A Study of Casting Defects and Supply Chain in Cast Iron Foundry Process

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***Abstract*—This Paper presents analysis of casting defects and identification of remedial measures and the supply chain between the foundry processes are carried out at Ammarun Foundries, Coimbatore, India. The detailed study carried out on the component Disc900 Castings revealed that the contribution of the three prominent defects in casting rejections are core blow, sand inclusion and sand blow. It was noticed that these defects are frequently occurring in the castings. Systematic analyses were carried out to understand the reasons for defects occurrence and how the defects affects the supply chain in foundry process and suitable remedial measures were identified. Outcome of the validation trials showed substantial reduction in rejection of castings and improved supply chain between the processes. Company has accepted the remedial measures and incorporated them in the standard operating procedure.**

***Keywords*— Supply chain; foundry process; defect;, casting rejection;**

I. INTRODUCTION

Ammarun Foundries is facing casting rejections due to some chronic defects, after observing five months' data of the company the most frequently rejected castings identified were indentified and out of which Disc900 casting was identified as most severely affected casting, hence it was considered for detail investigation. The work on Quality Improvement of castings was carried out in following steps.

- Identification of defects in the Disc900 casting and analysis
- Selection of most chronic defects which frequently occurred and carried out the analysis.
- Identification problems in foundry process supply chain.
- Identification of root causes and finding the remedial measures.
- Production trials in the company with the remedial measures and validation.

II. RELATED WORK

The literature studies made for this paper are summarized in Table I.

III. FOUNDRY PROCESSES

The output of the foundry is in the range of 1500 tons of good castings per month and out of which 850 Tons from SINTO high pressure molding line, 600 Tons from conventional ARPA molding line and 50 Tons by hand molding. Table II shows list of main equipments installed in the foundry and Fig. 1 shows the foundry process in detail.

In SINTO high pressure line the top and bottom moulds are prepared separately and moulds are closed carefully after placing cores. The moulds are moved in conveyor. The system is employed with auto pouring system and molten metal is poured accurately. After pouring the moulds are moved in the same conveyor in a zig zag path and reaches knockout place for separating the casting and castings are sent for further processing.

In ARPA line the top and bottom moulds are prepared separately and moulds are closed in mould closing unit after paling the cores. The moulds moved on a track and pouring of molten metal takes places in a ladle and the moulds are moved in the same track to knockout place for separating the casting and castings are sent for further processing.

In a hand molding line, the moulds are prepared by skilled employees and pouring of molten metal takes place in ladle and moulds are moved to knockout area for separating the casting and castings are sent for further processing.

A. *Mechanical Testing*

Spectro-meter ARL Thermo electron Corporation Switzerland make is equipped to analyze 20 elements with metallographic image analyzer to precisely to estimate the various micro structural constituents. Mechanical testing laboratory equipped to estimate tensile strength, hardness and sand laboratory to monitor foundry sand quality on a continual basis.

TABLE I. RELATED WORK

S.NO	AUTHOR & YEAR	TECHNIQUES USED	RESULT
1	Forrester (1961)	Developed supply chain for a factory.	Examined deviation between actual and targeted inventories
2	M.M. Nain (1996)	Developed Real World dynamic analysis for SCM	Process of planning, implementing and controlling operations of the supply chain
3	David Simchi-Levi (2008)	Developed two stage supply chain	Retailer/manufacturer and supplier supply chain
4	Yossi Aviv (2007)	Studied interaction between inventory and forecasting in a two stage supply chain	Faces stochastic demand
5	Tae Cheol Kwak (2006)	Supplier - buyer model for bargaining process	Supplier -leading model buyer - driven model
6	Terry (2007)	Supply chain relation and contract	Impact of repeated interaction on capacity investment and procurement
7	Chi-Leung (2009) S.D. Sharma (2008)	Scalable methodology supply chain inventory	Total cost of the system is minimum with EOQ and EPQ
8	Fangruo Chen (2001)	Coordination mechanism for one supplier and multiple retailers	Holding cost rates depends on whole prices of the items
9	Benita M.Beamon (1998)	Supply chain design and analysis	Models and methods for multi stage supply chain
10	Shotaro Minegishi (2000)	Dynamic modelling and simulation for food supply chain	Presented practical simulation results
11	Patroklos (2005)	Modelling and analysis tool	Strategic supply chain management
12	Rajesh Rajkohe (2014)	Standardisation(Optimisation)	Provided guidelines to find casting defects
13	A.P.More (2011)	Standardization (Optimization)	By enhancing quality, cost of casting reduced
14	Malcom Blair (2005)	NDE methods and simulation used to predict effects of defects in casting	Casting effects and defects determined and analyzed
15	Sunil Chaudhari (2014)	Reviewed related work for minimizing casting defects	Improved the entire process of casting manufacture
16	B.R.Jadhav (2013)	Seven quality control methodology to analyse and reduce casting defects	Casing defects reduced by controlling alloy composition and pouring temperature
17	Achamyeleh (2013)	Statistical analysis method used for optimizing the process parameters	Critical casting defects controlled

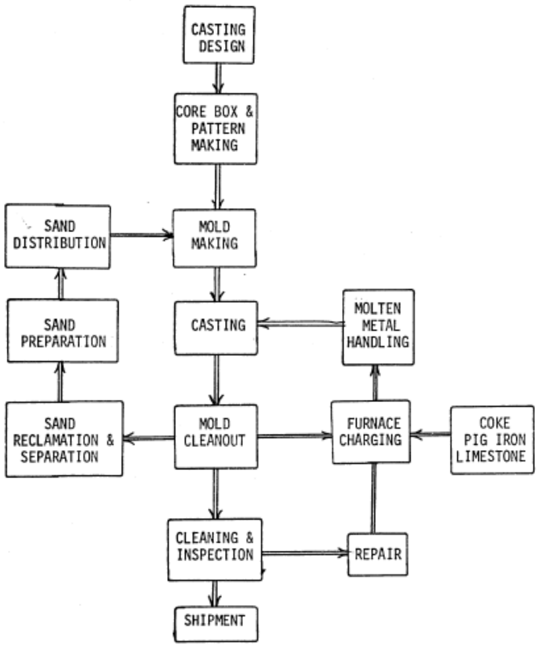

Fig. 1 Foundry Processes

B. Internal supplier and internal customer Relation

The core departments of foundry are Pattern shop, core shop, molding shop, melting shop are responsible for production of castings. The pattern shop is supplying pattern to core shop and molding shop and hence the pattern shop is internal supplier for core shop and molding shop. The core shop and molding shop is the internal customers to pattern shop. Similarly the other department will also be treated on the basis of internal supplier and internal customer.

The internal supplier and internal customer relationship will play an important role in supply chain for the continuous improvement.

TABLE II. FOUNDRY PROCESS AND EQUIPMENTS

S.No	Foundry Process	Equipment used
1	Pattern making	Pattern is supplied by the customer. Only day to day development activity is in process
2	Core Making	Core shooter 3 Nos, Core Oven 2 Nos
3	Moulding	High pressure moulding line, ARPA moulding line, hand moulding line
4	Sand Plant	Automatic sand plant with fluidized bed cooler
5	Melting	Induction furnace 1.5 T (2 Nos), 2 T (2 Nos)
6	Fettling	Shot blasting Machines and pedestal grinders
7	Painting	Immersed type

IV. IDENTIFICATION OF DEFECTS AND ANALYSIS

The frequently rejected castings in Co2 hand molding identified at Ammarun Foundries is Disc900. The number of castings produced from May 2014 to Sep 2014 and Oct 2014 to Dec 2014 and their weight, quantity and cost per kg are given in Table IV. As the production of Disc900 is maximum in hand molding and its cost of rejection is highest, this casting was considered for detailed study. Disc900 casting is having defects such as sand inclusion, blow hole, core blow etc. The data observation of defects in Disc900 casting for the above period is plotted as Pareto Chart (Fig. 2 and Fig. 3) . It may be noticed that the most occurring casting defects are core blow, sand blow and sand inclusion hence they were picked up for diagnostic study. To understand the reason for causes of these defects a detailed study was carried out in foundry.

V. PRODUCTION PROCESS OF DISC900 CASTING

The details of sand systems used for mould and core making are explained hereunder.

A. Sand System used for mould making

The mixing of sand is as follows:
A batch of 100 Kgs reclaimed silica sand with AFS No. 40 to 50, sodium silicate 4 to 5 Kgs, Clay 4 Kgs, water 200 ml are used for mixing in a mixer for 90 seconds. Soon after the mixing, mold sand mix is taken to molding making and adequately rammed manually and with pneumatic rammer, after the ramming Co2 gas is passed into molds till sand gets hard for about 90 seconds.

B. Sand System used forcore making

The mixing of sand is as follows:

A batch of 100 Kgs silica sand with AFS No. 40 to 50 , Digsil oil 4 to 5 Kgs used for mixing in a mixer for 90 seconds.Soon after the mixing, core sand mix is taken to core making by introducing a steel rod with proper venting holes and rammed vertically instead of making it in two half previously, after the ramming Co2 gas is passed into core box till core gets hard for about 60 seconds. After the moulds and cores are cured, and securing them properly in the mold box, the molten metal is poured and allowed to solidify. After 8 hours the mold boxes are taken to shakeout and the castings are separated and sent for further processing. Inspection of casting is done at different stages as per the requirement.

The average acceptable chemical constituents for Disc900 castings obtained from spectrometer analysis are :
C 3.719%, Si 2.870%, Mn 0.234%, P 0.038%, S 0.011%, Ni 0.006%, Cr 0.021%, Mo 0.007%, Cu 0.009%, Ti 0.087%, As 0.003%, Sn 0.004%, Al 0.012%, Pb 0.002%, Sb 0.002%, Nb 0.003%, Zr – 0.0005%, Mg 0.042%, Zn 0.005%, V 0.007%, W 0.003%, Co 0.003%, B 0.001%, Bi 0.001%, Ca 0.002%, Ce 0.007%, N -0.019%, Fe 92.50%.

VI. CASTING DEFECTS AND REMEDIAL MEASURES

The causes for most frequently occurring defects and the reason for occurrence of these defects and their remedial measure are briefly given in Table III.

TABLE III. CASTING DEFECTS

NO	DEFECT TYPE	DEFECT	POSSIBLE CAUSES	REMEDIES
1	Gas Defect	blow holes, open blows, air inclusion, pin hole porosity	Gas pass through mold, improper design of gating	Evacuate of air and gas, increase permeability of mold cores
2	Shrinkage cavity	Solidificatio n problem	Improper flow of molten metal, poor casting design	Proper casting design and feeding of molten metal
3	Mold material defect	Cuts, washes, metal penetration, fusion, run out, buckles, swell and drop	Molding sand erosion, higher pouring temperature, faulty molding practices	proper selection of molding sand, molding method, correct pouring temperature
4	Pour metal defect	miss run, cold shuts, slug inclusion	molten metal not filling the cavity completely, improper pouring	having sufficient molten metal to pour, proper gating system
5	Metallurgic al defect	Hot tears, hot spot	Poor casting design, damage at shake out,	Proper casting design and metallurgical control

Diagnostic study carried out on Disc900 Castings revealed that the contributions of the three prominent defects in casting rejections are Core blow, Sand blow hole and sand inclusion. It was noticed that these defects are frequently occurring at particular locations. Systematic analyses were carried out to understand the reasons for defects occurrence and the reasons identified are:

A. Core Blow

Due porosity in the core and improper process of making of cores, the Core Blow occurs when the molten metal enters the mold cavity. The defect occur due to improper mixing of core sand and also not providing adequate venting provision.

By proper mixing of core sand and core making process of having metallic pipe with hole on the circumference for venting and ramming of core sand axially for making core as a single piece instead of radial ramming with two halves.

B. Sand Blow Hole

Sand blow hole is a kind of cavities defect, which is also divided into pinhole and subsurface blow hole. Pin hole is very tiny hole and subsurface blowhole can be seen only after machining. Gases entrapped by solidifying metal on the surface, which results in a rounded or oval blowhole as a cavity and frequently associated with slag's and oxides. The defects exists in the core of the mold due to poor vent pockets.

By proper mixing of molding sand and mold preparation will improve gas permeability and good thermal conductivity.

C. Sand Inclusion

Sand inclusion defect looks like there is slag inside of the metal castings. Sand inclusion is one of the most frequent causes of casting rejections. It is very difficult to diagnose these defects generally occur at widely varying positions. Areas of sand are often torn away by the metal stream and then float to the surface of the casting.

By improving compact ability and plasticity of sand, reducing lumps in the sand and avoiding high pouring rate

Due to nature of defects they were analyzed by observation in the shop-floor for quite a long period and assessed. Wisdom of the experts in the company and long experience of the authors in the field of foundry technology has helped in identifying the nature of causes. Repeated trials were carried out in the foundry to arrive at appropriate remedial measures.

VII. VALIDATION WITH PRODUCTION TRIALS

Production trials on Disc900 casting were carried out in the company after incorporating the remedial measures in core making process. There is a substantial improvement in quality resulting in reduction in rejection levels of castings. For the purpose of comparison five months data of Disc900 casting before implementation of remedial is compared with three months data after implementation of remedial measure, details of validation trials are presented here below.

During the five month before implementing the remedial measures have been analyzed. Out of 41 castings produced five castings were rejected. Due to core blow three numbers of castings, due to sand blow one number of casting and due to sand inclusion one number of casting are rejected. The Histogram as per Fig 4 indicates the quantity rejection of castings before and after implementing the remedial measures. The graph Fig 5 shows the percentage of rejection of castings before and after implementing the remedial measures.

The major defect is due to core blow and the root cause analysis carried out for the defect and it is clearly indicated in Fig. 6. Fish bone diagram the various causes for the defect are studied and indicated in the diagram.

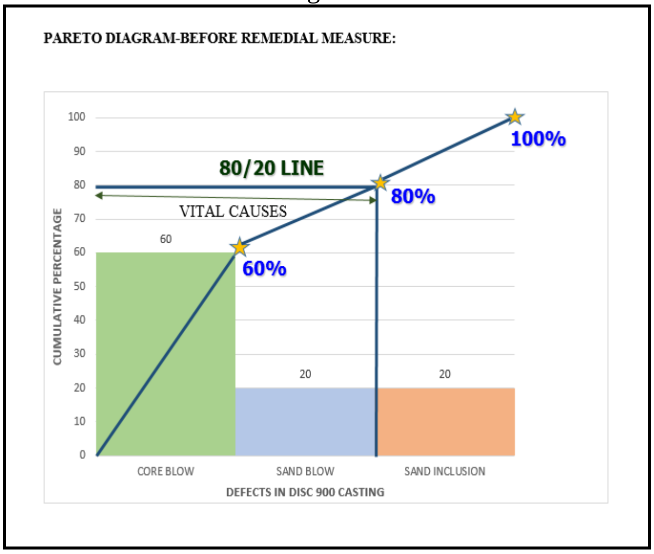

Fig. 2.Pareto diagram before RM

It is noted that number of Disc900 castings produced during these three months period are 132 and the rejection quantity is compared before and after implementation of remedial measure and it listed in Table IV.

Table IV. COST OF REJECTION

PERIOD	WT. KGS PER PIECE (A)	PRODN QTY. (Nos)	REJ. QTY NOS (B)	COST (Rs) per Kg (C)	COST OF REJECTION (Rs) AxBxC
May to Sep2014 (Before RM)	360	41	5	85	1,53,000
Oct2014 to Dec2014 (after RM)	360	131	1	85	30,600

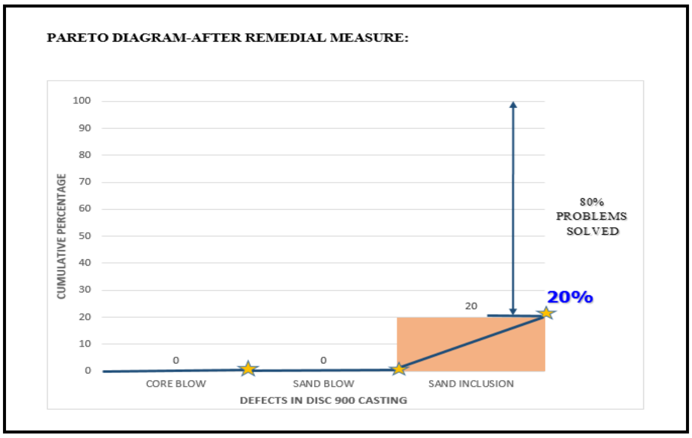

Fig. 3. Pareto diagram-After RM

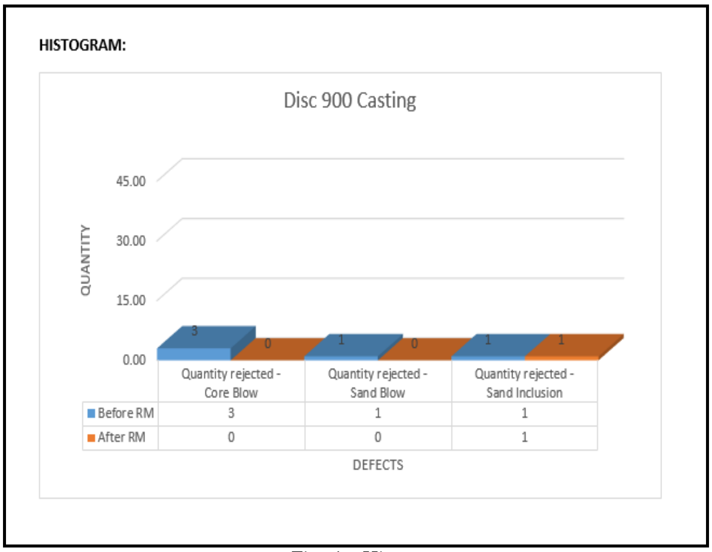

Fig. 4. Histogram

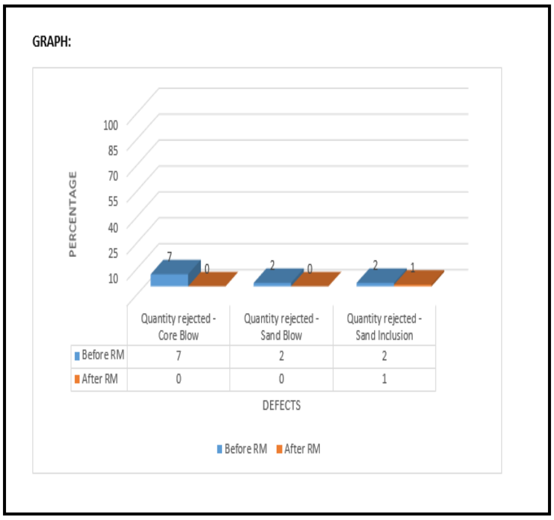

Fig. 5. Histogram after RM

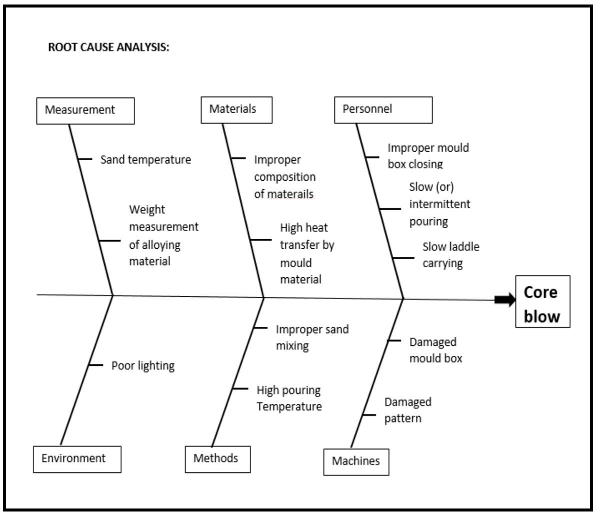

Fig. 6. Graph

VIII. SUPPLY CHAIN PROCESS

The Fig 7 indicates clearly the supply chain process of a foundry. This helps the foundry to assess the process flow in production of castings. It also gives the internal supplier and internal customer relationship for continuous improvement based on the feedback from the customer.

The pattern shop, core shop, molding shop and melting shop are the responsible departments for the production of castings inside the foundry and one of these departments will be of internal supplier and internal customer to each other. The internal supplier has to satisfy the internal customer in turn to satisfy the external customer.

After the production of castings, it passes through the various inspections. The castings with no defects will go the external customer and the castings with defects will go the melting shop for re melting process. The feedback from the end user through external customer helps the foundry for continuous improvement for the production of castings and also process updating.

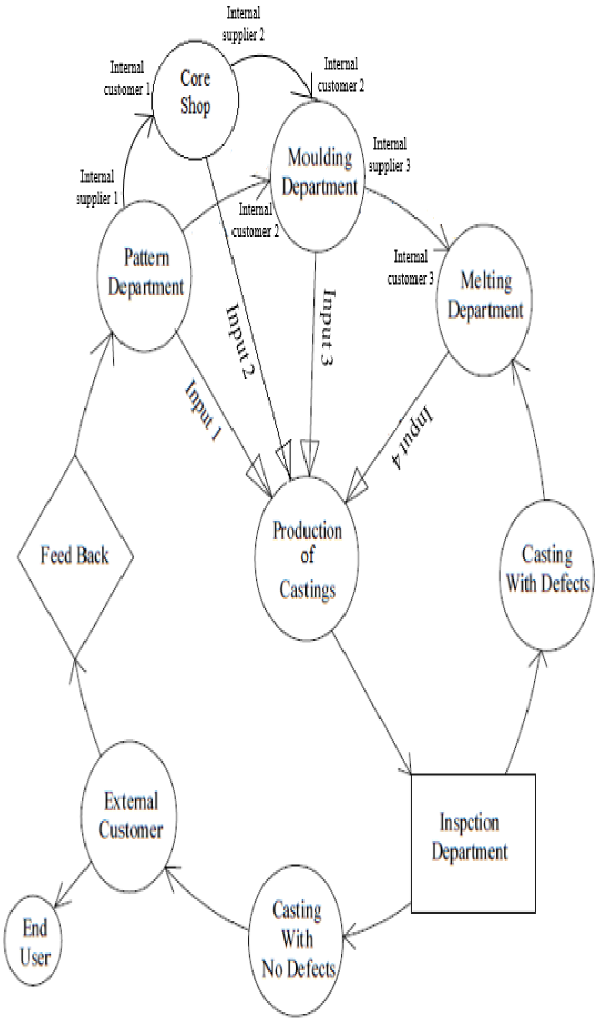

Fig.7. Supply Chain process

IX. CONCLUSION

The study carried out on Disc900 Castings revealed that the contributions of the three prominent defects in casting rejections are Core blow, Sand blow and sand inclusion. Systematic analyses were carried out to understand the reasons for defects occurrence and the reasons identified and rectified. Remedial measures identified to overcome the above defects are:

Core blow *:* Proper mixing of core sand, improved process of making cores with sufficient air vents are suggested and implemented.

Sand blow : Proper mixing of sand and proper ramming of sand during mold making process is ensured. It is noted that by providing effective method for mold making and setting of cores, the problems can be solved.

Sand inclusion: Uniform ramming of mold with high degree of core setting is ensured. Pouring practices improved with correct molten metal temperature and pouring time.

Production trials were carried out in the foundry for three months period by incorporating the above remedial measures and validated. Outcome of the results showed substantial reduction in rejection of castings and savings of Rs.122400/- as per Table IV . Company has accepted and adopted the remedial measures suggested in the production methods, also suitably modified the standard operating procedure.

The Fig 8 shows the photograph of casting before remedial measures and Fig 9 shows the Photograph of casting after remedial measures.

Fig. 8. Photograph of casting before RM

Fig. 9. Photograph of casting after RM

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