Improving the Aluminium Rolling Ingot Recovery using Tqm Technique

Ritesh S. Fegade, Rajendrakumar G. Tated, Rupendra S. Nehete

Abstract: ***To improve productivity and profitability in Aluminium continuous casting industry the main action is to reduce losses due to defects resulting into revenue losses. Improving Rolling Ingot Recovery is possible by reducing the rejections & using the resources effectively (resources MAN, MACHINE, MATERIAL & CAPITAL) by applying TQM technique. This study presents a case about minimizing defects in aluminium continuous casting using Total Quality Management (TQM) techniques in which why-why analysis, Standard Operating Procedures (SOPs),and Cause and Effect analysis is used. It can be concluded from study that rejections, shell zone & inclusion can be reduced by, Continuous monitoring the health of the moulds, quality & quantity of water, the metal casting temperature, metal head in mould, water impingement angle, use of Ceramic foam filter plates, awareness & the adherence towards the guidelines.***

Keywords: Aluminium Casting, Aluminium Rolling Ingot, Cause and Effect, Rolling Ingot defect, Standard Operating Procedures (SOPs), Why-Why analysis.

I. INTRODUCTION

Aluminum continuous Casting is the backbone of mechanical manufacturing industry and it is the prime goal of any organization to reduce defects and rejection for revenue generation and survival in the global competitive market for resilience and robustness. Main extract of various researcher in the literature reviewed is to promote higher productivity with least wastage or reduced rejection with good quality by applying various quality tools. As the industries are producing with full capacity to meet varying demands and the conventional quality techniques for maintaining quality of the product is no more contemporary.

Choudhari et al. (2012) [4] was of the opinion that the defect cannot just be eliminated by making changes due to process parameters and tooling but can be attributed to poor design of the part with respect to manufacturability and can be corrected by casting simulation and part design.

Due to the technological changes & global competition the customers are modernizing their facilities & hence quality which was acceptable yesterday is no more accepted today. To survive in present scenario is committed to improve their profitability by reducing the cost of production through reduction in rejection by increasing the recovery & giving required quality level to its customer. Improvement in recovery is possible by reducing the rejections & using the resources effectively (resources MAN, MACHINE, MATERIAL & CAPITAL). This paper discusses the improvement in yield in one of the manufacturing plant in Navi Mumbai, India by reducing defects using TQM methodology.

II. REVIEW CRITERIA

Various authors have carried out research in Aluminium alloy castings and its reduction and still there is always a scope for further research due to complex nature of alloys and processes. Fengming Du (2018) [5] has worked on the full-scale finite element model of a slab and its mould was developed to reveal the complex thermo-mechanical behaviours of slab in a vertical caster during continuous casting. An inverse algorithm was applied to calculate the heat flux and combined with the temperatures measured using thermocouples that were buried in different positions of the mold. It will provide a helpful tool for further improving and optimizing the operation parameters for continuous casting slab.

X Dai, *et al*. (2012) [13] have developed the new model, which is a two-dimensional program using two methods first one is finite difference technique and second one is the Marker and Cell (MAC) method to simulation of the flow of molten metal in a mold.

P. Senthil *et al*. (2012) [9] have worked on to prepare AC2A aluminium alloy castings of a unsymmetrical component using squeeze casting process and finding the optimum squeeze casting conditions also developed the mathematical models for the same process.

R. S. Taufik *et al*. (2013) [10] were prepare and developed thermal expansion model for casted aluminium silicon carbide the squeeze casting method. This model predicts the surface roughness of the casting product.

Latifa Begum *et al*. (2014) [6] have worked on the aluminium AA-1050 alloy and developed three-dimensional Computational fluid dynamics model for the study of heat transfer in the solidification and turbulent melt flow of vertical direct chill slab caster. Finally find out the result for velocity and temperature profiles local surface heat flux and sump depth.

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***** Correspondence Author

Prof. R. S. Fegade*, Department of Mechanical Engineering, Genba Sopanrao Moze College of Engineering, Balewadi, Pune, India. Email: riteshfegade@gmail.com

Dr. R. G. Tated, Department of Mechanical Engineering, Matoshri College of Engineering & Research Center Eklahare, Nashik, India. Email: rgtated@yahoo.com

Dr. R. S. Nehete, Department of Mechanical Engineering, SIES Graduate School of Technology, Navi Mumbai, India. Email: rsnehete@gmail.com

C. M. Choudhari *et al*. (2014) [3] have worked on the entire Designing of the feeder and optimized the location of the feeder for minimization of defects and compared the simulation result with the experimental trial.

Ambrish Maurya et al. (2014) [2] have discussed the casting speed and the effect of degree of superheat in continuous casting of steel. They had investigated the solidification behaviour of steel in between mold and Secondary Cooling Zone.

Mainul Hasan *et al*. (2015) [8] have worked on a Three Dimensional steady state numerical simulation for the magnesium alloy AZ91. Three Dimensional computational fluid dynamics codes were developed for the molten metal flow through the porous filter. The author are presented temperature and velocity field pictorially. Author correlated casting speed with all parameters like as solid shell thickness at exit of the mould, sump depth, axial temperature profile of magnesium alloy casting and mushy region thickness using regression analysis.

Amber Batwara *et al*. (2015) [1] have present the relation between factor and their responses using design of experiment techniques for the continuous casting product. For design of experiment analysis selected four factors in MINITAB software. In MINITAB software surface responded methodology use for finding the relation between factor and responses study.

Latifa Begumet *et al*. (2016) [7] have presented the work for the effect of casting speed and heat transfer coefficient on mould metal contact region on different parameters. The result presented and discussed in the form of velocity temperature, solid shell thickness as well as mushy layer thickness.

Ravindra Pardeshi (2016) [11] focuses on the developing the model of a steady-state computational fluid dynamics (CFD) and Use the this computational fluid dynamics (CFD) model for studied the thermal fluid flow and solidified process this is helpful for identifying the best process parameters.

Vasdev Malhotra *et al*. (2016) [12] have discussed the casting defects that degrade the quality of product. In this author are studied different papers and find out main root cause of the casting defects.

Most of the researchers cover the numerical model and FEM model, heat treatment, thermal analysis, various defects for steel but no one has discussed the pull in defect in selected grade of aluminium alloy. Hence there is ample scope for researcher to do research work in selected grade of aluminium alloy. So there is need to develop model for aluminium alloys continuous casting for many casting grades of aluminium alloys. Moulding temperature and casting speed are two critical parameters which affect the quality especially the solidification and cross section. Cross section largely decides the yield in continuous casting.

III. DATA COLLECTION

The basic data is collected from the Integrated Management System, raw data from the shift log. This is the step in the project about details on the occurrence of the problem & how the problem impacts the organization and how the project is relevant for improvement in the performance at the organization process. As the paper is on improvement in rolling ingot recovery so as a beginner it is important to check the baseline data for present level of recovery, in terms of RI defects & the present level of shell zone. The RI defects are mainly CRACK, COLD SHUT, RUNOUT, FILTER PUNCTURE, BEND, DRAG MARKS, etc. After collecting the raw data of rejection of the RI, we have collected the data to be refined with the collection of data on the reason for rejection or the type of the defects which ultimately are responsible for the scarp of RI and the shift in which the particular RI was rejected and the condition of casting when the rejection has occurred.

All the relevant data for this project is collected from the cast hose shift log, which is mother of all the required data. As the casting is a regular process only the shift crews that are manpower & supervisor are changing shift by shift therefore each & everything is recorded in shift log of Remelt cast house shift log & hence it is a perfect source to collect data. From the Remelt shift logs, last three years data is collected according to shift wise operator supervisor wise, alloy wise mould wise & defect wise casting details. All these defects carrying Ingots are non-conformance to the quality & hence these leads to rejection. The records of these non-conformances of products are recorded. The raw data from the shift log is compared with the SOP guidelines & the process parameters, where any abnormality or rejection found in the product in any particular shift. The data for Shell Zone is collected by actual measurement of the current shell zone in the RI which is being cast at the cast house. For studying the data three different alloys are taken with different mould sets. Ten sets of reading are taken for comparison to check the present level.

IV. METHODOLOGY FOR DATA ANALYSIS

After collection of the data from the system generated reports & the Remelt shift log the data is formatted according to shift wise, mould wise alloy wise and defect wise so that it will be convenient to compare the results & it should reflect the problem or the abnormality i.e. what went wrong either in particular shift crew or which defect is critical or occurrence of the defect in a particular product, is related to any specific mould or any alloy etc.

In this project the data is taken from Jan-2015 to May-2016, in which total 205 no. of defects were taken which lead to rejection of the RI. The data is segregated in the month wise rejection with defects identification, reason for the defect & related root cause dip tube broken, Drag-mark, Dross, Filter Puncture, Improper degassing, Misc. Run outs, short length. The data is collected for 17 months and then in each month the occurrence of the defect is collected for simplicity of the data. After formulating the data defect wise & occurrence wise in month each defects impact on overall rejection is taken into consideration. Then % of each defects occurrence contribution is counted in total given month.

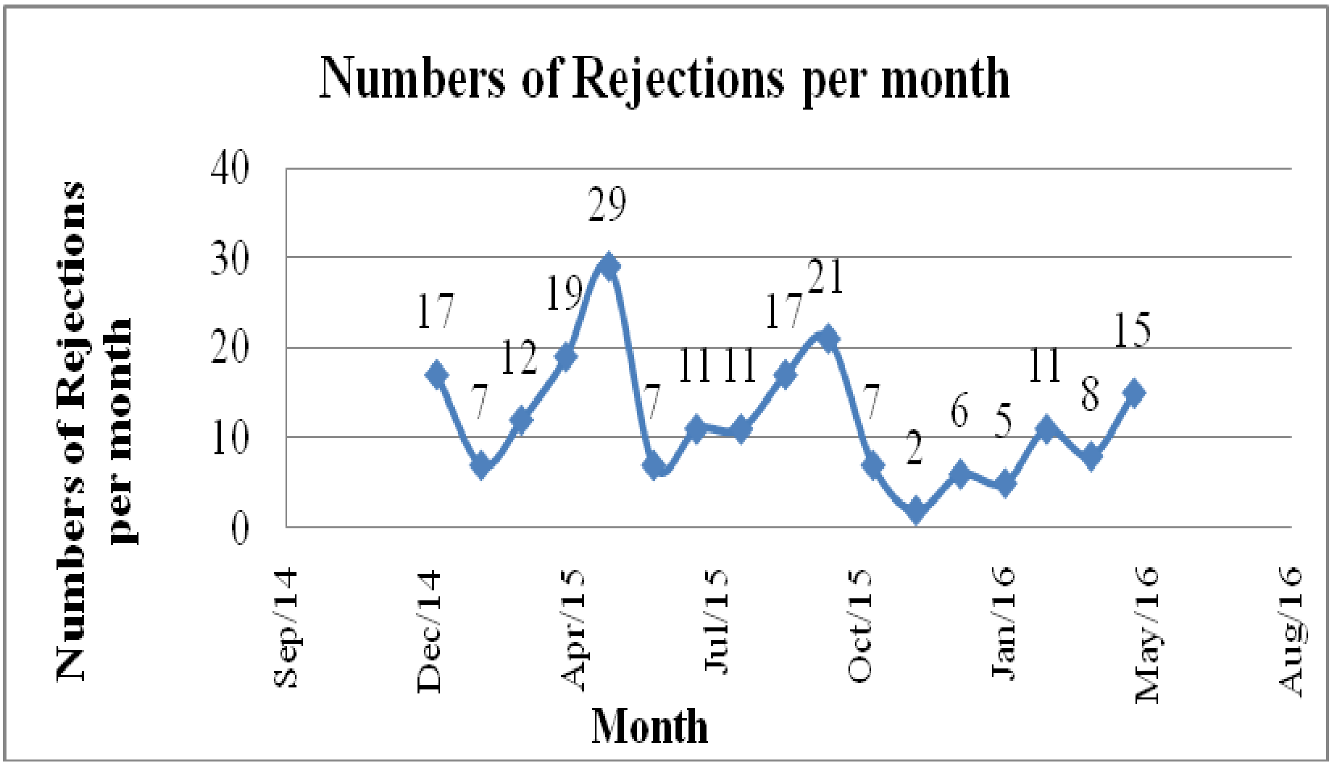

Fig. 1.Number of Rejection per month

This is done to indicate that from a given set of data which defects occurrence is more & lead to scrap of the RI. Then Figure 2 have been plotted to show the defect analysis form Jan-2015 to May-2016. Form where it is clear that we have to work on which of the major defects to minimize the rejection so that the RI recovery will be increased.

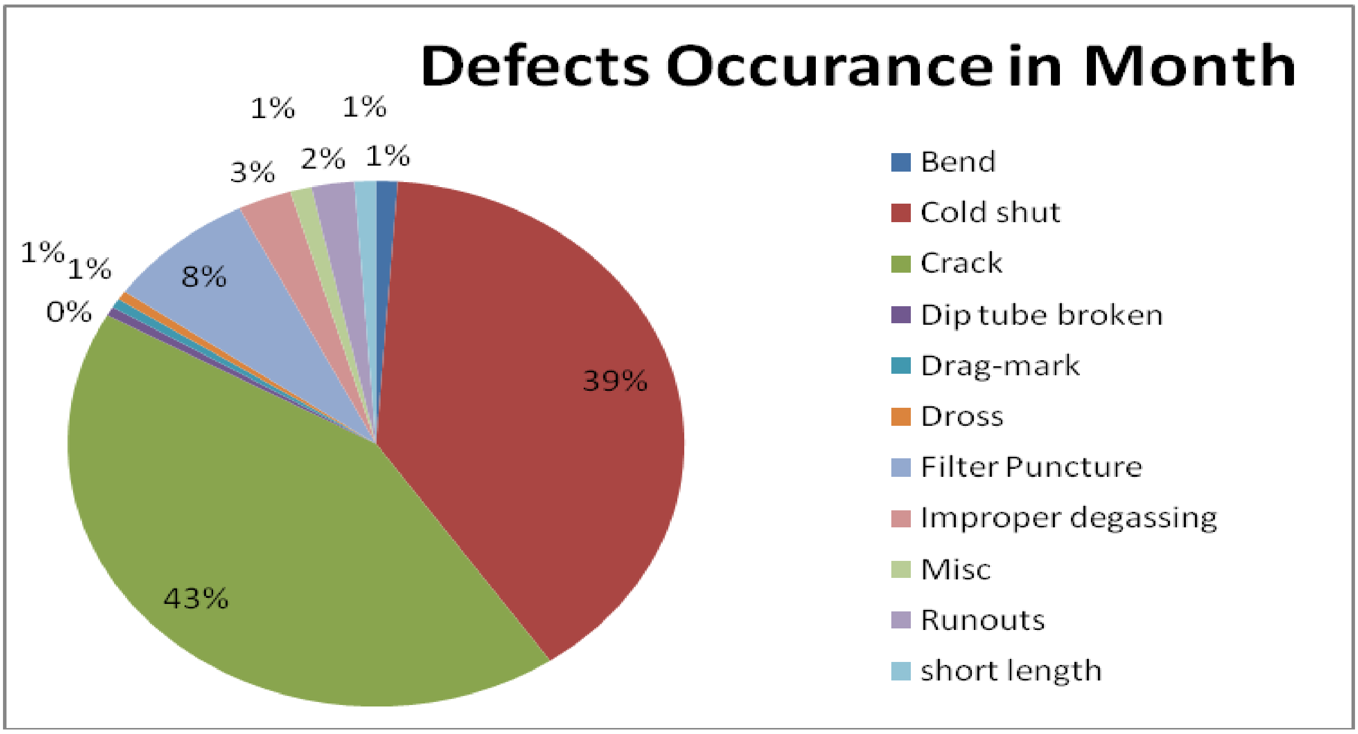

Fig. 2.Percentage of defects occurred in month

After processing of data in a presentable form or fixing the problem about which is the major defects those are mainly reducing the RI recovery the data is segregated. Own observation of the complete data has been done to find out the various probable causes which are leading to rejections. Each cause is compared with the given SOP's & process parameter or the guide lines to find out the cause that are responsible for the defects, its cause validation is compared with written actual casting parameters. During analysis of the data on each of the cause, brainstorming is done to find out the possible causes to modify the practices to minimize scrap of the product.

A. CAUSE & EFFECT DIAGRAM:

The inventor of this diagram is Prof Ishikawa. The purpose of using this tool is to provide the structure missing from traditional brain storming. Cause & effect analysis helps team member to identify which factors (Independent Variable) could, either directly or indirectly contribute to the effect (Dependant Variable) being studied the output, whether tangible or intangible result from the combining of the input factors Man, Material, Methods, Machine, these factors are inputs to cause & effect analysis. The output of diagram is factors affecting casting defects and rolling ingot recovery (refer figure 3)

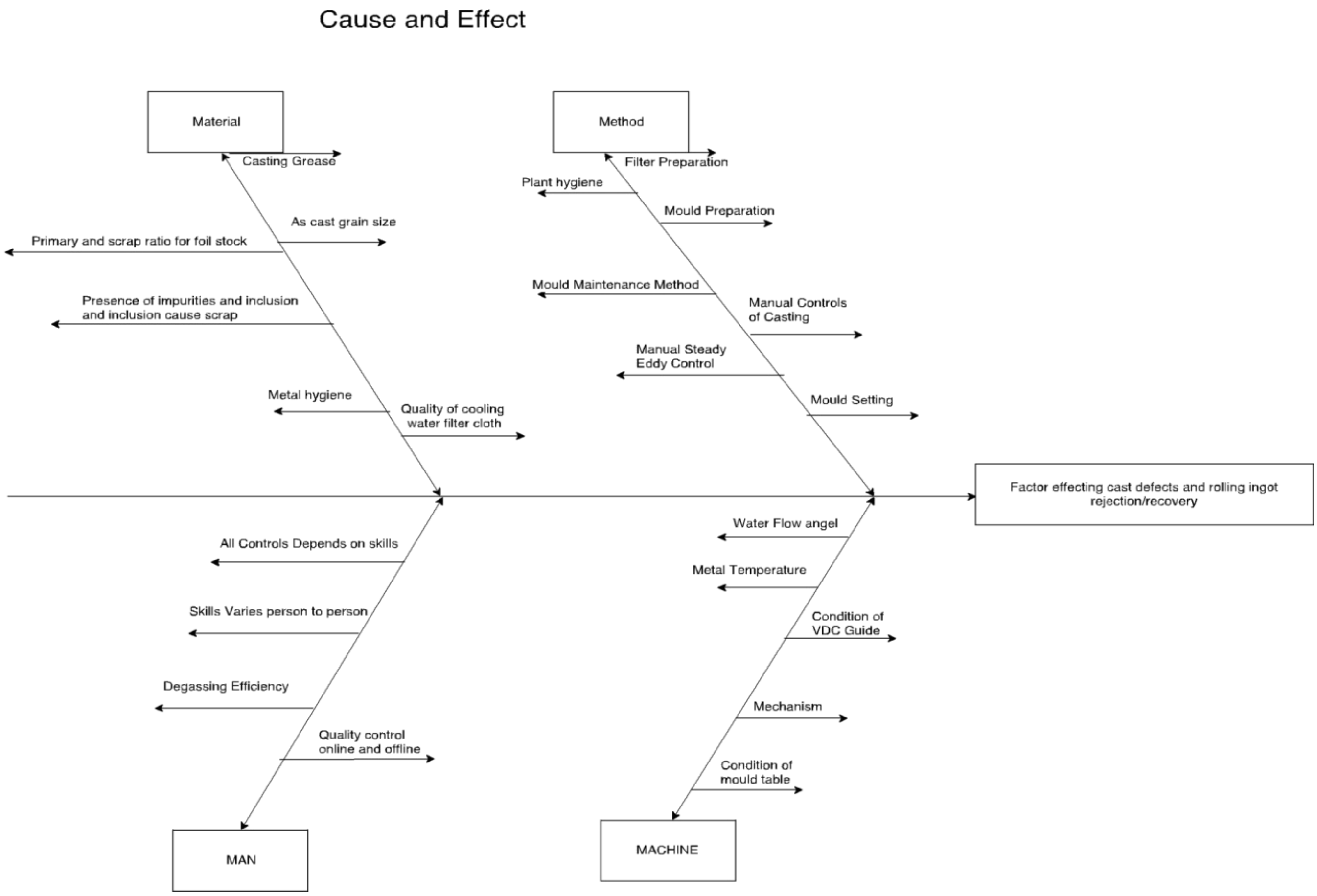

Fig. 3.Fish bone Diagram or Cause and Effect Diagram

B. BRAIN STORMING

People from different shifts were clubbed together to grab the best solution for the problem being undertaken & to trigger the idea through lateral thinking.Each member forms a quality group circle in their shifts to discuss the problem & to give the related possible causes of the defects. As now we are having the month wise defect data & the data for all the defects. It is very clear from the defect wise data, the recovery of the rolling ingot is effecting mainly by, CRACK, FILTER PUNCTURE, RUNOUT, COLD SHUTS, BEND, SHORT LENGTH & THE SHELL ZONE AREA. So, all the stated defects were given focus to find out the optimum solution to reduce the defects. Details of each of the defect are studied & occurrences of these defect, were critically examined. On each of the defects, Why-Why analysis was carried out, to find out the root cause & all the cases were discussed with each crew, to understand their viewpoint about the probably causes for the defects. Finally while preparing y-y analysis all the possible causes & their effects were taken into consideration. Defect wise study is done to compare the defect wise causes given by the members & the process parameter actual written while casting & SOP's given by the company. While making conclusions some time the changes were also done in SOP's to adopt some better practices to reduce the defects.

The figure 2 shows 75% of the defects are crack, filter puncture, cold shut, short length and bend. Out of the others like run out & dross are not having significant impact on the overall rejection. Hence we worked on the above mentioned five highly impacting defects one by one.

WHY-WHY ANALYSIS

- ZONE : 1
- Department : New Remelt
- Section : DC Casting Machine.
- Date of Problem / Failure : NL-217/3 /10-May-15
- Category of Problem / Failure : Scarp of RI
- Alloy & Mould size : AA-3105 / 18*52
- Description of Problem / Failure : RI Scarp due to Crack
- Tonnage lost : 5T
- Name of the Operators :MAM, SRM, GSN, PHP, MSM, KAM
- Name of the Shift Supervisor : SSS

Table.1: Why-Why Analysis

Why	Answer	Action
RI got rejected Due to Crack Starting from but end. Butt end found to be deformed at the Centre.	Excessive Shrinkage at butt end	-
Excessive Shrinkage at butt end	Faster solidification at start of casting	-
Faster Solidification at start of casting	High Cooling Rate at the Beginning of Cast	-
High Cooling Rate at the Beginning of Cast	Low Temperature of Stool Cap	-
Low Temperature of Stool Cap	Moisture Entrapment in Stool Cap	-
Moisture Entrapment in Stool Cap	Fine Layer of Algae Trapping Moisture	Covering of Mould in Rainy Season
Fine Layer of Algae Trapping Moisture	Mould being used after Pro-Longed Gap.	Drying of Mould with LPG Burners.

Table.2: Result table for Why-Why Analysis

Nos.	Problem/ Defect	Effect	Likely Causes	Corrective Action
1	RI got crack from butt end till last	Bulge of RI at butt end & scrapped	Moisture in mould Low temperature at start of cast. Excess cooling agent	Covering of Mould in Rainy Season Drying of Mould with LPG Burners
2	Filter puncture during casting	All the impurities which accumulated on the filter get passed in metal resulting scarp of RI.	Low metal temperature. Uneven distance between filter & stool cap. Less distance of the down spout & filter-cloth Filter frame condition.	Initial launder preheating is started. The distance between spout & frame is freeze by putting pickings. Casting temp SOP is revised. Use of CFF plate for each casting.
3	Corner cold shuts & surface cold shuts	If cold shut is more than 25mm it leads to excess scalping or scarp of the RI	Excess water flow of the 2-aduscent sides of the mould The lubrication of the mould is in sufficient near the end of the casting in our process. Uneven water flow that is excess of water at periphery of mould	Mould corner can be controlled by putting extra baffle plates at corner to reduce the water flow Lubricity of the lubricating agent is modified. Proper feedback is given to the manufacturing department for modifying the grease. Mould baffle plate gap is made uniform.
4	Short length	Recovery losses in cast house as well as final coil product also get for recovery or RI may get scarp.	Less metal in the holding furnace. Accumulation of dross inside the furnace. Furnace tilting capacity between of the casting length.	Furnace cleaning schedule is added in the SOP on weekly basis. Hydraulic oil checking frequency & top up is ensured in maintenance plan.
5	Bend or twist of RI	Excess scalping for giving flatness, if more that 6mm & further rework is not possible the scarp of RI.	Movement of the equipment during casting. Misalignment of the mould set. Individual alignment of the mould & stool, gap between mould & stool caps.	Teflon shoes & guide rod distance included in checklist. For mist alignment of mould set pivot guide is provided by doing kaizen. Mould maintenance frequency & checklist is fixed. Mould & stool gap is checked & if it is more than 3mm then the mould is replaced with new piece.

V. RESULT AND DISCUSSION

In the experimentation carried out lot of refinement of process parameters was required through integrated approach. Root cause analysis was carried out under the umbrella of Total Quality Management through Cause & Effect diagram &defect analysis. Chart shows the defect analysis after adopting the guidelines & the outcomes of the Why-Why analysis mentioned in the paper. Chart shows the data of month wise RI rejection trend from Jun-15 to Apr-16.In the chart it can be seen that many times we have achieved the rejection of the RI numbers below 5, this shows that with this approach we can achieve target of zero rejection in a month.

All this was achieved though continuous focusing toward quality & creating the awareness of SO giving on the job training to the operators towards the casting parameters & the related defects which occurred with respective casting parameters & the condition of the moulds. Not only the process but the equipment health also maintained, like conditions of the mould, its setting, DC W-guide conditions, and filter frames conditions *etc.*

The figure 5 shows the defects has been reduced mainly, in terms of cracks from 7% to 3%, filter puncture (1.4% to 0.7%), & dross (0.1% to 0%) run outs, short length which was the major contributing factors toward the rejections. A rejection due to off compositions is achieved to zero this is possible with efforts & the awareness of al shop floor members & the shit in charges,

who are working in all 3-shifts.

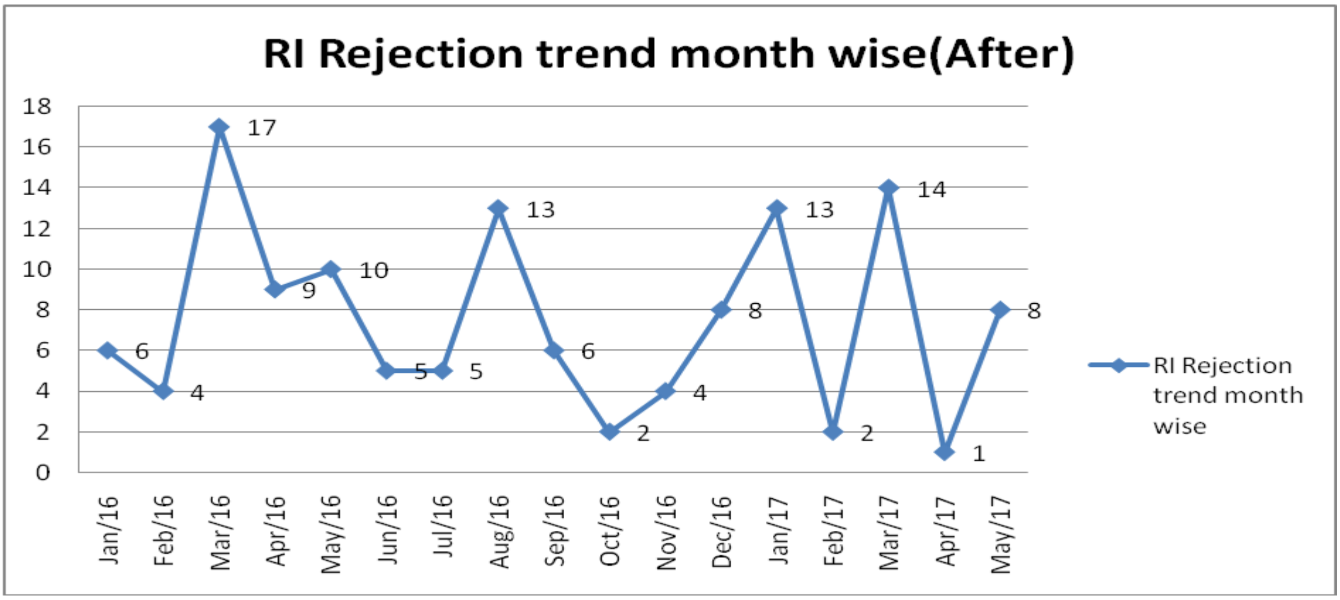

Fig. 4.Number of Rejection per month (After)

In the figure 5 bend defect was raised by 0.1, this is because of the W-shoes alignment is giving signal of abnormality, for arresting the annual shut down is required. All the targeted defects have been studied & controlled in the minimizing trend; this shows the improvement in RI recovery with relation to the defect wise data.

figure 5 shows % defect wise data before & after the project for comparison purpose.

From figure 5, it is very clear that all the defects have been in a reducing trend, which had improved the recovery in terms of rejection.

The 5 - major defects CRACK, FILTER PUNCTURE, RUNOUT, BEND & COLD SHUT, SHORT LENGTH which were considered for the study & are mainly responsible for the scarp of RI & its recovery are satisfactorily brought down in control. The only cold shut defects was raised as we have taken trial of some new alloy in the plant like AA8006, AA8079 & more casting of the magnesium based alloy for which the process of stabilization is still in progress.

Recovery in defect of crack, filter puncture, off composition is achieved almost 50% same is observed for dross defects.

Hence the approach towards the RI recovery project has been achieved in the mainly concerned defects which were taken for study in the scope for the project.

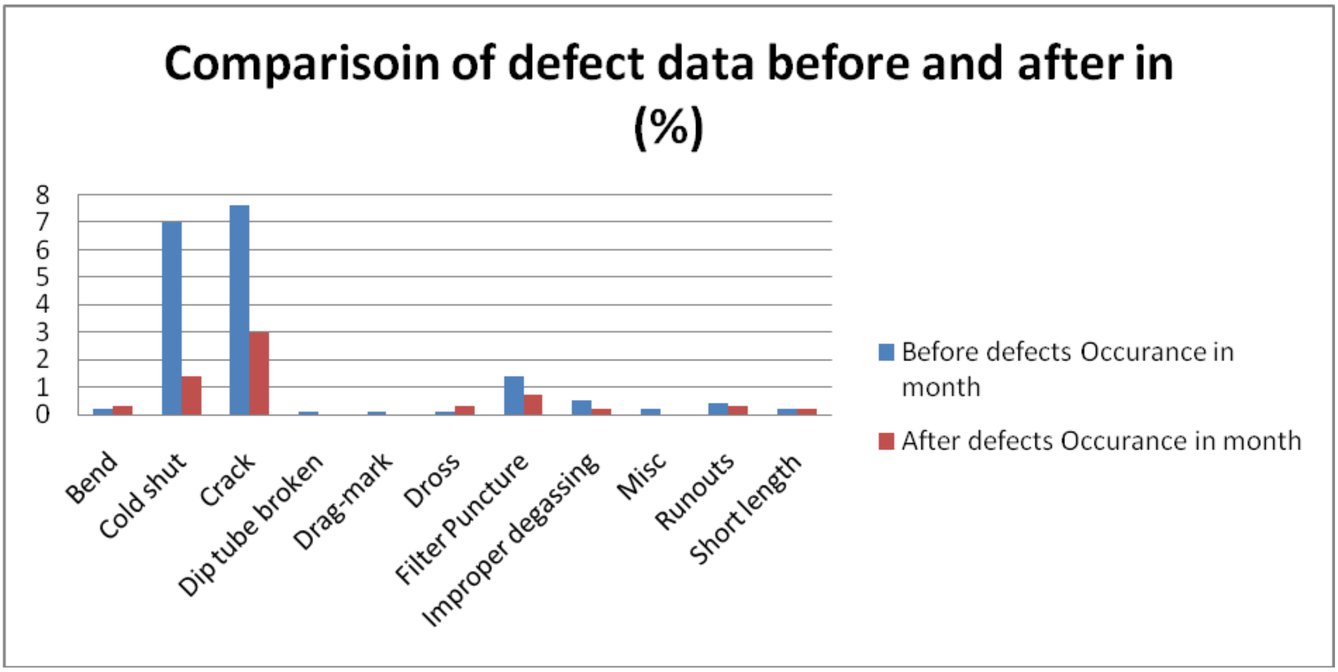

Fig. 5.Comparison of defect data before and after in (%)

VI. CONCLUSION

After working, it is clear that with all the team efforts & better adherence to SOP one can easily improve the recovery of the rolling ingots, which is raw material for producing the aluminium coils. For achieving this awareness towards the quality & the rejection trend, with reason has to be monitored. With the design of experiments & critical brainstorming reasons of the rejections & improving factor for the shell zone are traced out. After adopting the precaution the rejection trend is reduced this has increased the recovery. Since casting technology in our case is man-machine interface, the phenomena is completely governed by operator's skill. Though rejections, shell zone & inclusion can be reduced by, Continuous monitoring the health of the moulds, quality & quantity of water, the metal casting temperature, metal head in mould, water impingement angle, use of Ceramic foam filter plates, awareness & the adherence towards the guidelines. For catering those reasons for defect, on line & off line guidelines are developed. To avoid the root cause of the rejections new control plans are made, so that the reoccurrence of the rejection can be controlled, which can ultimately improve the overall recovery of the rolling ingot.

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AUTHORS PROFILE

Prof. R. S. Fegade working as a Assistant Professor in Mechanical Engineering Department, Genba Sopanrao Moze College of Engineering, Balewadi, Pune. He is currently pursuing PhD in Maharashtra Institute of Technology, Aurangabad. His field of research interest is direct chill continuous casting.

Prof. R. G. Tated received PhD (Mechanical), M.E. (Production Engineering), Area of Specialization: Mechanical Engineering, Designation: Professor at Matoshri College of Engineering & Research Center Eklahare, Nashik.

Prof. R. S. Nehete received PhD (Manufacturing engineering), M.E. (Process metallurgy), Area of Specialization: production Engineering, Designation: Professor at SIES Graduate School of Technology, Navi Mumbai.