Application Of Six Sigma Methodology For Reduction Of Alligator Defect Formation In Hot Rolling Industry.

Submitted By

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Abstract

Rolling is a forming operation where plastic deformation of a work piece is achieved by compressing it between two rotating rolls in the mill. It generates large surface area and therefore is useful for mass production of flat as well as shaped steel products. The paper presents a study of the different causes responsible for formation of Alligator defect in a hot rolling mill and measures to be taken to reduce the effect of these causes for improvement in the overall production of the rolling mill. The six sigma methodology was used for evaluation of various causes leading to the formation of Alligator defect, to find solutions over these problems, for improvement in production quality and enhancing mill productivity.using this method affected by providing a suitable taper at the end of the bar at the end of each pass the effectiveness of this procedure was tested by simulating the rolling process in ANSYS software,the analysis of the model revealed that by providing a taper at the end of the bar the conditions leading to alligator formation are reduced substantially.

Keywords: Hot rolling, six sigma, Alligator Defect, DMAIC,ANSYS

Introduction

Hot Rolling is the process of plastically deforming metal by passing it between rolls.The metal is subjected to high compressive stresses as a result of the friction between the rolls and the Rolling process metal surface. The initial breakdown of ingots into blooms and billets is generally done by hot-rolling. The need for the project was realized a large percentage of mill capacity is lost due to production of scrap. The financial loss associated with this waste of resources necessitates the adoption of process improvements in the mill.

Six Sigma is recognized as a problem solving method that uses quality and statistical tools for basic process improvements. Six Sigma is now widely accepted as a highly performing strategy for driving defects out of a company's quality system. Six Sigma is defined as a set of statistical tools adopted within the quality management to construct a framework for process improvement (Goh and Xie, 2004; McAdam and Evans, 2004). Statistical tools identify the main quality indicator which is the parts per million (PPM) of non-conforming products (Mitra, 2004). Achieving a Six Sigma level means having a process that generates outputs with 3.4 defective PPM(Coleman, 2008). The literature suggests the DMAIC and the design for Six Sigma (DFSS) methods as the two most common methodologies to implement Six Sigma, although according to Edgeman and Dugan (2008), the main objectives of the two techniques are quite different. While DMAIC is a problemsolving method which aims at process improvement (Pande et al., 2005), DFSS is in the context of new product development. Six Sigma-based methodology for non-formal service sectors, the framework which explores the quality need and maps them to define, measure, analyze, improve and control (DMAIC) methodology. Eisenhower (2008) used DMAIC methodology to show that quality performance data expressed as the usual percentage defect rate can be converted into a wide range of vital, Six Sigma metrics and that these can be used to develop insight into a company's quality system. The literature further shows that there are several variations for DMAIC (even if it remains the most commonly adopted methodology) such as Project- DMAIC (P-DMAIC), Enterprise-DMAIC (E-DMAIC) and DMAIC Report (DMAICR). The selection of the methodology, in the end, depends on the specific requirements. In the present work, Project-DMAIC (P-DMAIC) has been used.

The case study

The project was based in Ramson's steels and castings pvt ltd. situated in hingna MIDC area Nagpur. The concerned establishment houses two units.

1. Casting unit
2. Rolling mill

   The main products manufactured in the casting unit is ingot of various sizes. There are four induction furnaces of unknown capacity a EOT crane. The main raw materials used are scrap and sponge iron. The type casting, which is being practiced, is teeming ingot casting.

The main products manufactured in the hot rolling mill are flat bars, angle bars, channels etc.. there are two rolling mills. Each rolling mill houses 7 rolling stands out of which three are 3 high rolling mills and the rest of 4 are finishing mills. Each mill has a separate reheating furnace. The re heat furnace are coal fired and are pusher type. The main raw material used is the ingots and billets of different sizes. The mill operates in two shifts of 8 hrs each. There are approximately 200 skilled and unskilled workers in the company.

Application of six sigma.

Define phase

The objective of this phase was to clearly understand and articulate the current reality and the desired situation. A clear definition of the problem is the first step of a six sigma road map. Define phase identifies key issues and problems through both the voice of customer and the voice of business, as well as analysis of rolling process it can be said that rolling defects are the paramount defects to be reduced because it leads semi finished product to scrap.

Defining the problem

After historical data analysis and assessing the present situation, the following problems were identified for the company.

- Scale formation in inventory
- Pinholes
- Splitting of bars
- Slivers
- Scabs

Process flowchart:

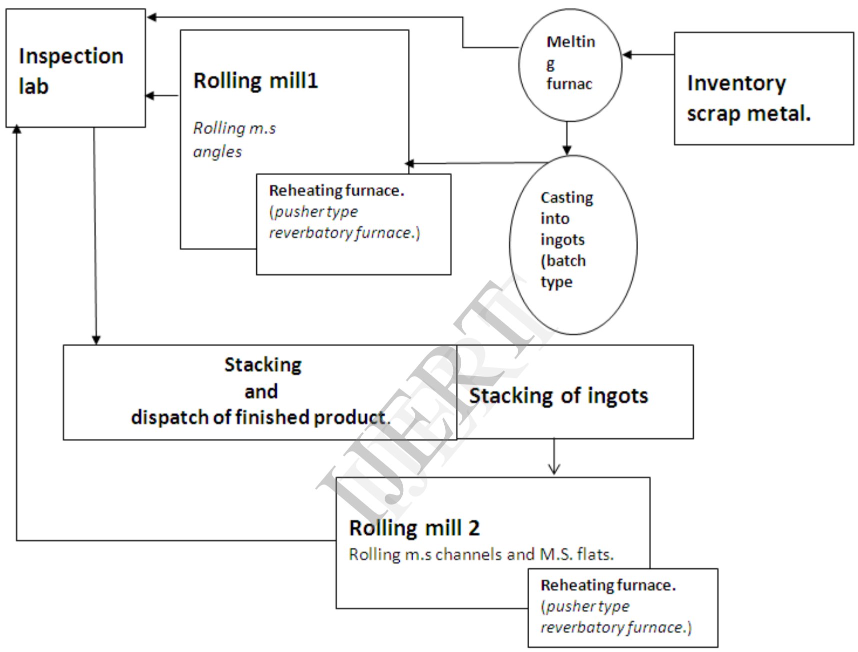


Figure 1 Process flowchart

Measure

This phase involves

1. Data collection

The reason to collect data is to identify areas where current process needs to be improved. Collection of data from three primary sources: input, process, and output. The input source is where the process is generated. Process is the functioning of the industry. Output is a measurement of efficiency.

2. Data evaluation

To evaluate how a process is working you will want to next arrive at the current base line sigma. To do this, you need to calculate the approximate number of defects. That is divided by the sum of units multiplied by the number of opportunities. The sum of this calculation is then multiplied by one million to find sigma.

Sigma level	**DPMO**	**Percent defective**
1	691,462	69%
2	308,538	31%
3	66,807	6.7%
4	6,210	0.62%
5	233	0.023%
6	**3.4**	**0.00034%**

Table 1 Performance standard for six sigma

Implementation of measure phase.

For measuring the sigma level of the company the data has been collected over three months from the industry and calculations are done in order to get the sigma level.

Month	Total production (in No. of bars)	Defectives formed (No. of bars)
August	26700	6380
September	23600	5960
October	26100	4960

Table 2 collected data

Data evaluation.

Calculate the current baseline sigma.
Total units produced in 3 months = 76400
Total defects found in 3 months = 17300
Calculations for sigma level of company:
No. of units produced = 11250
No. of defect opportunities = 4
No. of defects = 17300
Defects per unit (DPU) = defects/units produced = 17300/76400 = 0.226
Each unit manufactured has got "m" number of opportunities for nonconformance
Defect per opportunity (DPO) = DPU/m = 0.226/4 = 0.05660
Defects per million opportunities (DPMO) = DPO x 10^6 = 56610
Sigma level of company by comparing DPMO from chart = 2.9
The results of the calculation are summarized in the table below:

Parameters	**Readings for 3 month**
No. of items.	76400
No. of defectives	17300
Opportunity of defects	4
DPMO	56535
Sigma level	2.9

Table 3 Sigma level

Tools used

Pareto chart.

A Pareto diagram is similar to a histogram, but the bins show attribute data instead of measurement ranges. Also, the values plotted are arranged in descending order. This is due to Pareto Principle, which states that a small number of causes contribute to the majority of problem. The aim of the Pareto Chart is to identify these causes, so they can be eliminated later.

NO. OF ITEMS	DEFECT DUE TO ALLIGATORING	EXCESS COOLING OF BARS	ROLL FAILURE	IMPROPER HANDLING	TOTAL NO. OF DEFECTS
14600	1650	460	390	900	3400
15800	2560	560	480	700	4300
15700	2020	580	470	430	3500
14300	1970	760	530	440	3700
16000	1240	350	380	430	2400
16100	2610	680	590	620	4500

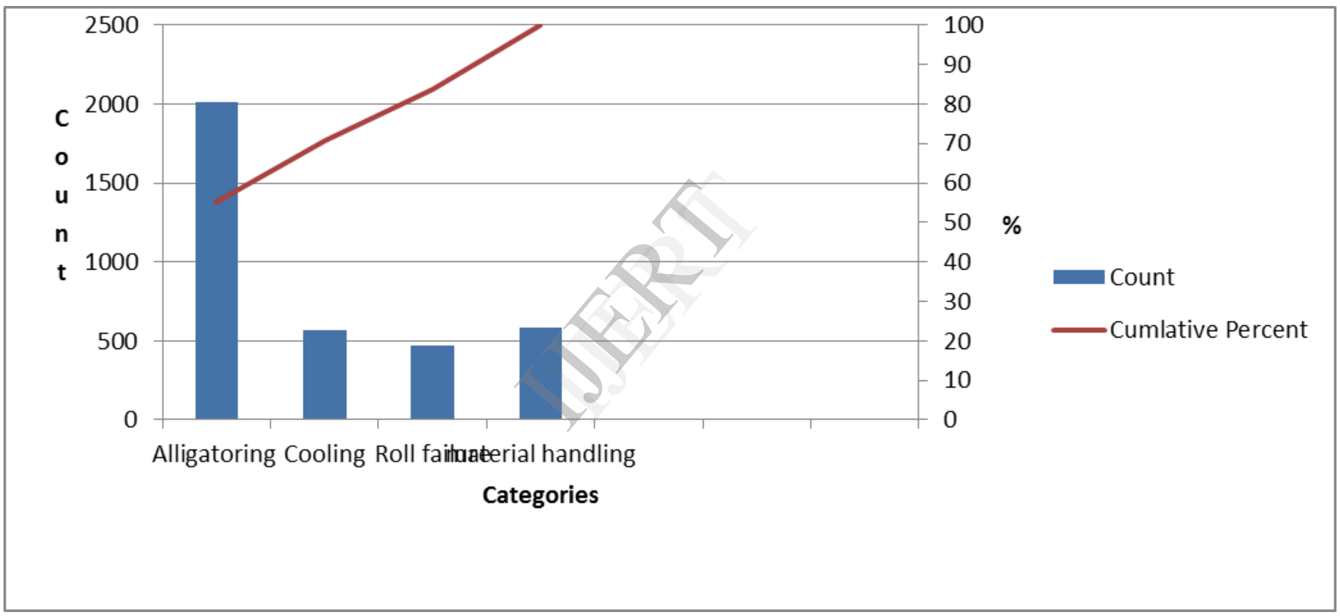


Figure 2 Pareto chart

Defining possible causes

Cause and effect analysis technique was used to identify all the causes as shown

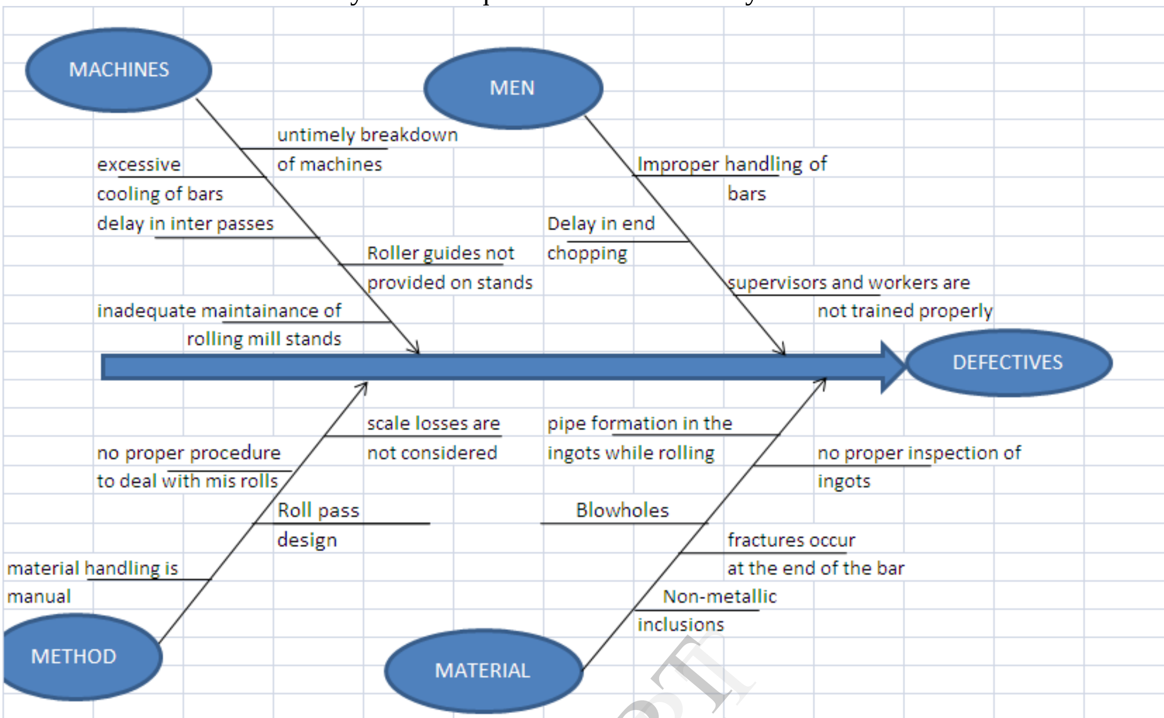


Figure 3 Fishbone diagram

Critical factors

- Critical factor 1: Fractures occur at the end of the bar (Material)
- Critical factor 2: Roll pass design (method)
- Critical factor 3: Improper handling of bars (Men)
- Critical factor 4: Proper roller guides not provided on the stands(machines)
- Critical factor 5: Excessive bending of bars (material)

Analyze

In this phase of the project the aim was to establish the base line of the project, its performance criteria by finalizing its target. Thereafter, hypothesis was established and tested to validate its contribution and finally potential causes were listed out. Finally a theory was proposed for best explanation of the problem. Thus basic steps followed under this phase were defining performance objectives, identifying variation sources and establishing process capability. In the analyze phase, different statistical tools were used.

FMEA:

The failure mode and effect analysis is done on the causes effects and failure modes with the help of benchmarking method. The severity of each problem is determined

Failure	**Mode of failure**	**Effect**	**Severity rank (S)**	**Occurrence rank (O)**	**Detection rank (D)**	**Risk priority number (SxOxD)**
splitting of bars	non-uniform stress distribution during rolling	Ingot is scrapped	5	5	4	100
Scale formation	Material oxidation	Material loss	1	2	3	6
Improper air fuel ratio	Low grade fuel	Fuel wastage	1	3	1	3
Operation control	Improper dimensions	Inaccurate sizing	1	1	3	3
Guide way blockage	Clearance problem	Mis- rolls	2	2	8	32

Table 4 FMEA worksheet for defects.

Conclusion from measure and analyze phase

From the analysis it is clear that the source of defects is the formation of spilt ends in bars (alligatoring) given the severity of the problem it is important that a effective improvement strategy be developed to reduce the formation of defects.

Centre splitting of bars (Alligator Defect)

Large ingots are reduced in cross-section by passing through rolls.After appreciable amounts of reduction involving several passes of the bar through the mill, fractures tend to occur in the ends of the bar. The fractures extend in a plane that is essentially parallel with the rolled surfaces of the bar and are centrally located between such surfaces.

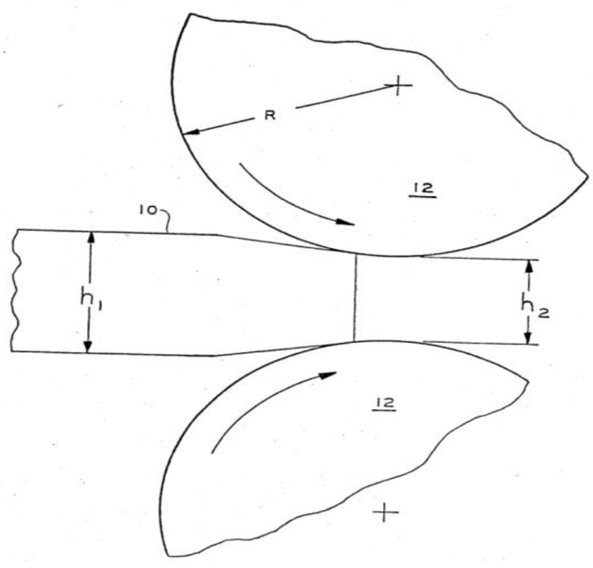
Alligator Defect, as it is known in the rolling art, may be caused by the internal stress state of the bar which results from the non-uniformity of the deformations that take place in the initial passes. As the breakdown rolling proceeds, the internal stresses are considerable and might be sufficient to open up a bar which contains either central defects or is of limited ductility.

Figure 4 Aliigator defect

Improve phase

The present study is directed to finding of certain parameters in regard to the thickness of the bar being rolled in a mill in relation to the amount of reduction in thickness taken in each pass in the breakdown process, in combination with the provision of tapered ends in the bar for each pass of the bar through the mill. The taper of the ends maintains a reduction process in an entry thickness to thickness reduction combination that is not subject to alligatoring. When the main body of the ingot is reduced in thickness, alligatoring is not a problem, as alligatoring must start at an end. In this manner, the main body can be reduced by an entry thickness to thickness reduction combination that is much higher and one that would normally produce alligatoring in the ends of the bar.

Use of improved roll pass design to reduce Alligator Defect.



Modeling and analysis of hot rolled bar.

- Software used: ansys 14 work bench.
- Type of model: 3D
- Type of analysis: 3D static structural.

Analysis of untapered bar

- Material: Mild steel
- Modeling software: Creo/parametric.
- Geometric properties:
    - Length: 6 x 10^3 mm
    - Thickness: 120 mm
    - Width: 60 mm
- Material properties:
    - mass: 100 kg
    - Density: 7680 kg/m3

Results of analysis of un-tapered bar

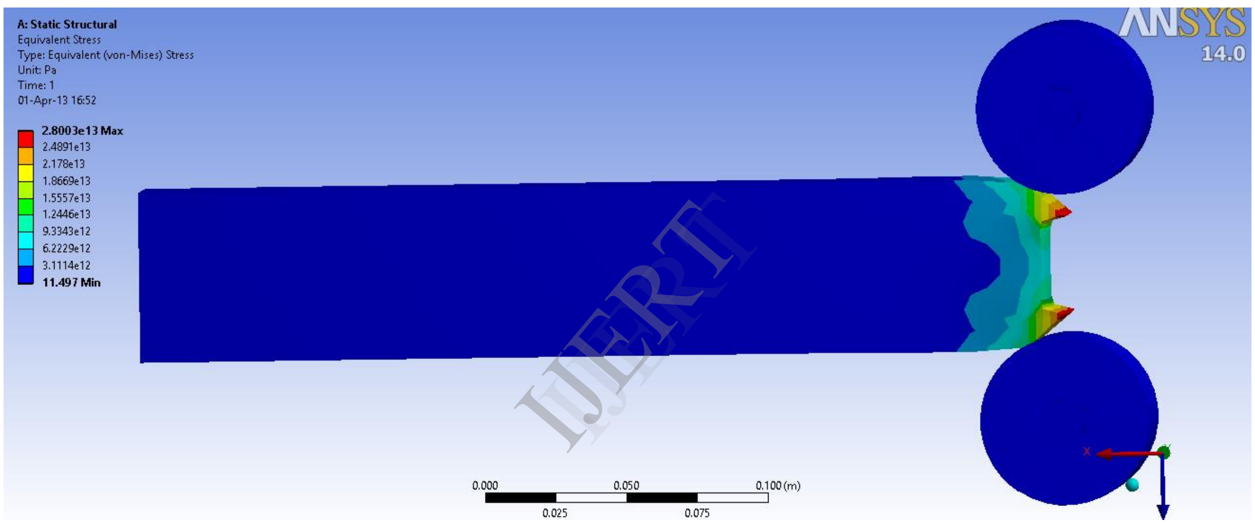


Figure 5: Stress distribution in un-tapered bar

Analysis of tapered bar

- Material: Mild steel
- Modelling software: Creo/parametric.
- Geometric properties:
    - Length: 6 x 10^3 mm
    - Thickness: 120 mm
    - Thickness of tapered end: 90 mm
    - Taper angle: 24.54^o
    - Width: 60 mm
- Material properties:
    - mass: 100 kg
    - Density: 7680 kg/m3

Results of analysis of tapered bar

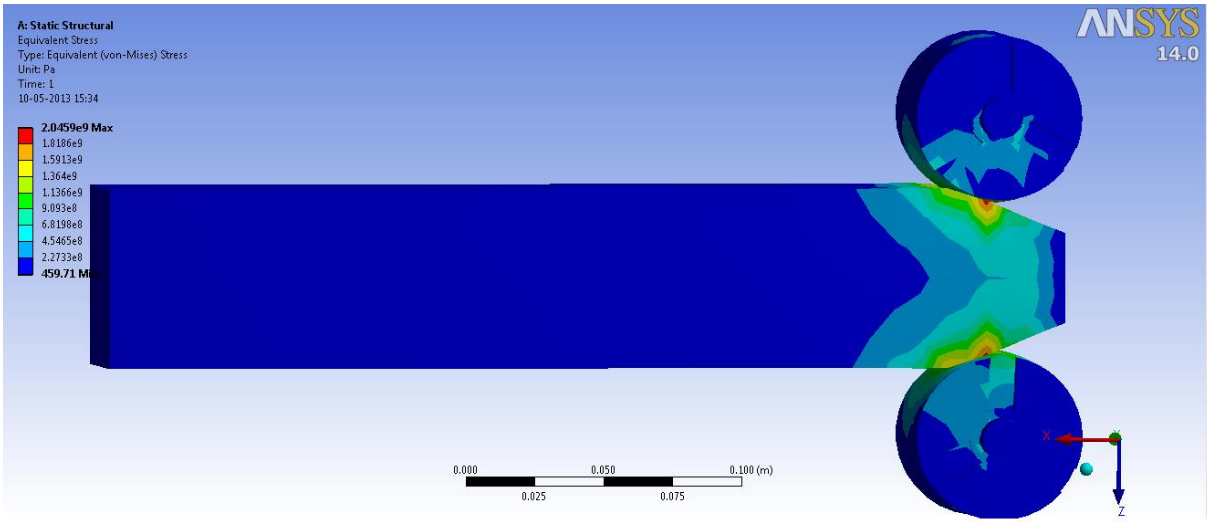


Figure 8 stress distribution in tapered bar

Conclusion from the analysis

In case of a un-tapered bar bi- directional stresses are developed on the edge of the bar increasing the chances of alligator defect formation. As the stress developed are distributed non uniformly in the region near the end of the bar.

Our assumption was that by providing a suitable taper on the edge of the bar the stress levels on the edges can be greatly reduced as the rolling does not take place on the edge due to its decreased thickness.

- Max. stress developed in the un-tapered bar = **2.8003 x 10^{18} pa.**
- Max. stress developed in the tapered bar = **1.0346 x 10^{10} pa.**

Thus we see that the stress levels in the center of the bar is reduced by a great extent by providing the taper on its ends. Therefore the chances of center splitting are minimized by providing a certain fixed combination of draft by providing a taper on the ends of the bar.

Control

The suggested root causes of these critical factors are documented and went through discussion with the management of the company. The suggested improvements are yet to be implemented, but agreed to implement. To minimize defect rates and or financial loss, control methods are needed. The solutions as presented in the above paragraphs, which includes . These control plans are only to sustain the improvements. Specifically, the safety authorities and employers are required to conduct regular inspection. Any problems found should be discussed in daily safety meetings. The authority should inspect the improvement plans on a monthly basis.

Conclusion and Results

The study shows how the six sigma methodology can be implemented in a small scale industry. It establishes the application of the DMAIC method to discrete problems on the shop floor that have large impact on the overall productivity of the company. The results of the study show that the alligator defect (split ends in the bars) was the primary cause of many problems faced by the company in the define phase various causes leading to the formation of defects were defined a process map of the company eas created to identify various input and output parameters to the process. In the measure phase the data pertaining to the number of defectives formed was collected and the sigma level of the process was calculated the impact of various sources on the defect formation was quantified and the pareto chart was prepared to pin point the most prominent cause of defects. In the analyze phase the FMEA analysis was done and the results of the analysis showed that the most prominent factor responsible for the formation of defects was alligatoring further in the improve phase the modeling and analysis of an improved roll pass design was done in the ansys software the results of the analysis showed with the new roll pass design the conditions leading to the formation of alligatoring was greatly reduced, and so by implementing the new roll pass design the sigma level of the company can be improved and the formation of scrap can be reduced.

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