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AN EMPIRICAL STUDY OF THE SIX SIGMA APPROACH FOR REDUCING THE NUMBER OF COBBLES - STATISTICAL SOFTWARE QUALITY ASSURANCE TECHNIQUE

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ABSTRACT

The blooms of size 250*320sqmm size which are being produced at steel melt shop are kept at bloom storage yard. Accordingly, these blooms are charged into the furnaces and rolled into the billets of size 125*125sqmm. The bloom is converted into billets when drawn through seven stands of variable speeds. Later the billet is passed through the shear to get cut into three pieces for passing to the Wire Rod Mill (WRM) feeding. The material passing from stand-1 is continuous and passes through the stand-7 where it gets the cross section of 125*125sqmm. whenever a problem arises due power failure or any other malfunctioning; the material struck up and is twisted in between the stands which is known as COBBLE. Removing the cobble takes minimum three to four hours which hampers the production and is a direct loss to the company. Thus the problem needs to be looked into and the solution aroused in the form of Six Sigma tools. Six Sigma is widely recognized as a business that employs statistical and non-statistical tools and techniques, change management tools, project management skills, team work skills and a powerful roadmap (DMAIC) to maximize an organization's return on investment (ROI) through the elimination of defects in processes. DMAIC methodology provides with a data-driven methodology for achieving sustained process improvements by reducing defects. This methodology is used to identify inadequacies in the existing process and to make lasting and controllable changes to products and processes that improve product quality, customer satisfaction and the company's profitability.

Thus, with the help of proper tools and techniques of this procedure the problem had been handled. Sufficient data was collected and the various factors that affect the process and lead to failure were analyzed. The Six Sigma roadmap enabled to identify the potential causes of the failure and provided effective methods to eliminate them or minimize them. The project is all about the way the problem was tackled and the process was improved.

Keywords: *Six Sigma, DMAIC, Cobble, Breakdown mill, WRM*

1. INTRODUCTION OF VIZAG STEEL PLANT

Steel is one of the most important components that can strengthen the economic backbone of any country. The high versatility of steel allows a vast range of products to use steel as their raw material. Visakhapatnam Steel Plant's product mix consists of Rounds, Reinforcing bars, Squares, Flats, Equal angles, Unequal angles, T-bars, Channels, Saleable billets providing a great variety in the composition as per customer requirements. The plant is designed to produce three million tons of liquid steel per annum to

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be converted to 2.656 million tons per annum of saleable steel. In addition, Visakhapatnam steel plant
will produce annually about 5.56 lakh tons of pig iron and various by-products and benzyl products for sale.

1.1. LIGHT & MEDIUM MERCHANT MILL INTRODUCTION:

Initial part of LMMM known as billet mill which designed to roll 1,915,000 T/Year of 320x 250sqmm concast blooms into 1,857,000T of 125x125sqmm square billets. While later part of the mills is known as bar mill which is designed roll 726,000T of billets to 710,000T of finished light merchant products as per product-mix.
The 1046m long mill is located at +5m level above the ground level. It has got two flat roof type walking beam preheating furnaces as shown in Fig.1(b), each 200 tones/ hour capacity, equipment with radiant roof burns to heat blooms to rolling temperature of 1150^{0}C – 1200^{0}C and one 2-strands roller hearth furnace (200 tones / hour) to maintain or increase the temperature of billets entering bar mills. This roller hearth furnace connects the two portions of light and medium merchant mill i.e., billet mill with bar mill.

Fig.1.1Bloom Coming Out Of Preheating Furnace

The billet mill is continuous rolling mill consisting of seven stands (4 Horizontal and 3 vertical). Maximum rolling speed is 1.6 m/sec. The mill can roll 400 tones of blooms/hour. The flying shear located after 7 stands cuts the billet to the desired length. Out of 1,915.000 tones of blooms, billets rolled are about, 1,857,000 tones.

The Distributions of Billets are:-

a) Bar Mill : 726,000 Tones
b) Wire rod mill : 885,000 Tones
c) Saleable Billets 246,000 Tones

Fig.1.2 Bloom Passing Through Rolling Mill

1.2DESCRIPTION OF LMMM:

Keeping in view the latest developments the light and medium merchant mill is designed with the operating floor on a second storey elevation, namely +5.0 mts. This arrangement has many advantages. It provides better drainages for both lubricants and water and mill scale. The oil cellars can be placed at slightly below the ground level without deep excavations but ensuring adequate drainage. The oil and water pipes and cable trenches are readily accessible. Blooms for LMMM are placed on three charging grids of 150 tones per hour capacity each by two 16 tones claw cranes.The blooms are then delivered to the furnace approach roller table (+5.8 mts) by an inclined elevator from bloom storage roller table (+0.8 mts).The approach roller table is provided with a weighing scale, a tilter and fixed and disappearing stops. The blooms are positioned automatically in front of the furnaces and then pushed by hydraulic pushers on to the charging skids of the furnaces.
There are two walking beam type furnaces of 200 tones per hour capacity with double row charging. The blooms also can be discharge from the charging side of the furnaces in case of emergency. Heated blooms are placed piece by piece by discharging devices on to the furnace delivery roller table. The blooms are descaled on all the four sides by a high pressure descaller. The continuous break-down group (none reversing) consists of seven Stands – two horizontal (850 x 1200sqmm) and five alternating vertical and horizontal (730 x 1000sqmm and 630 x 1000sqmm) .In five box passes and one each of diamond and square in the seven stands. The finishing speed will be 1.3 to 16 mts/ sec. A4- crank shear installed behind the mill stands is designed to crop both ends and to out fixed billet lengths between 5 and 12.2 mts. Billets feeding the LMMM mill are cropped at the front and back ends. Normally, one bloom is rolled for the LMMM and the next one for the WRM alternately. Billets are also sold. The billets for WRM and for sale are cooled on two turn over type cooling beds to a maximum discharge temperature of 400^{0}C. These billets are picked up by magnetic cranes of 16T capacity in the intermediate billets storage and transported to the transfer grids in the billets inspection area of dispatched for sale. Billets after cropping by the four crank shears and having a length of about 32 mts. are transported to the in line standard roller hearth furnace of 200T/H capacity. Billets normally arrive at the furnace with a surface temperature of 1100^{0}C billets are heated and soaked top a discharging temperature of 1150^{0}C to 1130^{0}C.The continuous multi line compresses eight stand double strand roughing train and two 5 Stand, double strand intermediate train and two 4 Strand single strand fining trains, Smaller section are rolled in second stand. In case of single

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stand rolling, it is possible to prepare in parallel the complete second intermediate and finishing mill for new product size. Finishing mill speed is 20 mtrs per sec. [1]

Loppers are provided in between the finishing stand for tension free rolling in order to obtain good surface quality and tolerance. Housing is of closed top type roll necks are mounted in – antifriction bearings. Shears for cropping and emergency cutting are arranged ahead of the first roughing mills stand and up stream of intermediate mills. Snap shears for emergency cuts only are ahead of finishing mill. The rotating shears after the finishing mills crop the materials leaving at rolling speed, and cut into multiples of specified sales lengths. A cooling stretch is provided after each finishing line for rapid cooling of rein forcing bard of 10-25 mm as per the process of temp core to improve mechanical properties. This is s special technological feature of this mill. Plain rounds from 12 mm- 40mm can also be cooled to reduce secondary sealing. A total cooling bed of 130 mts * 12 mts has been provided for cooling down the rolled section to about 80^0C maximum for straightening[2].

In the down stream of the cooling beds there are multi strand straighten machines (maximum eight straightening strands). The number of straightening rolls, are eight (four on top and four on bottom). The bar gropes from the straightness are collected in layers for the down stream cold shears by cross transfer the two cold shears have cutting pressure of 500MP each. Desired finished lengths between 5 mts and 12 mts or maximum 24 mts are set by girder type gauge carriage. Tail lengths less than 3 mts are discharged into cradles near the cold shears. Down stream of the cold shears, rounds, squares, flats and T beams are transported to the bar bundling facility. One bunking facilities provided for lengths up to 12 mt and another for lengths up to 24 mts. The bar bundling facilities have provision for counting the bars, automatically storing out the under lengths and strapping the collected bars in to bundles of 4,500 kg. 10,000 Kg. There are two pliers which automatically pile bars in to squares packs. Strapping of bar bundles and packs is by means of wire. The finishing section packs/ bundles are finally transported to the weathers which are connected to one printer each and which in turn are connected to label embosser. The loading grid permits the bundles / packs to be picked up magnetic cranes in the finished product storage area having lifting magnets of 20T capacity.[4]

1.3. NEED TO UNDERTAKE THE PROJECT

We have seen in the previous chapters the process of formation of billets from blooms in the break down mill. The material passing from stand-1 is continuous and passes through the stand-7 where it gets the dimension of 125*125sqmm. whenever a problem arises due power failure or any other malfunctioning; the material gets struck up and is twisted in between the stands which is known as COBBLE as seen in the figure below.

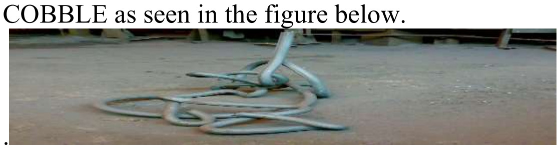

Fig. 1.3 Cobble

Removal of cobble takes minimum of three to four hours which hampers the production and is a direct loss to the company. An amount of 4.64 lakhs is lost by the company if the production stops for one hour. Thus the amount becomes four times if the production stops for four hours on an average. Not only in terms of production, but also there is a loss of material. The scrap has to be recycled again i.e. steel has to be melted again and converted into blooms. All this involves wastage of fuel and other resources. Thus the problem is serious that requires concern and preventive actions. There are various causes of the formation of cobbles. The causes can be operational, electrical, mechanical or related to any other area of production. The actual or major cause cannot be detected easily. Thus, when we are unaware of the actual defect in the process, we need to make many observations, collect a huge amount of data, analyze it and finally arrive at a solution. This methodology of defining a problem and later analyzing it to reach a solution is named as Six Sigma methodology which will be discussed in detail in the later chapters. [5]

In brief Six Sigma is widely recognized as a business that employs statistical and non-statistical tools and techniques, change management tools, project management skills, team work skills and a powerful roadmap (DMAIC) to maximize an organization's return on investment (ROI) through the elimination of defects in processes. DMAIC methodology provides with a data-driven methodology for achieving sustained process improvements by reducing defects. It is also a process of continuous improvement that gives better results every time when implemented properly. There are various tools and techniques which are very effective and will be discussed in the following chapters. Six Sigma is thus chosen to be the effective solution to the current problem and the results are obtained accordingly.[6]

2. WHAT IS SIX SIGMA?

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Six Sigma, in statistical terms, implies 3.4 defects or mistakes or errors or failures per million opportunities. Here Sigma is a term used to represent the variation about the average of a process. The focus "Six Sigma" is not on counting the defects in processes, but the number of opportunities within a process that could result in defects, which ultimately causes customer dissatisfaction and hence lost customers. In business, Six Sigma is defined as 'a business strategy used to improve business profitability, to drive out wastes, to reduce cost of pure quality and improve the effectiveness and efficiency of all operations so as to meet or even exceed customers' needs and expectations. The Six Sigma approach begins with a business strategy and ends with top-down implementation, having a significant impact on profit if successfully deployed. It takes users away from intuition based decisions (what we think is wrong) to fact based decisions (what we know is wrong). The average performance of mist processes today is in the range of 3-4 sigma quality level. The Six Sigma measure of process capability assumes that the process mean may shift over the long term by as much as 1.5 sigma, despite our best efforts to control it. In the six sigma process, 3.4 defects per million opportunities (DPMO) are obtained by assuming that the specification limits are six standard deviations away from the process target value and that the process may shift by as much as 1.5 sigma. The 3.4DPMO alue is the area under the normal curve beyond 6-1.5=4.5Sigma. Similarly the 66807 DPMO for the 3Sigma process is the area under the normal curve beyond 3-1.5=4.5 Sigma.[8]

Six Sigma is based in large measure on creating a closed-loop business system that is sensitive enough to reduce the company's "wobbling" and keep it safely on the path of performance and success. The internal "stimuli" are the measures of activity inside the process. As for the external feedback elements, the ones that tell the company if it has met its goals and is it still on the right path, they include profits, customer satisfaction and a variety of other data sources.

In the vocabulary of Six Sigma, the wobbling or inconsistency of a business system is "variation". The types of bad variation that have a negative impact on customers are called "defects". And the approaches used to create, monitor and improve that closed-loop business system are called "process management", "process improvement" and "process design/redesign".

SIX SIGMA ------ PRACTICAL MEANING

99% Good (3.8 Sigma)		99.99966% Good (6 Sigma)
* 20,000 lost articles of mail per hour	→	seven aricles lost per hour
*Unsafe drinking water for almost 15 minutes each day.	→	One unsafe minute every seven months
*5,000 incorrect surical operations per week	→	1.7 incorrect operations per week
*Two short or long landings at most major air ports each day	→	One short or long landing every five years.
*200,000 wrong prescriptions each year	→	68 wrong prescriptions per year
*No electricity for almost seven hours each month	→	One hour without electricty every 34 every 34 years

From the above chart we can understand what is the meaning of Six Sigma is and also how important it is to any company to increase its profitability in terms of both quantity and quality.[9]

2.1. SIX THEMES OF SIX SIGMA

THEME ONE: Genuine focus on the customer C
THEME TWO: Data-and-fact driven management
THEME THREE: process focus, management and improvement
THEME FOUR: Proactive management
THEME FIVE: Boundary less collaboration
THEME SIX: Drive for perfection; tolerance failure

2.2. WHAT MAKES SIX SIGMA DIFFERENT FROM OTHER QUALITY MANAGEMENT OR IMPROVEMENT INITIATIVES?

- Six Sigma strategy places a clear focus on achieving measurable and quantifiable financial returns to the bottom-line of an organization.
- Six Sigma strategy places an unprecedented importance on strong and passionate leadership and the support required for its successful deployment.
- Six Sigma methodology of problem-solving integrates the human elements (culture change, customer focus, belt system infrastructure, etc.) and process elements (process management, statistical analysis of process data, measurement system analysis, etc.) of improvement.
- Six Sigma methodology utilizes the tools and techniques for fixing problems in business processes in a sequential and disciplined fashion. Each tool and technique within the six Sigma methodology has a role to play, and when, where, why and hoe these tools are techniques should be applied is the difference between success and failure of a Six Sigma project.

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- Six Sigma emphasizes the importance of data and decision making based on facts and data rather than assumptions and hunches.
- Six Sigma utilizes the concept of statistical thinking and encourages the application of well-proven statistical tool and techniques for defect reduction through process variability reduction methods.

2.3. BENEFITS OF SIX SIGMA

Organizations adopting six Sigma business strategy have the following benefits:

- Effective management decisions due to heavy reliance on data and facts instead of gut-feelings and hunches. Hence costs associated with fire-fighting and misdirected problem-solving efforts with no structural or disciplined methodology could be significantly reduced.
- Increased understanding of customer needs and expectations, especially the critical-to quality (CTQ) service performance characteristics which will have the greatest impact on customer satisfaction and loyalty.
- Increased cash flow by making processes more efficient and reliable.
- Improved knowledge across the organization on various tools and techniques for problem solving, leading to greater job satisfaction for employs.
- Reduced number of non-value-added operations through systematic elimination, leading to faster delivery of service, faster lead time to production, faster cycle time to process critical performance characteristics to customers and stakeholders etc.
- Reduced variability in process performance, product capability and reliability, service delivery and performance, leading to more predictable and consistent level of product quality and service performance.
- Transformation of organizational; culture from being reactive to proactive thinking or mindset.
- Created new customer opportunities, improved market position relative to competitors etc.
- Improved internal communication between departments, groups etc.
- Improved cross functional team work across the entire organization, employee morale and team spirit.

3. SIX SIGMA METHODOLOGY

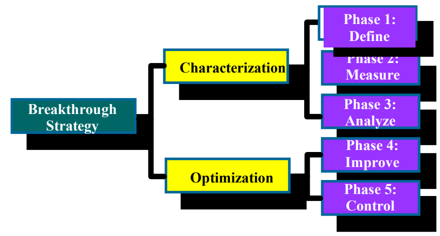

Fig. 3 .1 Schematic Of Six Sigma Methodology

The five –stage methodology sigma begins with the Define phase. The *Define* phase involves identifying a project's CTQ characteristics driven by the voice of the customer (VOC), followed by developing a team charter and finally defining a high-level process map connecting the customer to the process and identifying the key inputs and requirements. In the *Measurement* phase, the team identifies the key internal processes that influence CTQ characteristics and measures the defects currently generated relative to those processes. The project's CTQ characteristics are selected with the help of fishbone diagrams, quality function deployment (QFD), Pareto charts, etc. A gauge repeatability and reproducibility (GRR) study must be carried out to ensure that the measurement system is capable and acceptable. In service-related processes, GRR for attribute data is option. The *Analysis* phase consists of three steps (fundamentally). However, it heavily depends on the process and the type of business you are involved in. The first step is to establish process capability which means the ability of the process to meet customers' specification. The second step is to define performance objectives by the team benchmarking and identifying the sources of variation by performing analysis of variance (ANOVA) tests and hypothesis testing. Based on the above information the root causes of defects and their impact on the business/process can be identified. The *Improvement* phase helps the team to confirm the key variables or causes and quantifies their effects on the CTQs. In this phase, one may develop potential solutions to fix the problems and prevent them from recurring. Once the potential solutions are developed by the team, it is advisable to evaluate the impact of each potential solution using a criteria-decision matrix. Solutions that have a high impact on customer satisfaction and bottom-line savings to the organization need to be examined to determine how much time, effort and capital will need to be expended for implementation. It is also important to assess the risk associated with each potential solution. Techniques such as design of experiments, Taguchi

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methods, response surface methods etc. are useful in this phase.[10]

The *Control* phase consists of the following steps:

- Develop corrective actions to sustain the improved level of process performance (product/service/transactional).
- Develop new standards and procedures to ensure long-term gains.
- Implement process control plans and determine the capability of the process.
- Identify a process owner and establish his/her role.
- Verify benefits, cost savings/avoidance.
- Document the new methods.

Close projects, finalize documentation and share the key lessons learned from the project[11]

3.1. SIX SIGMA IMPROVEMENT PROCESS

Steps	Process improvement	Process design/Redesign
1.Define	Identify the problem define requirements set goal	identify specific or broad problems define goal/change vision clarify scope and customer requirements
2.Measure	validate problem/process refine problem/goal measure key steps/inputs	measure performance to requirements gather process efficiency data
3.Analyze	develop casual hypotheses identify "vital few" root causes validate hypothesis	identify "best practices" assess process design refine requirements
4.Improve	develop ideas to remove root causes test solutions standardize solution/measure results	design new process implement new process, structures, systems
5.Control	establish standard methods to maintain performance correct problems as needed	establish measures and reviews to maintain performance correct problems as needed

3.2.STATISTICAL AUTOMATION SOFTWARE IN SIX SIGMA INITIATIVES (MINITAB)

Since its inception at Motorola in 1984, the Six Sigma initiative has changed the way people work at companies around the world. Six Sigma companies expect those who make decisions to quantify the risks of their decisions; they expect engineers to predict the variation of new products before prototypes are built; they expect manufacturing managers to manage and control variation of all processes. These expectations require people to perform statistical tasks with a minimum of statistical training. Software to automate statistical tasks has become crucial to Six Sigma initiatives, because it allows people to perform a variety of important statistical tasks without requiring them to understand the theory or methods behind those tasks. To succeed in a Six Sigma environment, statistical software must have useful features, a familiar and easy user interface, and excellent support for both beginning and experienced users. For these and other reasons, MINITAB has become leading statistical automation products used by companies practicing Six Sigma methods. Minitab has been used for teaching statistics for many years especially in scientific disciplines. It has a strong tradition of Exploratory Data Analysis so there are lots of useful graphs and diagnostic charts such as the dot plots or the combination plots. Data can be read in from a variety of formats including Excel and is stored in Minitab's own **worksheet** format. Minitab has a simple command language and the ability to record and run macros. MINITAB is a fairly easy software package to use, since it uses the ubiquitous Microsoft Windows menu and windowing system. Familiarity with any Windows software will be enough to know how to get around in MINITAB. [13]

4. INTRODUCTION

This chapter illustrates the use of DMAIC (Define-Measure-Analyze-Improve-Control) methodology in a step by step function to reduce the number of cobbles that are formed in the break down mill of Vizag Steel Plant. It is already seen in the earlier chapters, what a cobble is and how is it formed. Similarly, the need to minimize the number of cobbles is also analyzed. Many factors are responsible for formation of a cobble. Out of them, operation related problems are the severe and are the major cause. So the company sensed the urgency to control those problems. They adopted the Six Sigma methodology to overcome the problem and get the positive results. This chapter is about how the company proceeded to achieve the end results. [14]

4.1. DEFINE PHASE

This phase aims at defining the scope and goals of the improvement project in terms of customer requirements and the process that delivers these requirements.

The first phase of the DMAIC process improvement project known as "DEFINE" has three steps:

1. Identify customers and "critical to quality" (CTQ) requirement that is the focus of the project. The CTQ may also be referred to as the project Y [as in Y=f(X)].

2. Create the project charter

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3. Develop a high level process map

IDENTIFICATION OF CTQ:

The project is to reduce the number of cobbles in BDM (breakdown mill, which constantly cause disturbance for rolling of billets in the mills. These cobbles obstruct the production in mills causing reduction in revenue. [15]

PROJECT CHARTER:

The typical components of project areas are:

BUSINESS CASE:

The number of cobbles occurring in the rolling mill is the direct indication of decrease in revenue. So, higher the number of cobbles in BDM, lower the revenue obtained. The calculations are:

THE NUMBER OF COBBLES IN 04-05 = 25

Taking avoidable cobbles it comes to = 15

Production loss due to these cobbles =15 *4 hrs (Avg 4hrs /cobble) = 60 Hrs

Monetary loss of 1HR delay in billet mill=4.64 Lk

Total loss annually = 60 * 4.64 = 2.78 Crores(Ap)

Total loss due to cobbles = 2.78 Crores

By reducing 25% of the avoidable cobbles the amount can be saved = 0.25 *2.78 Crores = 69.5

PROBLEM STATEMENT:

Since the cobbles are the main cause of decrease in revenue, their number should be reduced to zero. But it is not practically possible to reduce the number of cobbles to zero. There are a few causes which are unavoidable like power dips. Thus the problem statement goes as **"To maximize the production in break down mill by reducing the number of cobbles by 25%".**

SCOPE:

The project is concerned with only problems in operation of mill, but not with other problems (electrical, mechanical etc.).Operational problems means, problems like improper mill setting, guide setting, roll and wear out.

HIGH LEVEL PROCESS MAP:

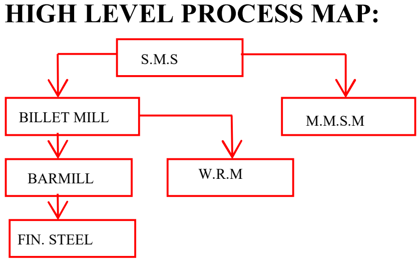

Fig.4 (a) Process mapping (high level)

The above process map shows how the steel travels from the Steel Melting Shop to the other departments. In this process there is a chance of formation of cobbles in billet mill, bar mill or Wire Rod Mill. This process chart gives us the idea where to focus our attention.

4.2. MEASURE PHASE

The purpose of the measure phase is to establish techniques for collecting data about current performance that highlight project opportunities and provide a structure for monitoring subsequent improvements. Data regarding cobbles i.e. when they were formed, the time, duration etc. are collected.

CAUSE AND EFFECT ANALYSIS

After collecting the data Cause and Effect analysis was carried out to illustrate the various causes that affect the rolling process and result in cobble. The figure 4 (b) illustrates the potential causes that could generate a failure in various processes that are being carried out in the bar mill. They were identified in a team brainstorming session.

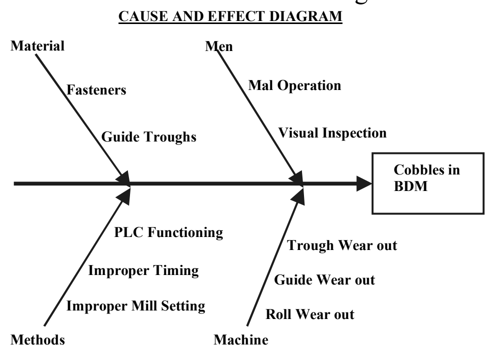

Fig.4.1 Cause & Effect diagram for cobbles in break down mill

Here roll wear out, guide wear out, trough wear out comes into mechanical problems and improper mill setting comes into operational problems and plc functioning, improper timing comes into electrical problems. So the reasons are categorized in to electrical, mechanical and operational problems and others. But among all the problems, the problem with higher priority is to be identified. So, for identifying a problem with higher priority, pareto diagram is necessary.

PARETO ANALYSIS

After collecting data, relating to cobbles, the reasons of the cobbles are categorized in to different problems such as electrical, mechanical and operational etc and number of times that type of cause is the reason for the cobble is calculated. The reason which has highest number has highest priority. Based on the different operational problems are considered and thus data related to operational problems is collected in the years. 2002-5

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DATA ANALYSIS 02-03

COBBLE ANALYSIS - BILLET MILL

Date	Shift	Location	Agency	Reason	Corrective action	Preventive action
30/6/02	C	Std 5,6,7	Oprn	Emergency stop pressed. One 32 m billet stopped at RHF entry.Two blooms were in rolling.One bloom came out and jammed in roller table.	Bar mill to communicate the problems immediately to BDM. Instructed to do slow rolling while Bar mill is taking single line.	Tilter delay timing increased to avoid faster rolling while less productive section is rolled in BM .
16/7/02	A	Std 3,4,5	Oprn	Emergency stop pressed Previous billet stopped on roller table after shear.	Pinch roll grip increased.	Billet dimensions checked and corrected to get longer billets.
14/8/02	B	Std 2&3	Oprn	Metal got lifted and failed to enter stand 3.	Stand 2 exit guide problem. Guide gap adjusted.	All other stands guide gaps checked and found OK.
17/8/02	B	Std 7,shear	Elec	Shear got closed.Position controller coupling failed.	Coupling temporarly rectified by welding.	One more coupling plate kept ready.The problem repeated on 18/8 and the coupling replaced.
24/9/02	A	Std 2,3	Oprn	Drive stopped by operator. Loop formed between 2&3. Pinch roll grip is less. Previous billet stopped on roller table after shear.	Pinch roll frame level down. Adjusted by lifting one end.	Operators instrucetd to use only emergency stop and not drive stop in such conditions.
5/1/2003	B	Std 6 &7	OPR	Std 7 roll broke.	Roll changed. Possible reason for roll failure is fire cracks.Water nozzels checked and cleaned.	Roll cooling water line and nozzles modified.
25/3/03	B	Std 5,6,7	OPRN	Metal failed to enter std 7.	The cobble has happened for the second bloom after the std 5 pass change. Cobble removed and mill setting checked.	Std 7 pass line lifted to avoid hitting.

DATE	SECTION	REASON	ACTION TAKEN
13/4/04	Oprn	Metal failed to enter std 5 Fin formed after std 4	Metal rolled in collar. Stand 4 pass line adjusted.
14/4/04	Oprn	Metal hit the std 4 guide	Spring steel head got split possibly due to metal problem or excess water
11/5/04	Oprn	Stand 4 pass change done. Metal slippage in new pass first bloom	The cobble removed and taken the next bloom after applyng more sand on pass and at lower speed.
20/6/04	Oprn	Tail stuck up at shear Next bloom coblled while cutting. Next bloom stopped at std 1& 2	The cobble removed and bend shear segment rectified.
26/7/04	Oprn	One HC billet got rolled with fin and got stuck up after std7 on the roller table. Next bloom was stopped at std 1,2. The cobble was due to emergency stop.	Cobble removed. Stand 3 pass change done. Fin formation can be due to worn out pass and soaking proble.
15/8/04	OPRN	Metal hit the entry guide frame	The guide frame heinght lifted.
20/8/04	OPRN RS&RS	Scrap dia roll . Center pass Cast steel	Roll replaced
3/9/04	Oprn	Std 7 tripped. Fin formed in billet. Overload	Stand 3 metal movement. Stand 3 pass change done.
20/9/04	Oprn	Std 7 tripped on over load. Less soaking temp of bloom.	The rolling started after a stoppage and the first bloom from fce 1 was coblled. The temp was not o.k. as the bloom was in the first row.
22/10/04	Oprn	Metal failed to enter stand 3	The stand 2 exit metal got lifted due to low temparature. It has hit the entry funnel and cobbled. Entry funnel replaced.
25/12/04	Oprn	Metal failed to enter std 3	Suspected pass line problem. Pass line setting done
18/1/05	Oprn/Qatd	Shear slow cutting	Metal sticking to shear in CAQ grade
23/1/05	Oprn	Metal liftef after 6 and hit std 7 wobbler	Std 6 exit guide setting problem.
23/1/05	Oprn	Emergency stop pressed	Operator done on panic hearing

DATA ANALYSIS 03-04

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Date	Shift	Location	Agency	Reason	Corrective action	Preventive action
7/4/03	A	Std 1,2,3	OPRN	Emergency stop	The third billet of the previous bloom stopped after shear. Emergency stop pressed for next bloom.	The third billet was short and the pinch roll was not able to push it. The billet dimensions adjusted to get more billet length and pinch roll pressure increased for better grip.
30/4/03	C	Std 3,4,5	OPRN	Stand 3 roll broke.	The roll broke due to overloading. The blooms from fce 1 were having cold spots due to skid leakage.	The furnace 1 shut down taken to arrest skid leakage.After that the load pattern is checked and found to be o.k.
28/5/03	C	Std 1,2	OPRN	Stand 1 exit guide frame came out.	Bloom has hit tje guide. The guide frame was replaced.	The guide setting was adjusted to avoid bloom hitting the guide.
6/8/2003	B,C	Std 5 , 4,3	OPRN	----- do -------	Similar cobble . Total three times. Std 5 moved out and total guide setting done. Std 4 speed variation normalised	Std 5 pass change Std 3 & 4 pass change Guide height setting done
18/11/03	B	Std 3,2	OPRN	Metal failed to enter std 3	Suspected pass line problem. Pass line setting done	Entry fixed guide replaced.
20/11/03	C	Std 7,6,5	OPRN	Emergency stop pressed	Billet jammed in roller table. The rest end kick off lever has moved to roller table and billet has hit it.	The kick off lever permantly arrested by providing mechanical stoppers.
6/1/04	A	std 6,7	OPRN	Metal lifted from std 6. Chip cutting in std 6 guide	Chip cleaning done. Std 6 guide adjusted to avoid chip cutting	Std 6 guide replaced.
12/1/04	B	std 6 ,7	OPRN	Metal hit the std 7 entry guide and got lifted. Std 7 roll broke.	Std 7 pass line adjusted.	Additional plate welded in std 7 entry funnel to prevent metal lifting.
21/2/04	B	std 7, shear	OPRN Mech	Billet hit the roller table	The roller inside the shear was in skewed position. It was adjusted	Additional channel welded in roller table to prevent billet hitting the sides.

DATA ANALYSIS 04-05

FAILURE MODE EFFECT ANALYSIS (FMEA)

Process Step/Part Number	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN
								0
1) Temperature	a)Lesser soaking	Cobble	5	Fast discharging	4	Uniform rolling rate	3	60
	b) Higher Temperature	Cobble	2	More Holding Time	3	Zone Tripping,reducing the gas	5	30
	c) Lower Temperature	Cobble	4	Thermocouple problem	3	Increasing the C.V	5	60
2)Input Bloom	a) Out of dimension	Cobble	4	CCD mould problem	3	Inspection by QATD	5	60
	b) Double pour	Cobble	2	CCD tundish/ladle change	3	Inspection by QATD	5	30
	c)Internal Pipe	Cobble	5	Casting Defect	4	Inspection by QATD	3	60
3)Mill Setting	a) Roll Gap	Cobble	3	Improper checking	3	regular checking	2	18
	b) Mill Speed adjustment	Cobble	3	Inexperience	3	checking during shut down days	3	27
	c)Compressin and Tension between stands	Cobble	4	Speed and Roll Gap	2	daily checking	4	32
	d) Guide setting	Cobble	7	setting problem	6	Inspection daily,setting on s/d days	6	252
	e) Alignment of Rolling Line	Cobble	5	Improper adjustment	6	daily checking	4	120
4)Speed	a)Uneven Speed	Cobble	3	Motor problem	5	regular checking	2	30
5)Rolls	a) Lesser Pass Life	Cobble	2	a)Material Problem	2	hardness checking	3	12
				b) Water Problem	3	daily checking of water pressure	4	24

Fig.4.2 Pareto Chart for operational problems

From the above tables the number of cobbles formed due to operational problems during the years 2002-2005 are being measured based on which the data is collected for the further steps. The Z score is calculated based on the above information.

PRESENT Z-SCORE

THE NUMBER OF COBBLES IN 04-05 = 25

Total number of avoidable cobbles till 2nd QTR = 9
Total production hours lost due to total cobbles = 9* 4 = 36 hours
Total rolling hours in the year = (21* 365)/2 = 3832.5 hours Percentage of hours not able to roll = 36/3832.5 =0.0093 %

Inverse Cumulative Distribution Function

Normal with mean = 0 and standard deviation = 1
P(X<= x) x =0.0093-2.35345 i.e Z score is **2.35**

This value is the measure of efficiency of mill in production of bars without any interruption (cobbles). So, increase in z-score indicates the increase in efficiency. This z-score can be increased by analyzing and improving the process.

4.3. ANALYZE PHASE

The purpose of analyze phase is to start learning about the data in order to generate, segment, prioritize and verify the possible root causes and their relationship to the outputs. The data collected from the measure phase serve as an input for the analysis phase.

With all the above information we move further to the analyze step where the collected data is analyzed with the help of FMEA chart and also pareto chart, cause and effect diagram etc. and improved Z score is calculated. We have seen that operational problems effect the formation of cobbles. The reasons behind it, such as mill adjustment , temperature, roll problem, human error, etc are analyzed and the problem which has highest number of occurrences is calculated and the problem with highest priority is identified from pareto chart

PARETO diagram is as above:

Form the above pareto chart we can conclude that the major problem causing area in the operational field is mill adjustment. Thus from the above pareto chart it is identified that 55% of the problem is lying with mill adjustment. So, if we check that part, 55% of the problem can be tackled and solved. The mill adjustment problem is then analyzed and various factors affecting it are taken into account. The factors are thus listed out in the form of cause and effect diagram as shown below:

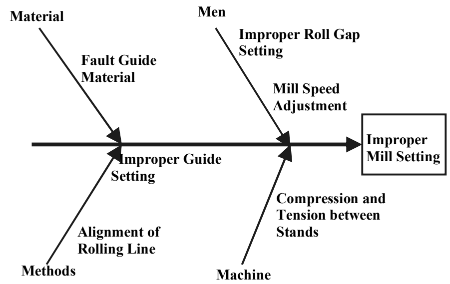

Fig. 4 .3 Cause and Effect Diagram for Improper Mill Setting

Thus various factors are dealt and various actions are recommended.

The reasons for improper mill setting are fault guide material mean that material with blows, material with less soaking. Improper guide setting mean a guide without proper alignment. Amongst all these problems a problem with high priority is identified using FMEA chart.

FAILURE ODE EFFECT ANALYSIS FMEA)

The objective of FMEA was to discover and to correct the potential problems during the earliest stages of the project and to find out potential actions to prevent them.Table.4 (a)shows the FMEA for the formation of cobbles. The FMEA reveals the potential failure modes and the corresponding effects of the processes. For each potential cause the current controls to detect and prevent the failure modes were identified and its detect ability assessed. Finally, a risk priority number (RPN) was estimated as the product of the severity, occurrence and detection to evaluate the risk of the product and the process. The failure modes with higher RPN should be solved first.

Process Step/Part Number	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN
								0
1) Temperature	a)Lesser soaking	Cobble	5	Fast discharging	4	Uniform rolling rate	3	60
	b) Higher Temperature	Cobble	2	More Holding Time	3	Zone Tripping,reducing the gas	5	30
	c) Lower Temperature	Cobble	4	Thermocouple problem	3	Increasing the C.V	5	60
2)Input Bloom	a) Out of dimension	Cobble	4	CCD mould problem	3	Inspection by QATD	5	60
	b) Double pour	Cobble	2	CCD tundish/ladle change	3	Inspection by QATD	5	30
	c)Internal Pipe	Cobble	5	Casting Defect	4	Inspection by QATD	3	60
3)Mill Setting	a) Roll Gap	Cobble	3	Improper checking	3	regular checking	2	18
	b) Mill Speed adjustment	Cobble	3	Inexperience	3	checking during shut down days	3	27
	c)Compressin and Tension between stands	Cobble	4	Speed and Roll Gap	2	daily checking	4	32
	d) Guide setting	Cobble	7	setting problem	6	Inspection daily,setting on s/d days	6	252
	e) Alignment of Rolling Line	Cobble	5	Improper adjustment	6	daily checking	4	120
4)Speed	a)Uneven Speed	Cobble	3	Motor problem	5	regular checking	2	30
5)Rolls	a) Lesser Pass Life	Cobble	2	a)Material Problem	2	hardness checking	3	12
				b) Water Problem	3	daily checking of water pressure	4	24

Table.4.4Failure mode& Effect Analysis (FMEA)

The key input variables for FMEA chart are temperature, input bloom, mill setting, speed, rolls. The potential failure modes referring to temperature are lesser soaking, higher temperature, lower temperature of bloom. If the material does not soak for recommended period or if the material is soaked more for longer period then it will cause for cobbles as the material characteristics of the bloom will change. There are also other causes such as bloom out of dimension, or any casting defects, improper speed adjustment, adjustment of roll gap, guide setting problems etc cause for cobbles. The term 'SEV' denote how severe the problem is?, 'DET' denotes the detect ability of the problem, 'OCC' denotes occurrence of the problem. So, from the above table the problem which has highest priority can be identified by identifying the problem with high RPN. A pareto chart is also drawn as following.

Fig. 4 .5 Pareto Chart for potential failure modes

4.4. IMPROVE PHASE

The improve phase has the objective of considering the causes found in the analysis phase and selecting the target solutions. At the end of the phase, the causes found should be eliminated and the improvement committed achieved. Thus various factors were considered and improvement actions were implemented as follows:

ACTIONS INITIATED IN BDM FOR "GUIDE SETTING PROBLEM"

Open entry guides before v. stands are modified to close type for avoiding material lifting.

- ✓ Base frames of guide trough between stand 3 & 4 has been replaced as guide was disturbed.
- ✓ Timely replacement of bearings and pins of swivel frames to align the guides.
- ✓ Fixed guides slide plate movement is arrested by putting addition support to ensure straight motion of material.
- ✓ Ledge block in v-stand was replaced to arrest movement of guides (to ensure proper mill setting)
- ✓ Stand –3 water line modified to prevent wear out of stand roll.
- ✓ Pass changes are done as per schedule
- ✓ More precautions are taken during pass changing and mill settings.

After the actions were taken, the data is collected again in order to find out the effects of the changes. It was from these observations, the conclusion was arrived at. From the data an improved FMEA chart is drawn and it was found that the number of cobbles was really decreased.

The improved FMEA chart is as below:

Actions Rec.	Responsibility	Actions Taken	SEV	OCC	DET	RPN
Making check sheets, recording readings, periodical replacements &checking	Site in charge BDM	Modifications on guides, pass changes are done as per schedule	7	4	5	140

R Table.4.6 Improved FMEA Chart

The chart above just shows the actions which were recommended to overcome the problems or to reduce the defects and the actions taken. We can see that the process had improved as the RPN decreased. The occurrence reduced which means the number of cobbles formed also reduced and hence the desirable results are obtained. The graph below represents the actual reduction of formation of cobbles in the break down mill in the year 2005-2006, which is really significant.

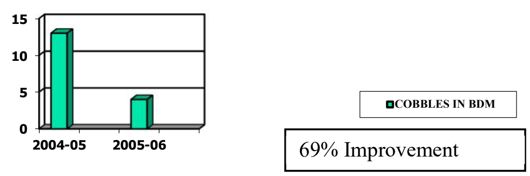

Fig.4.7Graph showing the reduction in no. of cobbles

IMPROVED Z SCORE

When it is found that the number of cobbles formed in the break down mill had reduced and that the process had improved, with the help of MINITAB software the Z score is calculated again which is called improved Z score.

Total production hours lost due to total cobbles
= 3* 4(Average)
(till 2nd QTR end 2005-06 (Operation Reasons))
= 12 hours
Total rolling hours in the year = (21* 365)/2
= 3832.5 hours
Percentage of hours not able to roll= 12/3832.5=
= 0.003%

Inverse Cumulative Distribution Function

Normal with mean = 0 and standard deviation = 1
P(X<= x) x = 0.003 -2.74778 i.e Z score is **2.75**

The Z score is became 2.75 from 2.35, which was calculated earlier. Thus the process has improved and the objective is achieved.

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4.5. CONTROL PHASE

The real challenge of Six Sigma methodology is not in making improvement of the process but in keeping the optimized results sustained. This needs standardization and constant monitoring and control of the optimized process. Thus this final phase of DMAIC methodology is to institutionalize product/process improvement and to monitor ongoing measures and actions to sustain improvement.

Now here in the control phase the actions taken were:

- ✓ Determine improved process capability:

The Z score is calculated in proper time intervals to check whether there are any changes in it.

- ✓ Implement process controls;

The following are the current controls:

1.Uniform rolling rate is maintained for having average soaking period.

2. Zone tripping and reducing gas supplied to furnace helps to lower the temperature in furnace.

3.Increasing the C.V helps in proper functioning of thermocouple ,which helps in measuring temperature accurately.

4.Regular checking of roll gaps must be done

5.Regular checking must be done to adjust mill speeds.

6.Regular checking of motor to avoid uneven speed. 7.Daily inspection and setting on shut down days to avoid guide setting problems.

The corrective actions were taken at regular intervals so that the Z score is improved or maintained.

In this phase, after regular updating of the actions recommended and taken, the process was again observed and data was collected. With this data (2007-2008), analysis was done and the Z score was calculated again.

VERIFICATION OF Z SCORE

Total production hours lost due to total cobbles = 2* 4 till 2nd QTR 2007-08 (Operation Reasons) = 8 hours Total rolling hours in the year=(21* 365)/2=3832.5hr

Percentage of hrs not able to roll= 8/3832.5=0.002%

Inverse Cumulative Distribution Function

Normal with mean = 0 and standard deviation = 1

P(X <= x) x = 0.002 -2.87816

This means that the Z score has been further improved to <u>2.878</u>

This shows that with proper implementation of solutions, which were sorted out during the process, a continuous improvement can be achieved and thus sigma value can be improved.

4.6. CONCLUSION

This chapter presents an application of DMAIC methodology within Vizag Steel Plant. It revealed how the process was applied in a step by step way and finally the objective was achieved. The success of this Six Sigma case study can be attributed to the following key factors:

1. Six Sigma methodology
2. Management involvement and commitment
3. Project selection and its link to business goals
4. Teamwork and training
5. Project progress tracking and monitoring

The company saved more than 70 lakhs per annum. Additional soft benefits were perceived, including increased process knowledge and use of statistical thinking to solve problems.

5.. INTRODUCTION

We have seen in the previous chapter about how the DMAIC methodology was applied to reduce the number of cobbles in the break down mill tackling the operational problems. The next priority goes to the electrical problems that come next to operational problems in the pareto diagram. Our interest is to apply the same procedure, following the previous steps, to reduce the opportunities that cause the electrical failures. However in this case the 'improve' and 'control' phases have not been described. Instead, after the analyze phase solutions were being suggested to the company so as to improve the process further and to obtain the desired results. The procedure contains pareto charts, cause and effect diagram, and FMEA chart to improve the process.

5.1. DEFINE PHASE

The significance and the objectives of this phase are already seen in the previous chapter. Following the same, here the problem is stated. This time electrical problems are taken into consideration.

The definition of the project is the same that is **"To reduce the number of cobbles in the break down mill.**

The project charter, business metrics and the process map remain the same in this case as it was in the previous one. Thus we can move to the next phase that is MEASURE.

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5.2. MEASURE PHASE

In this phase different data is collected and the main causes are identified. And after that the cause and effect diagram, pareto charts are also drawn with the help of MINITAB software.

The data corresponding to the years 2005-2008 are:

2005-2006

Cobble in	Reason	Duration
# 3 & # 4	Shear programme modification	4.83
# 3 & # 4	Shear programme modification	3.00
# 1 to # 2	Billet slow down on RORT Emergency pressed	1.25
#1	Fault in # 4	1.15
# 1,2,3	Cross transfer wrong strock	2.00
# 7,Shear	TACO problem	3.45

2006-07

Cobble in	Reason	Duration
Stand-3 to Twist guide	Shear got closed ,Shear motor lug got cut	2.45

2007-08

Cobble in	Reason	Duration
From # 5,6,7 & Shear	Shear tripped and made empty cuts resulting in cobble	2.45
From # 2,3,7 to Shear	Shear tripped during Head cut inBM mode and made empty cuts resulting in cobble	3.20
From # 2,3,6 to Shear	Shear tripped during Head cut inBM mode and made empty cuts resulting in cobble	4.15
From # 7 to Shear	Shear tripped during 3rd cut in WRM mode and made empty cuts resulting in cobble	3.00
From # 7 to Shear	Shear tripped during 3rd cut in WRM mode and made empty cuts resulting in cobble	3.30
From # 7 to Shear & RoRT	Shear tripped during 2nd cut in WRM mode and made empty cut resulting in cobble on roller table.	1.15
From # 7 to Shear	Shear got closed after second cut in WRM mode	2.00
From # 6 to Shear	Stand-7 got tripped after shear made three cuts in WRM mode and shear also got tripped	1.00
From # 7 to shear & from #3 to TG	Shear made slow cut during first cut in WRM mode resulting loop between shear and #7	6.15

Based on the above data the present Z score is calculated as it is an important step in the measure phase. The present Z score gives a picture of the current situation and helps in the further steps. It also helps to set a target and is thus a reference to access the progress after implementing the preventive actions taken in the later stages. Thus the present Z score is calculated as:

The number of cobbles in the year 2007-2008 = 32

The number of avoidable cobbles

(due to electrical reasons) till 2nd QTR = 11

Total production hours lost due to total cobbles = 11* 4 = 44 hours

Total rolling hours in the year = (21* 365)/2 = 3832.5 hours

Percentage of hours not able to roll = 44/3832.5= 0.0115%

Inverse Cumulative Distribution Function:

Normal with mean = 0 and standard deviation = 1

P(X<= x) x=0.0115 -2.27343 i.e that the Z score is**2.27**

So the Z score has to be improved by the Six Sigma methodology. This score will now be the reference and the end result will be compared with it so as to know the performance of the process.

5.3. ANALYZE PHASE

This phase is, as known, to study the data that was collected in the measure phase and to dig deeper into the problem. The major tools that have been used in this process are second level pareto analysis and failure mode effect analysis.Pareto analysis is to identify the area of focus i.e. to find out the major causes that lead to failures in electrical field. Similarly FMEA is to identify the potential failure modes, causes and effects. It also helps to find out the risk priority number (RPN) that confirms the reason for the failure.

The pareto chart is drawn with the help of MINITAB software as below:

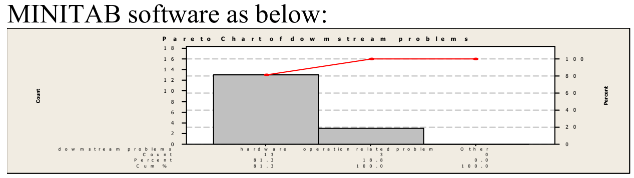

Fig. 5 .1 Pareto Chart For Downstream Problems

The hardware related problems are the problems or failure of the converters. If we look at the past data we will find that almost all the troubles were with the shear. Te next step in this phase is failure mode effect analysis. Form the pareto chart we came to know that hardware related problems and consequently from the data shear problems are the major cause for formation of cobbles. But to get even clearer picture, these factor need to be further analyzed. FMEA is thus an effective tool that reveals the high risk factor.

After studying the data, brainstorming session and close observations the FMEA chart is drawn for the electrical problems as below:

Process Step/Part Number	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN
Communication	1.improper communication	cobbles	1	poor communication skills	1	encouraging communication skills	2	2
operator responsibility	lack of decision taking ability	cobbles	2	negligence	1	awareness classes among the employees and workers	2	4
material	converter problems	cobbles	8	outdated mechanisms and machinery	9	use of analog drives	7	504
system	improper programming	cobbles	2	lack of updating	1	usage of old systems and software	2	4

Table.5 .2 Failure Mode Effect Analysis For Electrical Problems

From the above table we can conclude that it is the failure of the converters which leads to the improper shear cropping. The highest RPN is corresponding to the converter problems and they need the first attention. Converter plays an important role in the shear functioning. It converts the signals of one form to the other so that the shear crops the material at proper speed and at proper time. Thus, the effects of the converter failures and various factors that can lead to its proper functioning are analyzed in this phase.

Following are two graphs, one explaining the working of the shear when there is no failure in the process and the other showing the variation in the parameters (current, acceleration) due to which a cobble is formed.

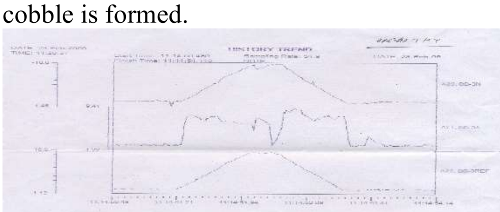

Fig. 5.3 Graph Showing The Variation Of Acceleration W.R.T Current

In the above graph, time is varied in the X-axis and acceleration and current in the Y-axis. The bottom most curves refer to the reference curve i.e. the acceleration of the shear should vary in the similar fashion when the current is varied with respect to the time. When the material enters to be cropped, current signals are given to the shear so as to increase its acceleration. Hence the speed increases to a certain value (usually 16m/s-25m/s) greater than the speed with which the material is entering. With that speed it crops the head and tail (so are they called) of the billet and retards returns to its original position. But if the converter and signaling problem persists the shear doesn't retard and come to its stationary position. Instead with the inertial force it pierces into the material again, but this time with lesser speed. As a result it is unable to crop the material and gets struck inside forming a cobble.

The graph below shows how the acceleration parameter affects the formation of cobble:

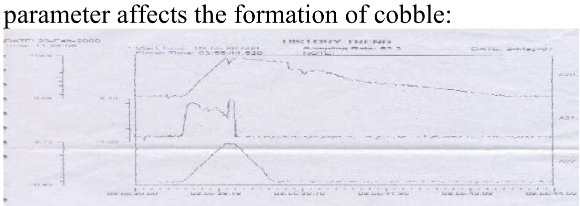

Fig. 5 .4 Graph Showing The Performance Of Shear When Cobble Is Formed

With the above analysis, some conclusions are drawn so as to improve the performance of the process and suggestions are given to reduce the number of electrical failures.This is done in detail in the next phase.

5.4. IMPROVE PHASE

This phase is an important step to implement the whole analysis to get the desired results. Generally in this phase the actions that are recommended during the analysis are highlighted and implemented and the process is checked for improvement. However, here in this phase suggestions are given to the company for the better performance.

6.. CONCLUSIONS

The project shown here is an example of the Six Sigma implementation, which has been carried out in Vizag Steel Plant. The project was targeted to customer satisfaction by improving the reliability of the process and hence the product. However here the customer is an internal one i.e. different departments within the company. While using DMAIC methodology, several tools and techniques were employed. The problem was identified as formation of cobbles in the breakdown mill. According to Six Sigma approach, the profitability should be increased by reducing the number of defects or failures. Here defects mean the factors that influence the process and may lead to failure.The first and very important step is to define the problem. It is very important because unless and until we define a certain problem we cannot take proper and planned steps to analyze it. We can never move forward with a vague idea. Thus, it is essential to define a problem very clearly.After defining the problem for the project, the data was collected about various factors regarding formation of cobbles. The more data we have, clearer will be the reasons and easier will be the analysis. The data showed the formation of cobbles due to various reasons.The next step was to categorize various factors and study them. Fishbone diagram, pareto chart proved to be helpful in this aspect. While pareto analysis it was discovered that power dips affect a lot, but they are unavoidable. Next were operational problems and electrical reasons were after them. The objective was thus to tackle the operational problems and then the electrical causes.Based on this data Z score was calculated to know the present performance and to set the target. In the analysis phase, with the help of tools like ishikava diagram, pareto analysis, FMEA, brainstorming etc. the main problem was identified to be as the failure in guide setting. Actions were recommended and were implemented to reduce the defects in guide setting and as a result the performance improved. Later the process was observed again and the data was collected for the calculation of Z score. The Z score did improve and

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the objective was thus achieved. Electrical problems were dealt with in the similar fashion, following the same steps because the definition of the problem was same. Data related to electrical problems was collected and was analyzed. The same tools were used and potential cause was identified to be as problem in the converter. Due to the converter problems the shear trip was failing resulting in cobble.

Teamwork was a fundamental element within this project. Here in the second stage of the project i.e. when the electrical faults were considered, at the improve stage, various actions were recommended and uggested to the company so that they can be implemented and the desired result, that is improvement of the Z score, is obtained.

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