	-	-	*305*

Table II. Mechanical Properties of SG 400/18.

Properties	*Yield Strength*	*Tensile Strength(Kgf/mm^2)*	*Elongation %*	*Reduction %*	*Hardness(BHN)*
MIN	*28.10*	*42.20*	*18*	-	*143*
MAX	-	-	-	-	*187*

RESULTS AND DISCUSSIONS

Various parameters are considered and keeping the record of production, Results from the green sand mould process are considered with new process adopted in industry i.e. shell mould process.

1. Increase in the Production rates leads to beneficiary outcomes in any foundry which can be decided by considering Yield of the Process.
Yield can be calculated by using the formula:

$$\text{YIELD} = \frac{\text{CASTING WEIGHT}}{\text{POURING WEIGHT}} \times 100$$

Calculations: For green sand mould process, consider that 3kg molten metal is poured to get castings out of which final castings weighed were of 1.95kg , if we calculate yield for this calculation is as fallows;

$$\frac{1.95}{3} = 0.65$$

In percentage value we get **65%** yield.

In shell mould process as we have little wastage casting weight will be more, usually for a 3kg of molten metal, casting weight will be around 2.35kg.When we calculate yield for the set of castings which gave this readings we get,

$$\frac{2.35}{3} = 0.7833$$

This gives a percentage value of **78%** yield.

Another set of castings were produced using 2kg of molten metal in both processes and results found were as below;

$$\frac{1.35}{2} = 0.675$$

Percentage value of which is **67.5%** in green sand mould process.

$$\frac{1.63}{2} = 0.815$$

Percentage value of which is **81.5%** in shell mould process.

By the above results it can be seen that around 13% yield can be increased shifting to shell mould process from green sand mould process. Hence it is clear that shell mould process is advantageous compared to shell mould process. Yield for the calculations done are graphically shown in the graph shown below.

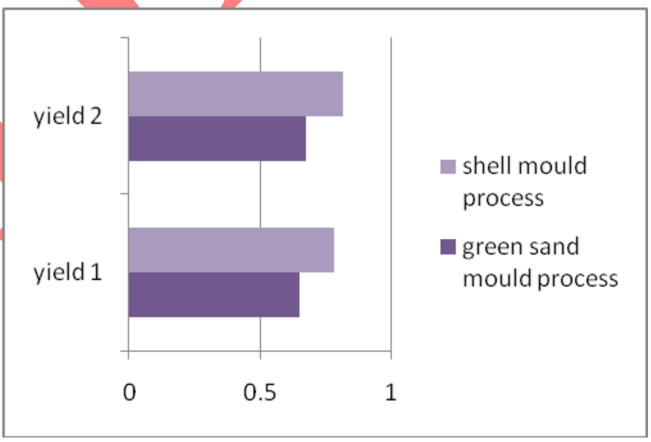

Figure 8. Graphical Representation of Yield.

2. Customers will be satisfied by the timely delivery of castings which can be increased up to 700/month by shell mould process compared to green sand mould process. This can be justified by the fact that in green sand mould process 1box gives 4castings whereas in shell mould process as there will be cakes arranged one above the other usually which contains 10cakes/box which yields 40castings at once.

Green sand mould process:

1box ⟶ 4 castings

Shell mould process:

1box ⟶ 10cakes; 4×10=40 castings

3. Fine finishing of castings is done using CNC machines as discussed earlier. Machining time by green sand mould process was 45min/piece and now it is only 37min/piece so it can be noted that around 8min/pc can be reduced/piece which is a remarkable difference. Above calculation is done for gear blank. Considerable difference is achieved since the machining allowance provided will be less in case of shell mould process as we get fine finished castings, consider that it is required to produce a casting with 100mm thickness, machining allowance given in green sand mould process will be 108mm whereas it will be 105mm in case of shell mould process.

4. Productivity in kilograms /man/day was 30kilograms by green sand mould process whereas it is 72kgs by new process adopted which gives huge benefit.

5. Around 3.5% rejection of castings is achieved adapting shell mould process as it was 8% before and reduced to 4.5% later. Rejection of castings depends upon their hardness, sand drop, volatility, mismatch etc. These problems are very rare in shell mould process and are common in green sand mould process hence rejection rate will be more in green sand mould process. When gear blanks are manufactured and supplied using both processes above difference in rejection level is noticed.

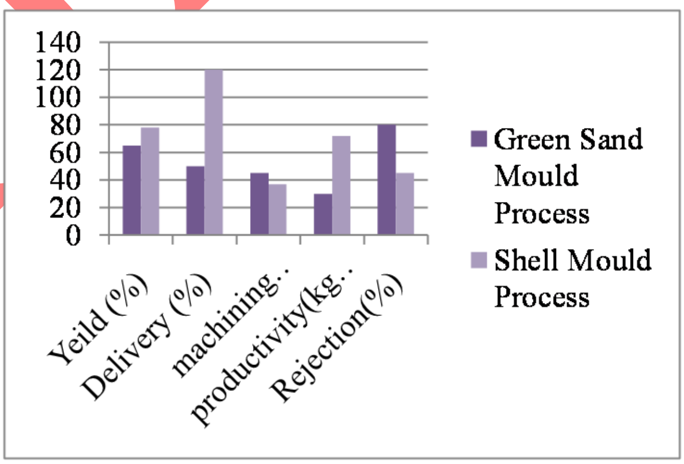

Figure 9. Graphical Representation of Result.

Apart from these the main raw material used for casting process is sand. Sand metal ratio used in green sand mould process was 1:14 whereas this reduced drastically in case of shell mould process which is 1:5 so it can be clearly noticed that around 9% sand is reduced. Finally the work carried out by us concentrates on how parameters of interest changes when castings are produced by shell mould process. Experimental results are the facts upon which an industry can concentrate to make necessary changes. So both the processes are compared with the results drawn, to apply better process in the foundry.

CONCLUSIONS

This work provides brief idea about overall change in production parameters of interest in a foundry when casting production is shifted from green sand mould process to shell mould process.

- Yield of the Process which was 65% by green sand mould process and it is increased to 78% when castings are produced by shell mould process.
- Customers will be satisfied by the timely delivery of castings which can be increased upto 700/month by shell mould process compared to green sand mould process.
- Fine finishing of castings are done using CNC machines as discussed earlier. Machining time by green sand mould process was 45min/piece and now it is only 37min/piece so it can be noted that around 8min/pc can be reduced/piece which is a remarkable difference
- Productivity in kilograms /man/day was 30kilograms by green sand mould process whereas it is 72kgs by new process adopted which gives huge benefit.
- Around 3.5% rejection of castings is achieved adapting shell mould process as it was 8% before and reduced to 4.5% later.
- Sand metal ratio used in green sand mould process was 1:14 whereas this reduced drastically in case of shell mould process which is 1:5 so it can be clearly noticed that around 9% sand is reduced.

This study was done considering various parameters as discussed above, it is because results of which clears provides how and to what extent various parameters increased which intern have great influence customer satisfaction and hence on profit margins. Effort was made to improve quality, delivery of castings, and yield in a foundry. Apart from these raw materials required for the process is less and also manual work comparatively can be reduced. All these improvements prove to be beneficial for any foundry which wants to survive in competitive market condition as well as to see growth in profit margin.

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