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Scrap Reduction in TMT Reinforced Bar Production by the Application of Lean Techniques

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Abstract: Lean aims to eliminate the non-value-added activity which affects the cost of production along with the scrap rate Lean is often considered as a collection of tools and practices for superior operational and financial performance, through process improvement. Lean is an improvement concept for operational performance in the manufacturing environment. In this work, lean techniques are applied to the manufacturing of random rods at a leading manufacturing company of Thermo Mechanically Treated (TMT) reinforced bars to reduce the scrap. The hot billet coming from the extrusion machine is sent to the rolling mill machine where the TMT bars are produced; this consists of three stages – roughing mill, shear cutting, and programming logical controller. During the shear cut operation performed on the billet, a large amount of scrap was being generated. To reduce this scrap and the non-value-added activities, lean techniques have been applied. Also, the size of the billet was changed to produce maximum yield. With this, the scrap rate at the rolling mill machine has significantly decreased leading to a notable reduction in the cost of production.

***Index Terms**: TMT bars, shear cut operation, lean technique, scrap reduction.*

I. INTRODUCTION

Reducing waste maximizes the customer value which involves the lean technique. With this lean technique the customer value increases there by, this process is utilized by the organization with an aim to reach the Zero waste process. The primary goal of any lean system is to eliminate the waste which is directly related to lean techniques. Thus the product value is not effected by this waste or Muda. Muda or waste exists in two types as follows:

- **Type I: -**These are necessary for an end customer but they exhibit properties of non-value adding type. Because of this property it is harder to eliminate but it may still be a necessary. For an example in a car assembly during the time of quality inspection the end-customer might not view it as a value adding, but it its necessary to make sure that car meets its safety standards.
- **Type II: -**These are unnecessary for an end customer but they exhibit properties of non-value adding type. Due to this unnecessary property it contributes to waste and incur hidden costs which should be eliminated. Muda is a technique of lean to eliminate the wastage which incurs cost on production, and this is important to tackle the underlying causes of wastage and have a clear observance on every processes. A manufacturing process involves many operations that convert the raw materials to finished goods; during this, productivity may be reduced due to various types of scraps that get generated. A company with more than 4 decades of experience in the field of iron ore, manganese mining and steel which is carried out scientifically and sustainably, and has started the production of Thermo Mechanically Treated (TMT) reinforcement bars. Any production process of wire, rod and reinforcement TMT bars has a high scrap rate which is directly proportional to the cost of production as the scrap has to be reheated.

II. LITERATURE RIVIEW

The review of literature has been carried out by referring to refereed journal papers and renowned books and collated into three groups namely, TMT re-bar production, Lean tools and technique, and quality tools.

According to **Naeem Khawar [1]** The higher productivity is achieved from optimizing the manufacturing process and thereby it reduces wastage. The steel bar manufacturing industry optimized by defining it, measuring, analysing, improvement and controlling the various parameters related to productivity. After the collection of data and analysed, the analysis lead to design for significant factor is identified. Optimum levels and significant factors that affect the process yield and a methodology to optimize the steel bar manufacturing processes.

According to **Rachel L. Milford[2]** How to achieve the potential to make the existing products with minimum liquid metal usage. The Various yield ratios have been measured and case study was made to get detailed information by observation in various factories. The energy utilised in final product may be higher up to 15 times than the energy required.

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Tejas Chaudhari and Niyati Raut[3] stated that systematic waste elimination through lean manufacturing. The non-value-added activity is focused to eliminate. This paper provides the information to use the lean manufacturing techniques in nut-bolt manufacturing company. The reduction in through-put time is increased and the productivity also increased.

Alberto Simboli, Raffaella Taddeo [4] in his study presented lean manufacturing by various tools in potential synergies in integrating I&E approach on the evolutionary dynamic of manufacturing, Further the types of MUDA and systematic approach to reduce the waste is the basis for improving eco-efficiency by competitiveness.

According to **Gnieszka Grzelcza**k and **Karolina Werner-Lewandowska [5]** the last type of waste was under-utilization of the employee potential. They opined that MUDA does not interrupt working hour of employees. In according to author the lack in standardization of working time of employees, the ideal time of employees was analyzed and standardized**.**

According to **Jorge Madias [6]** During the continuous process in rolling mill, in the long products end splitting (alligatoring defect) and central bursting occurs, which effect on quality and productivity of the product and the different aspects of defects are represented.

J. C. Pandey [7] found that there are various reasons for billet cracking in hot rolling process. The various factors were analyzed and other parameter affecting the flow process noted. The appearance of cracks was associated with large surface, off-centered cracks. Thus suggestion made to prevent such defect in continuous rolling mill to eliminate spilt ends.

AtulModi, RavikantSharma, YogeshJaiswal, SukhlalMujalda, Sujeet Pratap Singh Baghel[8]The optimization of energy and cost also increased the efficiency of rolling mill plant. The new developed hot charging system and analyzed critically. The pollution was also controlled by using optimization strategy, which is essential as per norms. Manufacturing organization is to work in robust condition and the efficiency to be increased.

According to **R S Nalawade, V R Marje, G Balachandran and V Balasubramanian [9]** with the use of Finite Element Matrix(FEM) model the deformation behavior of grade 38MnVS6 hot rolled micro-alloyed steel bar was examined. Blooming mill involves the initial process which acts as a function of three different passes schedules which include collar tape angle, groove roll depth, and corner radius.

Zygmunt Wusatowski [10] it provides an overview to the principal methods of rolling**.** It includes three principal methods such as longitudinal process, transverse process, and skew rolling process. According to the overview there is a distribution of constrained yield stress along the gap due to the hardening of work on cold rolling between ideally smooth rolls.

III. PROCESS DESCRIPTION

TMT bar production process involves roughing mill operation, intermediate mill and finishing mill operation, the flow chart for TMT bar production is shown in figure 1. In the roughing mill, the billet size is reduced from 160*160 sq. mt. cross-sections to (48*48) sq. mt. This is conducted by passing the billet through rollers in 5 passes. After this intermediate mill is carried out, in which shear cut operation is performed. Here, the rod will be cut at its head and tail ends to eliminate the alligatoring defect. In the intermediate mill, the cross-section of 48*48sqmt rod diameter is reduced to sizes of 8,10,12,16,20,25 and 32 mm, according to requirements are sent Thermax where it is quenched in water. These rods are now quenched in water medium and their length is reduced to 60-Meter during the finishing mill. After this, the rods are sent to the cooling bed, where they are cooled to atmospheric temperature. After this, depending on customer requirements the rod length is reduced to 12-Meter. These TMT bars are sent to bundling and ready to use.

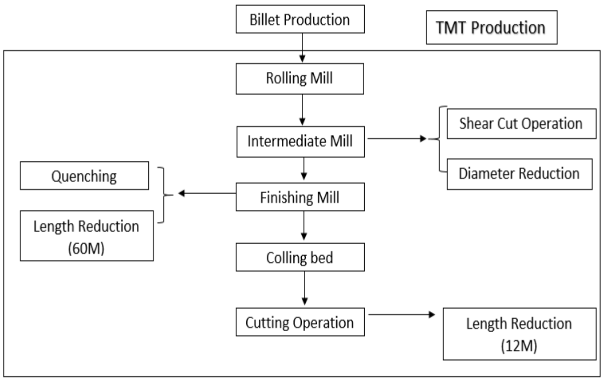

Figure 3.1: Flow chart for TMT bar production

IV. PROBLEMS BACKGROUND

During shear cut operation, the rod is cut at its head and tail ends to eliminate alligatoring defect. For this, a length of 4 inches has been specified to be cut at both the end of the rod. When a sample of 50 rods was measured, it was found that in all the rods in the sample, an excess length of 4-8 inches was cut at both the ends. Due to excess cut, the scrap of 160 ton/month is generated, which is very high. Also, the required number of rods are not being produced i.e. about 30% deviation from the required product is absorbed.

After finishing mill operation, a sample of 1m TMT re-bar is checked for its weight, which should adhere to BIS, as shown in the below table 4.1

Table 4.1: The weight of 1-meter TMT bar as per BIS

Section weight chart			
Size (mm)	Section weight (kg)		Number of pcs/bundle
	min	max	
8mm	0.37	0.38	10
10mm	0.58	0.59	7
12mm	0.85	0.86	5
16mm	1.51	1.54	3
20mm	2.4	2.42	2

25mm	3.75	3.8	1
32mm	6.15	6.25	1

Amongst these different section rods, 8mm and 10mm diameter rods are not meeting the required number in each bundle. For 8mm diameter rod 10 units of production are expected whereas the actual production is, on an average only 7 and for 10mm diameter rod the actual production is 5 units against the expected number of 7. This can be traced to the wrong selection of billet size which happens initially.The excess cut that happens during shear cut operation coupled with the selection of wrong billet size, which becomes visible during finishing mill, leads to the generation of random rods. During the cutting operation, the 60-Meter rod is into bars of 12-Meter each. If the length of the rod is exceeding or falling short of 60-Meter, it would result in small bars of 4-5 meters. These bars are called random (scrap) rods/bars. These bars cannot be used for construction purpose and hence is treated as scrap. The total scarp production during the TMT bar production on an average 6% per month.

V. OBJECTIVE

This paper aims to:

1. Reduce the scrap generated during the TMT re-bar production.
2. Determine the right size billet selection, to minimize the scrap during the cutting operation.

VI. METHODOLOGY

The data regarding scrap generation was collected it was noted that three types of scrap get produced:

i. Ends cuts (formed during shear cut operation)
ii. Cobbles (formed during intermediate mill)
iii. Random rods (formed during cutting operation)

The three types of scrap were analyzed for possible causes using the MUDA concept of lean technique. The end cuts formed while cutting off the split ends of the rods. This was attributed to the wrong PLC settings on the cobble shearing machine. This has been set right by programming the correct cutting length into the PLC with this, the scrap percentage in shear cuts operation 100 ton/month The cobbles formed due to various reasons during intermediate mill operation are analyzed and the scrap due to cobbles is about 100ton/month. Design of experiment has been applied to reduce the cobbles production. Table 6.1 shows the control factors and levels considered for experimentation.

Table 6.1: Control factors and the levels

Symbol	Control Factors	Levels		
		1	2	3
A	Conveyor speed (m/s)	18	22	25
B	The gap between the pressing rolls (mm)	9	10	11
C	Number of strands	10	12	14

Based on the number of control factors and their levels, Taguchi's L9 Orthogonal array has been selected for experimentation, and shown in the table 6.2

Table 6.2: L9 orthogonal array

L9(3^4) Orthogonal array					
	Independent variables				Performance Parameter value
Experiments	Variable 1	Variable 2	Variable 3	Variable 4	
1	1	1	1	1	P^1
2	1	2	2	2	P^2
3	1	3	3	3	P^3
4	2	1	2	3	P^4
5	2	2	3	1	P^5
6	2	3	1	2	P^6
7	3	1	3	2	P^7
8	3	2	1	3	P^8
9	3	3	2	1	P^9

VII. EXPERIMENTATION AND DATA ANALYSIS

From the SN ratio graph shown in S/N analysis in Graph optimum level is identified. As shown in below table 7.1

Experiments are conducted as per L90A. All the trails were carried out on 100 tonnes of bars on intermediate mill operation and the weight of cobbles in each trial is noted and presented in table 7.1

Table 7.1: DOE to find an optimum value

A	B	C	weight of cobbles in tons	Signal-to-Noise Ratio (dB)
18	9	10	3.9	-11.8213
18	10	12	2.8	-8.9432
18	11	14	4.5	-13.0643
22	9	12	3.4	-10.6296
22	10	14	3.7	-11.364
22	11	10	4.2	-12.465
25	9	14	4	-12.0412
25	10	10	3.2	-10.103
25	11	12	4.4	-12.8691

From the experimental results S/N ratio values are calculated using Taguchi's smaller the better case. The formula for this is:

$$S/N\ ratio = -10 * \log(\Sigma(Y^2)/n))$$

The S/N ratio for each control factor and level combination is presented in table 7.2.

Table 7.2: signal to noise ratio for factor-level combination

Level	A	B	C
1	**-11.28**	-11.5	-11.46
2	-11.49	**-10.14**	**-10.81**
3	-11.67	-12.8	-12.16
Delta	0.39	2.66	1.34
Rank	3	1	2

From this table optimum levels for control factors are identified. This is presented in table 7.3

Table 7.3: The optimum values for control factor

Symbol	Factor	Optimum level	Optimum value
A	Speed of conveyor (m/s)	**1**	18 m/s
B	Gap between the roller (mm)	**2**	9 mm
C	Number of strands	**2**	12

The intermediate mill has been conducted with by keeping the factors at their best levels and the scrap has been reduced from100 tons/month to 80ton/month.The third type of scrap is the generation of random rods, formed during cutting operation This issue in TMT production of 8 and 10 mm diameter rods was due to two main reasons:

1.Shear cut at random lengths.

2.Mis-calculation of billet length.

For shear cut at random length problem a sample of 50 rods was checked for the length of alligatoring defect occurred and it was found that on an average the alligatoring defect was 2.9 inches at both the ends of the rod, but shear cut was made at 11inches, leading to extra cut of about 7inches. To avoid these changes were made in the PLC setting and ensured 4 inches cut in the case of alligatoring defect.

To avoid the miscalculation of billet size 8mm dia bars are considered, these rods had 9% of random rods generated due to wrong calculation of billet size.

Billet length calculation for 8mm diameter bar:

Length = 4.30 meter

Weight of billet = 383.35 kg

Weight /1mt length as per BIS for 8mm from table 1=0.370 weight

We would need length of 60 meter = weight * length (60)

= 0.370 * 60

Weight for 8mm = 22.2 kg

Number of rods in 1 billet = 383.35/22.2 =17.2.

where 17 is the number of bars obtained and 0.2% is the random rod generated. With the revised calculation, the % of random rods is reduced from 9% to 0.2%. The rectified billet calculation for 8mm and10mm is shown in table 7.4

Table 7.4: Rectified billet calculation for 8 and 10 mm dia rods

Sl.no	TMT bar Diameter in mm	Billet length in meter. (rectified)	# of rods produced from 1 billet
1	8mm	4.3mt	17
2	10mm	4.3mt	11

VIII. RESULT

Based on the above experimentation, it is clear that the rate of scrap production was reduced and another alternate solution was provided to decrease the scrap production using the MUDA concept of lean techniques. The overall scarp produced from different operations is reduced to 4%. The scrap reduced at different stages is shown in table 8.1

Table 8.1: Scrap reduction at different stages

Sl. no	Name of the operation	% of scrap (prior)	Steps taken	% of scrap (after)
1.	Shear cut	2.6	Corrected PLC setting	1.6
2.	Cobbles (mis-roll)	1.66	Carried out Design of experiment	1.3
3.	Billet Length calculation	2.3	Rectified length of Billet	1.2

IX. CONCLUSION

The different types of scrap produced in the TMT bar production was affecting productivity which lead to increase in cost production of TMT. Accordingly, the work had been carried out by collecting the data and analyzing it, different methodology is used for different scrap generation. The overall scrap generation was 6% which is more than any industry. Eliminating this non value adding activity the rate of scrap production was reduced. Based on this concept the overall percentage of scrap production was reduced to 4% which is important for any leading company in the steel sector. This concept of wastage elimination is the MUDA concept of lean technique.

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