

Improving Recovery Rate during Aluminium Casting Process by Eliminating Bends using Quality Tools

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Abstract— Extrusions (or profiles) made of aluminium have repeatedly demonstrated their superiority in terms of effectiveness, durability, and efficiency in a variety of applications, including consumer goods, transportation, electronics, engineering and construction. Aluminium extrusions provide advantages unequalled by other materials and processes where time, cost, and process reliability are crucial considerations for the manufacturer. The objective of this study is to use data obtained in the industry to characterize and quantify the bending defect that occur during the casting process. During Aluminium casting process, the quality of the completed product was significantly reduced by bending defect as they result in higher production costs and a higher percentage of scrap. To locate the fundamental causes, correct likely deviations, and make major changes, a variety of quality techniques are used, including Brainstorming, 4W-1H Analysis, Ishikawa diagram, 5-WHY Analysis and Preventive / Corrective action methods. The main goal of employing these tools is to give operators and supervisors the right indications that govern the production process and help them locate the crucial casting variables or other factors that are to blame for excessive waste, errors, and decrease in productivity. The findings showed that Log Bend makes up a sizable portion of the overall analyzed flaws, proving the necessity of tracking this issue. The present study revealed that a number of factors have a role in the development of these flaws. To lower the rejection rate and achieve the internal rejection objective, certain action strategies have been put up. The outcomes could serve as a benchmarking tool for other extrusion facilities of similar nature..

Index Terms— Aluminium Casting, Extrusion Process, Log Bend, Quality Tool and Cost saving.

I. INTRODUCTION

An increase in competition and competitiveness among businesses engaged in aluminium casting is being brought on by the globalisation of the economy and the rising demand for aluminium by the main powers of the globe. As we live in a digital era where the media and transportation form a worldwide market, a company's product now faces competition from multiple firms throughout the world. As a result, businesses are compelled to adopt new procedures that concentrate on managing the raw material to the final product and building trusting relationships with customers. This method of thinking is essential to ensure that businesses can develop long lasting operations and that customers will buy products in the present and the future [1]. However, if there is no on-going concern for the continuous improvement of their operations, resulting in

reduction of costs and waste, the likelihood of businesses surviving and flourishing is impacted [2]. In this way, the improvement activities which makes them more effective, simpler, and safer, essentially with less nonconformity, minimises the amount of scrap and leads to the reduction of the level of quality defects and the manufacturing of high quality goods [3]. A foundry is a facility where metal castings are made. Here, pure aluminium ingots, aluminium scrap, and certain alloying ingredients are melted and formed into aluminium logs. This process of making commercial aluminium billets is known as billet casting, which is then further processed through extrusion to make profiles. Here the molten metal is poured into a shallow, water-cooled mould with a typically circular cross-section. When the metal in the mould starts to freeze, the fake bottom is lowered with regulated speed, and when the freshly formed billet emerges, water is sprayed on its surface. With little segregation and at high output rates, this technique creates fine-grained billets. The production of high-value products and scrap reduction depend on metal quality and little downtime [4].

Like some writers who characterise quality as a customer-centered strategy, it must serve as the foundation for every firm that aspires to continuously enhance its quality [5]. On the other hand, Godfrey & Juran [6] assigned two definitions for quality and related it to the concept of management. Quality is measured by how satisfied customers are with the items (fewer defects = lower costs) and Quality can be measured by how closely items adhere to the requirements or not because of the presence of defects [7]. Therefore, it is vital to identify solutions by gathering data about the complete production chain, evaluating it, and make better decisions in order to fulfil client expectations and assure product delivery in accordance with the standards. This will aid businesses in enhancing both the general quality of their products and operational effectiveness.

Through the application of quality, it is intended to contribute to the reduction of the variability of the processes and products and consequently to reduce production costs [8]. In particular case of aluminium industry, whose waste/scrap represents significant costs for the company, it is considered appropriate to implement a program to improve the quality of the process based on the following objective

1. To define Non-Conformities.
2. To identify causes of Non-conformities and to study possible corrective actions.

To determine the root causes of nonconformities and research potential solutions, several high-quality tools, including brainstorming, 4W-1H analysis, Ishikawa diagram, 5-WHY analysis, and preventive / corrective method, was used throughout this work.

II. DIFFERENT KINDS OF QUALITY TOOLS

A diagram, a technique, or strategies are all examples of tools that are used to guarantee that the quality of all products is maintained during manufacturing processes. The increase in information in an organization creates a growing need for tools to collect and process data to aid effective decision-making. The definition, measurement, analysis, and suggestion of remedies that have an impact on performance are carried out using quality tools [9]. According to Professor Ishikawa, 95 % of a company's issues may be resolved with basic, high-quality equipment. Additionally, recognising the issue and acting fast with the appropriate tools are essential for finding a solution. Considering the nature of the issue, the type of quality tool can be decided and be informed to others [10]. Simple problem-solving techniques that all employees can utilise to foster cooperation since everyone can comprehend its visualisation are examples of good quality tools. Although there are numerous quality tools, Ishikawa's seven basic quality tools are the most significant [11]. Root cause analysis tools are few of the additional good-quality tools, which are utilised together with Ishikawa's seven high-quality tools. It is typically used to address issues in businesses when flawed systems, processes, or other policies are to be utilised to guide personnel in making choices. The 4W-1H may be used as a tool to describe the basics of an event/situation, and it can then create an Ishikawa diagram for the above mentioned issues. The possible cause of the issues may be confirmed using a potential cause table through root cause analysis. The root cause may then be identified using the 5-Why analysis by distinguishing the effects of different causes in the Ishikawa diagram. The cause and effect diagram, commonly referred to as the Ishikawa diagram or Fishbone diagram is a methodical enumeration and arrangement of all the causes of an impact of the quality problem. The process flow and interactions between the phases are shown by a flowchart. Potential control spots can be found with its aid.

III. COMPANY AND CASTING PROCESS

A. Company Overview

The firm specialises in creating aluminium extrusions, goods, and related services that are manufactured specifically for each customer. It continuously aspires to become the clients' chosen supplier by offering a high level of technology-enabled value creation. Its trademark has always been the quality. To eliminate everything that is less than spectacular, all work processes are put through the strictest quality standards. Total client satisfaction and on-time delivery schedules are its two main goals. The company always strives to enhance its products and services and is consistent in its commitment to growth. The company follows Quality Management Systems ISO 9001:2015 standard. The different departments of the company are Foundry, Extrusion, Tool room, Anodizing and Powder Coating. The present study is carried out at Foundry. The foundry is equipped with a four-ton melting/holding furnace, a fluxing/degassing machine, and a direct casting machine for casting billets with diameters of 6", 8", and 9". The molten metal is filtered through ceramic filters to achieve a high level of cleanliness.

B. Aluminium Casting Process

It is necessary to understand the processing of the billet and the raw material used for extrusion. This paper provides an overview of the casting process by discussing some of the fundamental features of billet casting. Extrusion productivity and quality are directly influenced by the billet quality. The profitability of the extrusion depends on the cost of the billet and the process of billet casting. The cost of the casting and the quality of billet are two key considerations for the manufacturer.

The furnace charge is made up of aluminium and other alloying ingredients that are required for the production of alloy. High quality aluminium ingots, alloying elements and master alloys, and internal process scraps make up the bulk of the charge materials. The current trend is to feed the Direct casting operation with tilting-holding furnaces rather than fixed ones. To make stirring, skimming, and hearth cleaning easier, the tilting furnace features a front door that is completely open. In order to retain a billet of high quality, a metal treatment to eliminate impurities and degas the metal is crucial. Similar to the extrusion business, metal treatment technology is improving and excelling in terms of quality. Master alloys of titanium and boron or titanium and boron in aluminium are the most often used grain refiners. The most often used filters in the filtering system are ceramic foam filters. The Pouring Temperature, Casting Speed, Mold Type, Metal Head, and Water Flow Rate are the main factors in aluminium billet casting that affect production performance. A flowchart representing the sequence of steps is shown in Fig. 1.

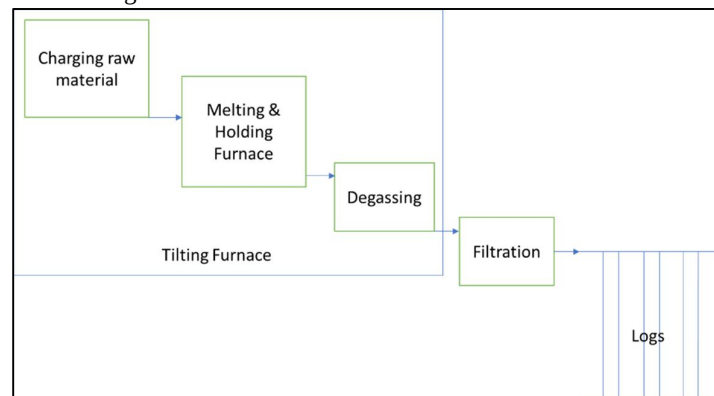


Figure 1. Casting Process

C. Nonconformities

Defects frequently appear during the casting process for aluminium. Some are easily repairable; some are just minor enough to be tolerated. Others however are so bad that there is no choice but to scrap them. Bends occurring during casting are the ones that can't be tolerated and end up being scrapped. Bending is defined as the phenomenon where the longitudinal axis of the log is not in a straight line after casting. A typical bend defect which has occurred during casting is shown in Fig. 2.

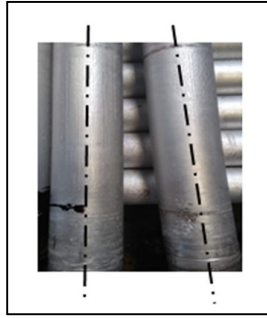


Figure 2. Bend Defect in a Casting

IV. METHODOLOGY

A simple flowchart representing the methodology used in the present work to analyse, locate, gather, and evaluate data that aids in understanding the problem is depicted in Fig. 3.

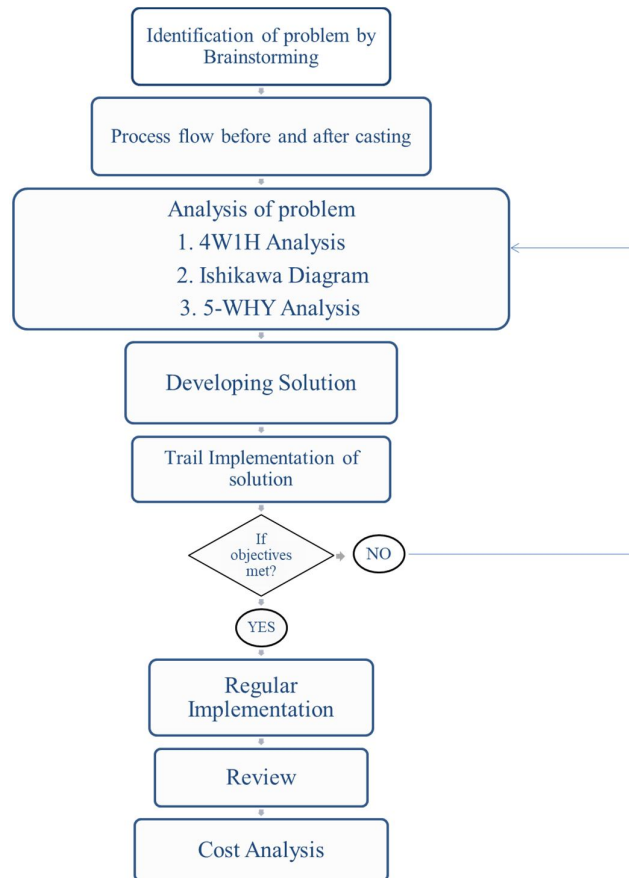


Figure 3. Methodology used in the present work

A. Identification of Problem by Brainstorming

Brainstorming is a method for generating original ideas. It is also a method of problem-solving. With the help of this approach, one can offer their views freely without fear of judgement. Every suggestion made is logged and evaluated as a potential problem-solving strategy. Through this an issue was found in 8" Log, among the categories of 6", 8", and 9" Logs. Fig. 4 depicts the picture of log book where the lengths of 8" Log that are casted are entered.

Heat Number (HT)	Log length in Metre	
385	3.73 + 3.77 + 3.75 + 3.77 + 3.75 3.93 + 3.94 + 3.91 + 3.84 + 3.89 4900.53603	3311 512
391	4.07 + 4.01 + 4.03 + 3.92 + 3.99 + 3.98 + 3.77 + 3.90 + 3.61 + 3.91 4900.54220	3331 500
396	3.72 + 3.91 + 3.77 + 3.96 + 3.70 + 4.20 + 4.18 + 3.90 + 4.16 + 4.18 4900.54527	3328 482

Figure 4. Extracts of log book indicating log lengths of 8" logs

In aluminium casting, a standard log length of 4.4m are casted, where a standard lengths of 0.1m are sheared at both the ends which is about 100-120 kg i.e. considered as the standard scrap. But also an extra length was cut at the ends due to bends, which approximately weighed about 200-300 kg. This has led to more cutting edge scraps. This has resulted in 3311 Kg of output whereas the approximate target was 3806 Kg, accounting to approximately a total of 512 Kg of scrap. This reflected in production losses and an increase in the amount of scrap produced.

Example: HT NO – 385 (Refer Fig. 4)

$$\text{Input} = 3823\text{kg} \quad (1)$$

$$\text{Output} = 3311\text{kg} \quad (2)$$

$$(1) - (2)$$

$$\text{Input} - \text{Output} = \text{Scrap}$$

$$3823 - 3311 = 512\text{kg}(\text{scrap})$$

$$\text{Recovery} = \frac{\text{Output(Kg)}}{\text{Input(Kg)}} \times 100 = \frac{3311}{3823} \times 100 = 87\%$$

Table I illustrates about the data on 8" Log production data and their Recovery rates in the first half of April month with their Heat Numbers (HT).

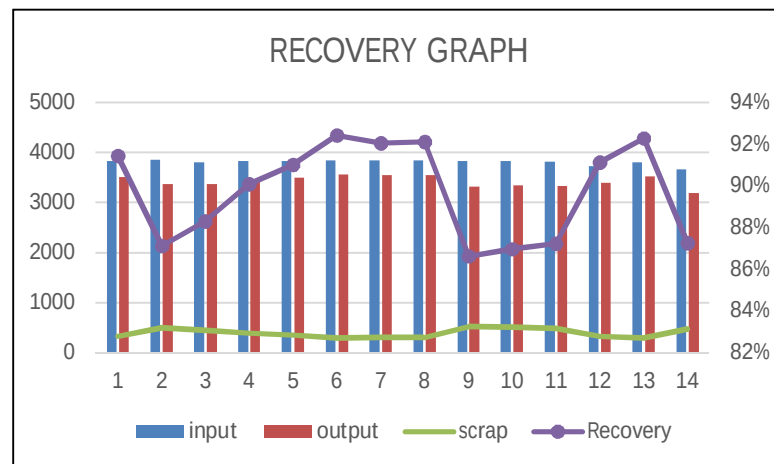


Figure 5. Recovery Graph

TABLE I. RECOVERY RATES OF 8" LOG DURING AT FIRST HALF OF APRIL, 2022.

HTNO	INPUT in Kg	OUTPUT in Kg	SCRAP	RECOVERY
371	3832	3504	328	91%
372	3858	3361	497	87%
373	3806	3360	446	88%
374	3832	3452	380	90%
375	3832	3487	345	91%
382	3841	3550	291	92%
383	3841	3535	306	92%
384	3841	3538	303	92%
385	3823	3311	512	87%
391	3832	3332	500	87%
396	3815	3328	487	87%
398	3720	3390	330	91%
410	3806	3512	294	92%
427	3659	3192	467	87%
Total	53338	47852	5486	90% (Average)

Considering the average recovery rate of logs for all the HT numbers, it was observed that only 90% recovery rate was obtained and the other 10% was lost. Fig. 5 is a graphical representation of recovery rates in the first half of April where the scrap rate increased as the recovery rate decreased.

B. Process Flow Before And After Casting

Process flow, often known as process diagram, offer a representation of the actions and connections involved in a process. Through an evaluation of the process' current status and the opportunities for process improvement can be identified which can be used for process efficiency and accuracy. A typical process flow is outlined in Fig. 6 where ① ② and ③ suggest the areas where errors are occurring.

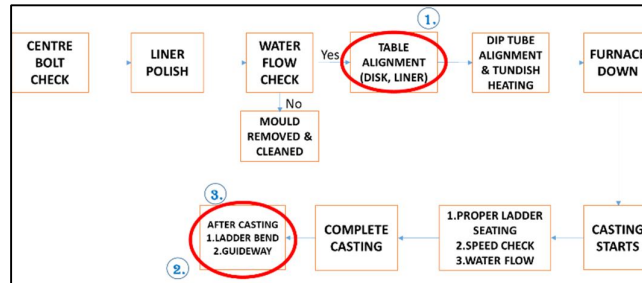


Figure 6. Casting Process Flow

C. Analysis of the Problem

1. 4W-1H Analysis

This analysis is used to understand in detail, the reason for occurrence of errors ① ② and ③ during casting process. The four W's (Who, What, Where, When) and one H (How) are used. Fig.7 shows a flowchart representing the activities involved in 4W1H analysis.

2. Ishikawa Diagram

It is frequently used in manufacturing and product development to outline the different stages of a process, highlighting possible quality control trouble areas, and indicates the resources required at specific times to address the same [8]. Several factors that are present throughout the casting process having a direct impact on the quality of casted logs is depicted in Fig. 8.

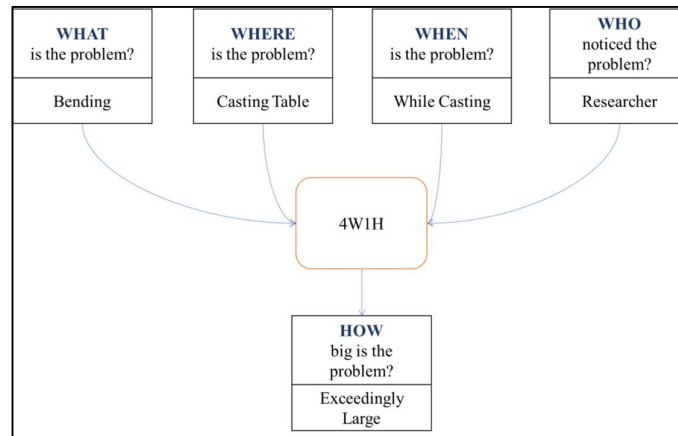


Figure 7. 4W1H Tool

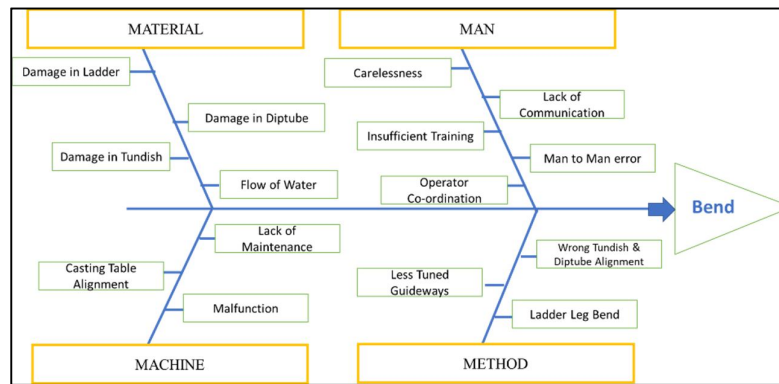


Figure 8. Ishikawa Diagram for Bend Defect During Casting Process

After analysis through Ishikawa diagram, it is observed that the following three factors are influencing the occurrence of bend defect during casting:

- i) Wrong Tundish & Dip tube Alignment
- ii) Less Tuned Guide ways
- iii) Ladder Leg Bend and Channel bends

Potential Causes for Bend: Through root cause analysis, the probable source of the problems may be verified using a potential cause table. Table II shows the potential causes for bending.

TABLE II. POTENTIAL CAUSES FOR BENDING

Cause	Verification	Impact
Wrong Tundish & Dip tube Alignment	Assemble correctly to ensure levelness and verticality	High
Less Tuned Guide ways	Guide route should have easy movement	High
Ladder Leg Bend	Ladder should be properly seated, avoid bends in ladder and channel	High

3. 5-WHY Analysis

The 5-why analysis is a group analysis technique created to swiftly identify the source of an issue. The method involves asking why about a problem, obtaining an answer, and then keep on asking why to reveal further layers of the problem until the core cause of the problem is identified. The 5-Why analysis is one of the strongest

evaluation techniques available for non-statistical analysis. It can reveal and locate issues that weren't immediately apparent or clear.

- 1-WHY? Misalignment of table, of both disk & liner.
- 2-WHY? Man to man error during alignment.
- 3-WHY? Improper Dip tube & Tundish Alignment.
- 4-WHY? Less Tuned Guide ways.
- 5-WHY? Improper seating of Ladder & Friction with Guide.

D. Developing Solution

In order to know if there is a bend in the casting, the first step is to check the straightness.

Steps to check for the same are:

- Check & mark the side of the logs with directions as indicated in Fig. 9.
- Check the sides on floor.
- If there is a bend found, then Study the guide ways.
- Align the guide ways as per convenience.

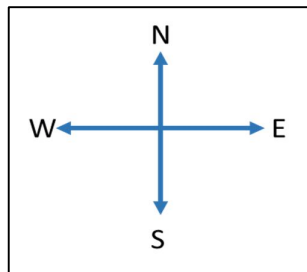


Figure 9. Directions to check straightness

In order to make the log straight, the actions like altering the guide ways, tundish-diptube alignment & ladder leg are adopted using the following two strategies.

1. **HOW-** by arresting the movement of table, and also by having 0° TO 0° alignment between disk and table.
2. **HOW-** by Proper seating of ladder, and to make sure there is no friction between guide & ladder channel.

Changes Implemented during Casting Process:

1. Casting table should be correctly installed.
2. The casting table is to frequently checked for eliminating abnormalities in alignment with the disk and liner.
3. Proper flow rate of water is to be ensured.
4. The casting machine is to be checked and adjusted frequently ensuring stability without any shake during operation.
5. The top plate, base plate and centre bolt are to assembled correctly to ensure proper levelness and verticality; centering and tightening is to be done frequently to prevent any movement during casting process.
6. Initially, the top plate was 110mm apart from the base plate at the corners after the changes; the top plate is kept straight in the corner, with 0mm difference to the base plate as depicted in Fig.10.



Figure 10. Corner Plates

7. The taperness should be maintained in the guide way with 25mm on the left side and 30mm to the right, as opposed to the previous taper of 23.2mm in the left and 31.8mm in the right as shown in Fig.11 and Fig.12 respectively

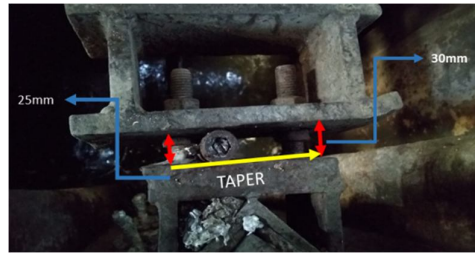


Figure 11. Guide Ways

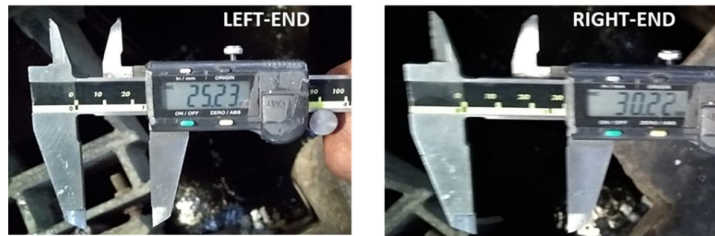


Figure 12. Required Taperness

8. The ladder should be properly seated by removing the ladder channel bends, which eliminates friction between the guide routes directly as depicted in Fig.13. In addition, the ladder leg bends should be straightened.



Figure 13. Ladder Channel

9. To avoid reverse pressure, a bolt with a diameter of 25mm is inserted between the lock nuts at the left corner as shown in Fig.14.



Figure 14. Bolt

E. Trial Implementation

The intension during trial implementation is to test the plan developed for the solution by making necessary changes while controlling the outcomes and evaluating the results. By verifying the potential causes and altering the errors that occur during casting and making changes, the 8" logs were casted as a trial and found that the castings were sound without defects. The altered parameters and changes were noted down. Fig.15 shows the

excerpts of the log book for the 8" casting after incorporating the changes as mentioned above. It is seen from the figure that the lengths of the logs have been improved in comparison with earlier ones by approximately 4.25m and the end scrap has been reduced.

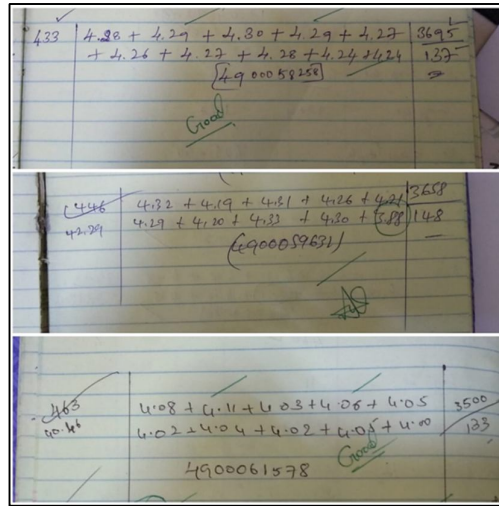


Figure 15. Trail Implementation

Thus the trial met all the requirements of the sound restricting the occurrence of bends. This is implemented on regular basis.

F. Regular Implementation

After regular implementation of the changes made, the recovery rates have been improved till date as suggested in Fig.16 which indicates the lengths of the logs for different heats. Fig.17 shows the photographs of logs before and after implementing the changes.

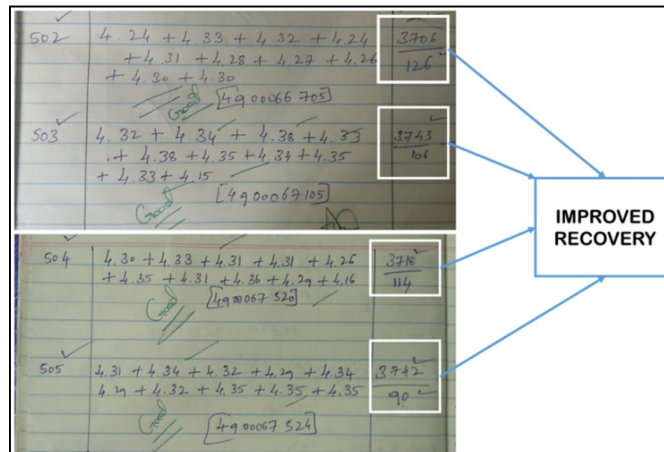


Figure 16. Regular Implementation

G. Review

To highlight the important details, quality review was made recording the performance against quality goal at regular intervals. The data is presented in Table III which represents the recovery rates in the second half of April, where the recovery is improved to 96%, suggesting an increase of 6%. This has been depicted in the recovery chart as shown in Fig. 18.

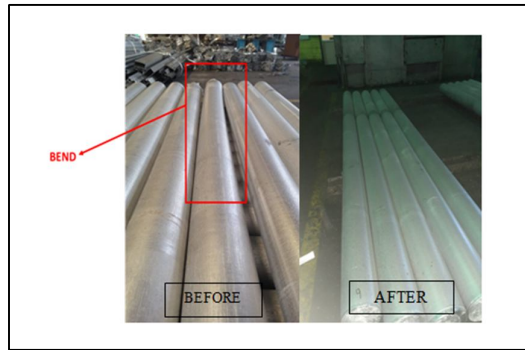


Figure 17. Comparison between Before and After Implementing

TABLE III. RECOVERY RATES AT SECOND HALF OF APRIL, 2022.

HTNO	INPUT in KG	OUTPUT in KG	SCRAP in KG	RECOVERY
446	3806	3658	148	96%
451	3782	3657	125	97%
463	3633	3500	133	96%
466	3745	3652	93	98%
465	3745	3623	122	97%
468	3806	3665	141	96%
471	3676	3520	156	96%
484	3806	3633	173	95%
485	3503	3377	126	96%
486	3547	3392	155	96%
487	3702	3554	148	96%
488	3538	3426	112	97%
489	3693	3578	115	97%
490	3685	3575	110	97%
493	3547	3457	90	97%
500	3849	3695	154	96%
501	3720	3559	161	96%
Total	84785	81300	3485	96% (Average)

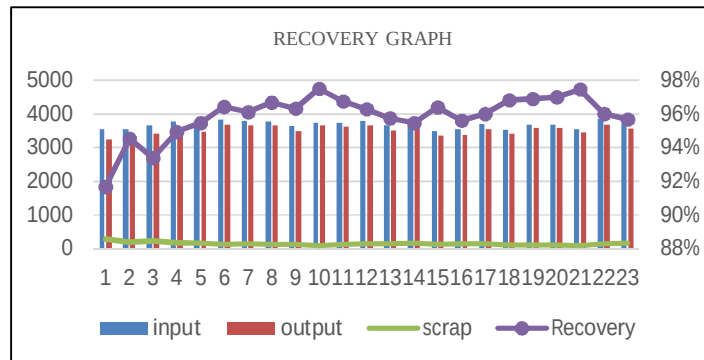


Figure 18. Recovery Graph

H. Cost Analysis

Manufacturing cost analysis is the sum of costs of all the resources consumed in the process of making the log. The manufacturing cost is classified into three categories; direct materials cost; direct labour cost and manufacturing overhead. The cost considered here is the cost incurred in Foundry.

Cost Incurred in Foundry:

$$\rightarrow 1 \text{ Ton} = \text{₹}11,000 \text{ (direct materials cost, direct labour cost \& manufacturing overhead)}$$

$$\rightarrow 1 \text{ Kg} = \text{₹}11$$

Cost for 8" log Production:

$$\rightarrow 10 \times 4.4\text{m} \times 86.5 \text{ W/m} = 3806 \text{ Kg (1 HT Production)}$$

$$\rightarrow 3806 \text{ Kg} \times 11 \text{ Rs} = \text{₹}41,866 \text{ (For 10 logs or 1HT)}$$

Production Details:

$$\rightarrow 190 \text{ Tons/Month (Considering Average of 4 months)}$$

$$\rightarrow 190 \text{ Tons/Month} = 1,90,000 \text{ Kg/Month}$$

For 500 Logs/Month (Production)

$$500 \times 4.4\text{m} \times 86.5 = 1,90,300 \text{ Kg} \approx 190 \text{ Tons} \quad (3)$$

Standard Scrap:

$$500 \times 4.2\text{m} \times 86.5 = 1,81,650 \text{ Kg} \approx 181 \text{ Tons} \quad (4)$$

$$=(3)-(4)$$

$$\rightarrow 190\text{Tons}-181\text{Tons}= 9\text{Tons/Month (Standard scrap-Not considered)}$$

- Taking 100-120Kg (for 1 HT) as standard scrap, the same is not considered for cost saving as it is Standard regular scrap.
- From the observation of previous 3Months, **an average of 190-200 kgs of extra scrap was generated** (for 1HT). This directly is taken for cost savings.

$$\text{Total Scrap generated} \approx 120 \text{ Kg (Standard scrap)} + 200\text{Kg (Extra scrap)} \approx 320\text{Kg (for 1HT)}$$

Cost Savings:

$$\text{Considering} \rightarrow 200\text{Kg} \approx 1\text{HT (10 Logs)}$$

$$\rightarrow 1\text{Log} = 20\text{Kg (saving)}$$

$$\rightarrow 10\text{Log} = 200\text{Kg}$$

For 500 Logs:

$$\rightarrow 500\text{Logs} \times 20\text{Kg} \approx 10,000\text{kgs (10Tons)} \rightarrow \text{Savings/Month}$$

$$\rightarrow 10\text{Tons} \times 11,000\text{Rs} \approx 1,10,000 \text{ Rs/Month (As 11,000 = Foundry cost/Ton)}$$

$$\approx 13,20,000 \text{ Rs/Year (Savings)}$$

V. RESULTS

As a result of problem analysis and corrective measures the issue of bend occurrence in 8" logs has been resolved successfully. Initially the recovery losses during production were 90%. Using quality tools, the root causes were identified and improvement solution was proposed. Finally the effect of improvement was measured by comparison of recovery rates before and after implementation of changes. The recovery rate has improved by 6 %, bringing it to 96 % as graphically represented in Fig.19. This has resulted in saving of nearly 10 tonnes of scrap every month. A monthly cost savings of almost ₹1,10,000 is also achieved. A year's worth of savings is

roughly 13,20,000. The process is now standardized thus the total scrap is minimized as the quality is improved and the production has been increased. Through this there is a savings in time and cost.

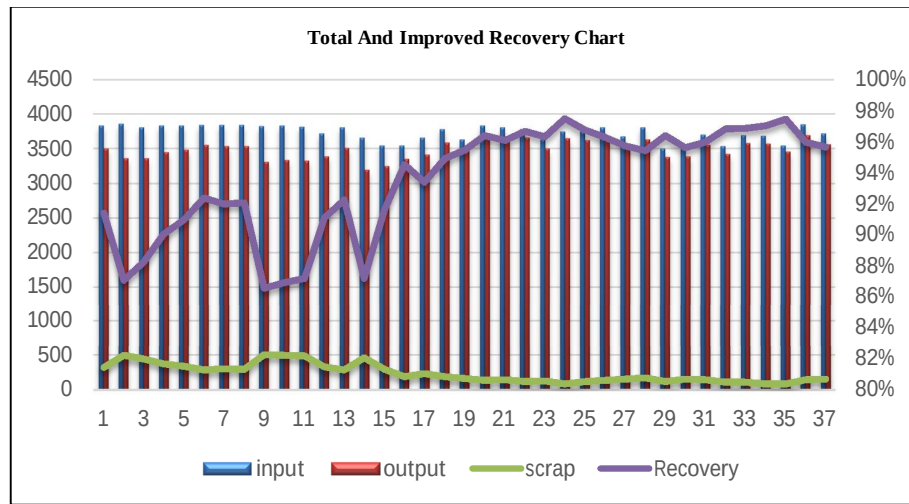


Figure 19. Total Recovery Chart

VI. CONCLUSION

The main objective of the present study was to use and implement quality tools in Aluminium casting process by eliminating and quantifying the bending defect through lowering the process variability resulting in scrap in production. The fundamental causes have been located using variety of quality techniques to determine the root cause of the problem. By employing these tools, the operators and supervisors have the right indication to govern the production process and know the crucial process parameters. The preventive/corrective action plan is suggested for eliminating the bending defect which was contributing to 10% loss in the form of recovery rates considering the average of four months. The recovery rate has been improved from 90% to 96% by introducing the action plan, almost close to the company's target recovery rate i.e. 97%. This plan nearly saved 10 tonnes of scrap every month and a monthly cost saving of Rs. 1,10,000. In the light of the above, it is crucial to create a new culture inside the business that encourages everyone to work together in the quest for on-going process improvement so as to significantly enhance quality and productivity. Finally, the process is now standardized.

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