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Improving Productivity on a Grinding Line through 'Small & Large' Improvements

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Abstract - *In practice, small improvements (kaizen, continuous improvement) and large improvements (process reengineering) always complement each other. To effect any such improvements to enhance the effectiveness of a process/system, it is usually recommended to begin with streamlining the processes (small improvements - to reap that low hanging fruits first) followed with rapid improvements (process reengineering). This work is also the manifestation of the above principle. It proposes a systematic procedure in enhancing the productivity of a grinding line by initially optimizing the present process through minor improvements. This was followed with a radical change proposed in the form of new tooling design. Sustenance of improvements can be ensured through standardized work. The improvements effected were implemented with the help of standard operating procedures (SOPs). Thus, this work addresses a full-fledged productivity improvement work in its entirety supplemented by guidelines of International Labour Office (ILO), Geneva.*

***Key Words*: Kaizen, Flow Process Chart, Overall Equipment Effectiveness, International Labour Office, Maynard's Operations Sequence Technique, Standardization, Multiple Activity Chart.**

1. INTRODUCTION

According to the emerging field of Lean Six Sigma, in order to enhance the effectiveness of a particular machine or a system, it is recommended to begin with streamlining the processes and Rapid Improvement Events as this gets the operation in good order. Further, the chronic problems would be easier to deal with, and as it is said that "Low Hanging Fruit" would be easily eaten by executing radical changes. This paper is the manifestation of the above principle. The work consists of a systematic procedure in enhancing the productivity of a grinding line. This was done by initially optimizing the present process by making a minor investment. Then, a radical change was proposed by new tooling design in order to experience a lucrative improvement in productivity of the line. Further, in order to comply with "the change" proposed above, some more changes in the manual "standard operating procedure" (SOP) were proposed. Thus, this work addressed a full-fledged productivity improvement project in its entirety on the guidelines of International Labour Office (ILO), Geneva.

1.1 Literature Review

According to the book World Class Manufacturing[1], most manufacturing companies are now experiencing rapid and continuous change in their business environment, which can be identified in terms of product change and/or in terms of process change (Luftman 1996). These two types of change can be classified as either stable or dynamic. Stable change is slow, evolutionary and generally predictable, while dynamic change is rapid, often revolutionary and generally unpredictable. Taken together, these two types of changes provide a matrix of four possible combinations of 'change conditions' that can confront an organization. The matrix combinations and the relevant manufacturing strategies are described below in fig 1.

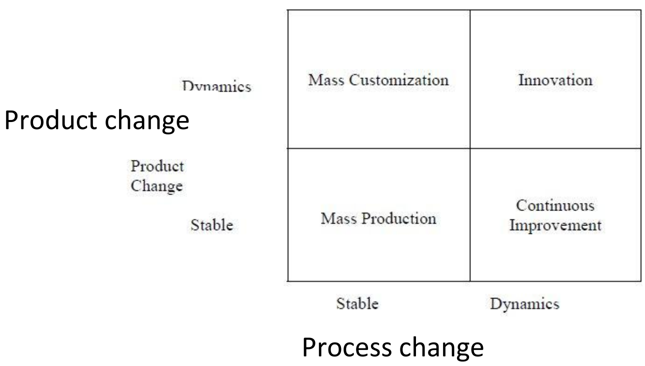


Fig-1: Manufacturing strategies for change [1]

Dynamic Product and Process Change: Innovation Strategy
The focus of innovation strategy is to frequently create small volumes of new products, while constantly innovating the processes required to develop and produce them.
Stable Product and Process Change: Mass Production Strategy
This strategy permits to standardize products, centralize decision-making, routinise work and reward, develop and enforce standard rules and procedures, and allocate work to

dedicated, specialized jobs i.e. to mass-produce goods or services.

Dynamic Product Change, Stable Process Change: Mass Customization Strategy

Organizations in a number of industries are facing customers making increasingly unique and unpredictable product demands. However, the basic processes that these companies are instituting to meet these demands soon evolve into identifiable patterns enabling them to build stable but flexible platforms of process capabilities.

Stable Product and Dynamic Process Change: Continuous Improvement Strategy

Continuous improvement is followed in some industries, such as automobiles and machine tools, where the nature of product demand is still relatively mature, stable, large and homogeneous. (In this paper, continuous improvement strategy is taken into consideration).

But the competition in the industries adopting this strategy is based on dynamic process terms, i.e. the organizations are competing by achieving constant improvement in process quality, speed and cost. The focus of organizations in these industries is on customer satisfaction through process improvement. As opposed to mass production firms, they are very customer- or market focused, striving to better satisfy the market as a whole through continuous process improvement. These organizations manage rapid innovation and the use of new process capabilities and, therefore, require systems and structures that facilitate long-term organizational learning about products but simultaneously achieving radical changes in the processes. To make process innovation efficient, these organizations employ cross-functional teams that collaborate to improve processes or plan for product enhancement. The members of these teams then turn to their function-specific work and execute the rules they just developed, accomplishing a sort of micro transformation. In this sense, the teams of continuous improvement firms need to be as process-innovative as 'invention' organizations, and as process-efficient as 'mass production' firms.

According to Laura Costa Maia et al [2], to achieve Lean Manufacturing benefits, a continuous improvement effort must be formally implemented. They explore TRIZ as a tool that could be helpful during Lean implementation, in particular, during the continuous improvement process efforts. Denis A. Coelho [3] describes the principle of TRIZ given by Altshuller which states that only a small proportion of the patents have somewhat inventive solutions; while the rest are straight forward improvements. Altshuller found that, often, the same problems had been solved over and over again using only one of forty fundamental inventive principles. Thus, according to Laura Costa Maia et al [2], TRIZ addresses any continuous improvement problem by addressing a database of causes/effects built based on experiences from others.

Stage 1 of this paper attempts to address the continuous improvement strategy by taking care of the above principles. The paper also addresses the concept of Overall Equipment Effectiveness (OEE).

OEE is an internationally accepted measure of the effectiveness of a piece of equipment during planned production i.e. it measures how effective a piece of equipment is at adding value to the manufacturing process.

A particular "Theoretical Production Time‟ is divided into two components viz. the planned production time and the planned downtime. The "planned downtime‟ is strategically kept aside for mandatory activities like preventive maintenance, measurement, etc. The remaining „planned production time‟ has two more components in it viz. unplanned downtime e.g. equipment breakdown, setup/adjustment, etc. and the remaining time is the "gross operating time‟. But, due to working inefficiencies i.e. reduced working speed due to "unknown" reasons, minor "unavoidable" component of idle time, the "gross operating time‟ further shrinks and the remnant is termed as "net operating time‟. Further, if some nonconformities in the final product or service are detected then the time elapsed for operating on the prospective non-conforming product becomes a waste which is termed as "quality loss‟. And, the remainder is the "final operating time‟. Thus, intrinsically, actual effectiveness of particular equipment is much less than what is perceived extrinsically.

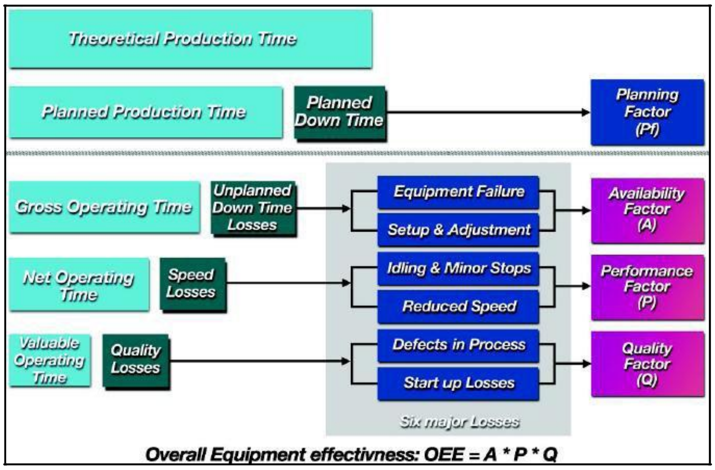


Fig-2: Concept of Overall Equipment Effectiveness [4]

It is calculated as a product of availability factor (A), performance factor (P) and Quality factor (Q) as shown in the figure (2). Losses such as equipment failure and setup/adjustment are taken care by the availability factor, losses such as idling/minor stops and reduced speed are taken care by the performance factor. And quality factor takes care of defects in process and start up losses. In this way, the actual effectiveness of equipment is calculated.

Availability factor

= (planned production time – downtime)/planned production time

Performance factor
= (theoretical cycle time * processed no. of units)/gross operating time

Quality factor
= (processed no. of units – defective units)/processed no. of units.

In the stage 2 of this paper, the OEE of the grinding machine is enhanced by working on the performance factor, specifically by working the "reduced speed" loss.

Thus, this paper addresses the continuous improvement strategy in the form of "small" improvements by using core Industrial Engineering "pearls" such as method study, setup time optimization, standardization and Kaizen. On the other hand, "large" improvements are addressed in the form of enhancement of the overall equipment effectiveness (OEE) and change in the conceptual design in the fixture.

2. METHODOLOGY

A grinding machine, at a grinding shop, was used for maintaining the specified length of the ferrite bar (the product). It was a single spindle machine with a grinding feed around 400mm/min. As the machine proved to be a bottleneck, it was attempted to execute a productivity improvement project for the same. The machine involved use of a fixture which used to be loaded with ferrite bars and would get processed through the grinding chamber.

2.1 Rationale for increasing grinding feed

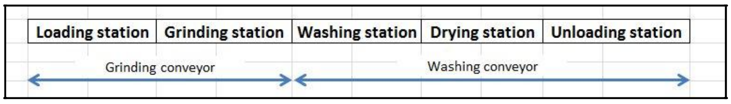


Fig - 3: Details of the grinding line

The grinding line had 5 stations viz. manual loading station, grinding station, washing station, drying station and manual unloading station. All the stations were connected by two conveyors viz. grinding conveyor and washing conveyor as shown in the fig 3.
The speed of the grinding conveyor i.e. grinding feed was found to be 400 mm/min and the speed of the washing conveyor was 1319 mm/min. From time study through video analysis, it was revealed that for every 46.67s, there was a supply of 47 bars from grinding conveyor onto the washer conveyor (for every 46.67s, the bars come in a batch of 47). On the other hand, at the unloading side, for every 46.67s, 44.93 bars were picked. Thus, the supply rate was 10.07 bars/10s and the picking rate was 9.62 bars/10s. Thus, if picking speed was increased by implementing the Kaizen proposed in the paper then it was inferred that the supply rate from the grinding conveyor to the washing conveyor should also be increased. For this, either speed of the grinding conveyor should be increased or the capacity (no. of ferrite bars) of the present fixture which is used for length grinding should be increased. The present capacity was 47 bars. For increasing the speed of the grinding conveyor, it was inferred that the speed of loading

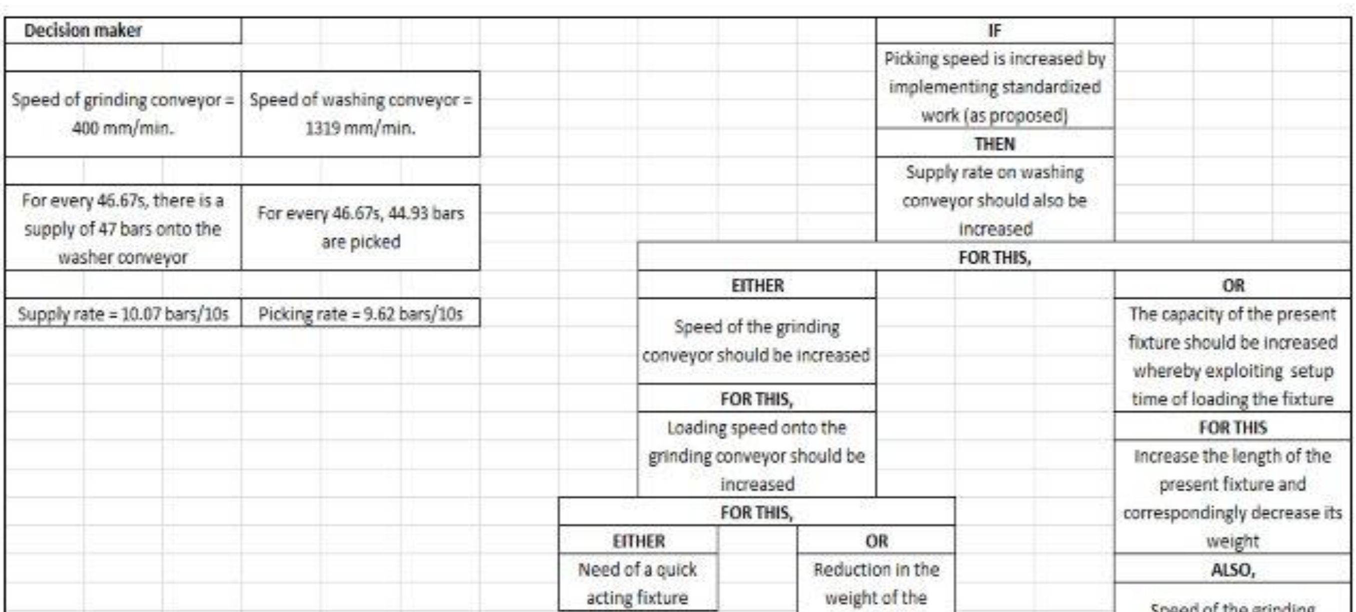


Fig – 4: Decision making logic for Kaizen at LA 1 grinding line

(which was manual) should be increased. For this, the weight of the present loading fixture should be reduced or fixture should be made quick-acting. On the other hand, to increase the capacity of the present fixture, it was required that the length of the fixture should be increased by corresponding decrease in the weight.
Consider the following decision making logic for the Kaizen proposed in the work for the grinding line as shown in fig - 4. Thus, the entire work was executed in 3 stages. Stage 1 took care of the manufacturing losses which involved optimum utilization of the setup time and reduction in air-cutting time i.e. optimal increase in the capacity of the present fixture per setup. On the other hand, stage 2 aspired for increase in the grinding productivity of the machine i.e. the grinding feed. At last, stage 3 took care of increasing the manual working productivity of unloading activity i.e. the manual picking activity.

3. RESULTS AND DISCUSSION

3.1. Stage 1: Optimum utilization of the setup time of the loading fixture

3.1.1 Summary:
From the flow process chart (fig – 5) of the loading activity, it was revealed that the time required for some work elements

FLOW PROCESS CHART

Plant: FCG grinding
Charted by: Amit — Sheet
☐ Man or ☑ Material
Chart begins
Chart ends

Summary	Present No.	Present Time	Proposed No.	Proposed Time	Difference No.	Difference Time
Operations	1					
Handlings	11					
Transportations	10					
Inspections	0					
Delays	0					
Storages	1					
Distance Traveled						

Details of Method: ☐ Present ☐ Proposed

No.	Details of Method		Quantity	Time	Notes	VA/NVA	
	First side of the bar						
1.	Grasp the fixture		1	0.082	Fixed loading time	NVA	
2.	Place the fixture on the table		1	1.67		NVA	Can be eliminated
3.	Place the part 1 of the fixture on the conveyor belt		1	1.67		NVA	Can be combined
4.	Travel towards the tray to grasp the stacked bars		0	1.87		NVA	
5.	Grasp the stacked bars		47	0.5		NVA	
6.	Travel towards the part 1 of the fixture placed on the conveyor		47	2.31		NVA	
7	Position the bars in the part 1 of the fixture		47	12.55		NVA	
8.	Travel towards the part 2 of the fixture placed on the table		0	1.22		NVA	
9.	Grasp the part 2 of the fixture		0	0.082		NVA	
10.	Travel the part 2 of the fixture towards the part 1 placed on the conveyor		1	0.96		NVA	
11.	Position the part 2 of the fixture with the part 1 placed on the conveyor and foolproof the entire assemby of fixture and bars		1	10.03		NVA	
12.	Fixture abondoned	Travel in	1	36.66	Variable grinding time	NVA	
13.		Inside grinding chamber	1	134.74		VA	
14.		Travel out	1	38		NVA	
15.	Travel the hand towards ground bars		1	1.29	Fixed unloading time	NVA	Can be combined
16.	Grasp the ground bars		47	3.92		NVA	
17.	Travel the ground bars towards the tray		47	3.21		NVA	
18.	Place the ground bars in the tray		47	5.53		NVA	
19.	Travel towards the fixture placed on the conveyor		0	1.12		NVA	
20.	Grasp the fixture		1	0.082		NVA	
21.	Unload the fixture and keep it in the tray		1	2.16		NVA	
	Total			259.66	4min. 20sec		

Fig – 5: Flow process chart for length grinding and its analysis

(motions) was the function of total number of ferrite bars. This could be termed as 'variable activity time'. Remaining work elements represented the 'fixed activity time'. Thus, the total loading activity was the sum of the 'variable activity time' and 'fixed activity time'. In the present case, 47 ferrite bars were loaded in the fixture. Thus, in the proposed case, if this number was increased then the fixed time for loading and unloading activities could be exploited.
Fig - 5 (flow process chart) explains the actual loading activity for length grinding at the line. From the flow process chart, it was revealed that the time of the activities 12, 13 and 14 were the function of total number of ferrite bars. The other activities were fixed to some extent. In the present case, 47 bars were loaded in the fixture. It was inferred that if this number was increased then the fixed time of loading and unloading could be exploited.

This is explained by the following example.
Fig - 6 shows the length grinding time of a single set of 47 bars. The 'fixed time for length grinding' is the sum of all the yellow colored cells in the flow process chart.

'Variable time for length grinding (per bar)' = Variable grinding time/47.

Thus, the total time = 'Fixed time for length grinding' + 'Variable time for length grinding*47'.

The total time, as shown in fig - 6, matches with that of the flow process chart. On the contrary, as shown in the figure 7, if 84 ferrite bars were to be processed in the same setup then the total time would be 424.476s. But, in the present case, to process 84 bars, two setups were required and hence the total time was 519.282s. (259.641*2) Thus, the difference can be detected.

Component	Time (in seconds)	
Fixed time for length grinding	50.256	
Variable time for length grinding (Per bar)	4.455	
Total Time for length grinding (Per bar)	54.711	x↓
Total Time (x bars)	259.641	47

Fig-6: Snapshot of the calculations for total cycle time of 47 bars

Component	Time (in seconds)	
Fixed time for length grinding	50.256	
Variable time for length grinding (Per bar)	4.455	
Total Time for length grinding (Per bar)	54.711	x↓
Total Time (x bars)	424.476	84

Fig-7: Snapshot of the calculations for total cycle time of 84 bars (exaggerated case)

Therefore, in the proposed change of the fixture, the length of the fixture was increased. With this design, 10 more ferrite bars (of 5mm. thickness) were added in each setup. This was the optimum number as further increase in the length would lead to increase in the weight of the fixture leading to operator fatigue. Also, in the flow process chart (fig - 5), it was pointed out that the activities 3 to 7 and 15 to 21, which were non-value adding activities, could be combined by providing a magnetic surface to any one part of the fixture. The change in the fixture design was accepted. The fixture, presently, is in use. Fig.-8 shows the snapshot of the productivity improvement calculations:

3.1.2 Results

Parameter	Before Improvement	After Improvement
No. of ferrite bars per fixture	47	57
Fixture length	290mm.	340mm.
Conveyor length utilized by fixtures	1450mm.	1550mm.
No. of fixture trips (for a particular time)	500	455
No. of ferrite bars processed (for a particular time)	23500	25935
Productivity Improvement	**10.36**	**%**

Fig – 8: Snapshot of the quantified improvements

3.2 Stage 2: Increase in the Overall Equipment Effectiveness (OEE) of the machine

As discussed earlier that the OEE of the machine considered was enhanced by increasing the performance factor of the machine, specifically by working on the "reduced speed" loss. This was done by changing the design of the fixture in order to increase the grinding feed of the machine.

3.2.1 Principle
According to a book published by International Labour Office (ILO) [5], Geneva named 'Introduction to Work Study', Decoupling of worker/machine systems, that is, freedom from being tied to a machine during the entire working day can lead to 3 specific results:
1) Elimination of waiting time/slow speed of the machine because an operative works at a different speed from the overall speed of the technical process. 2) Elimination of waiting time of the operative because he/she is forced to wait while a machine does its part of the work. 3) Increased job satisfaction.

3.2.2 Present case
With reference to this principle, design of the fixture was required to be changed. In the present case, the loading activity at the grinding machine was online i.e. the loading activity was done on a moving conveyor. This can be seen in the figure (9) and its flow process chart in the figure (5). As a result, the speed of the moving conveyor was driven by the speed of manual loading activity i.e. the speed of the conveyor was bound to be kept slow in order to match with the manual loading activity speed. And the speed of the conveyor was nothing but the grinding feed of the machine. This hampered the grinding productivity of the machine.
On the operator's side (both loading and unloading operator), it resulted fatigue, as the operator had to match with the "legitimately" designed machine speed and moreover was continuously tied with the machine. This

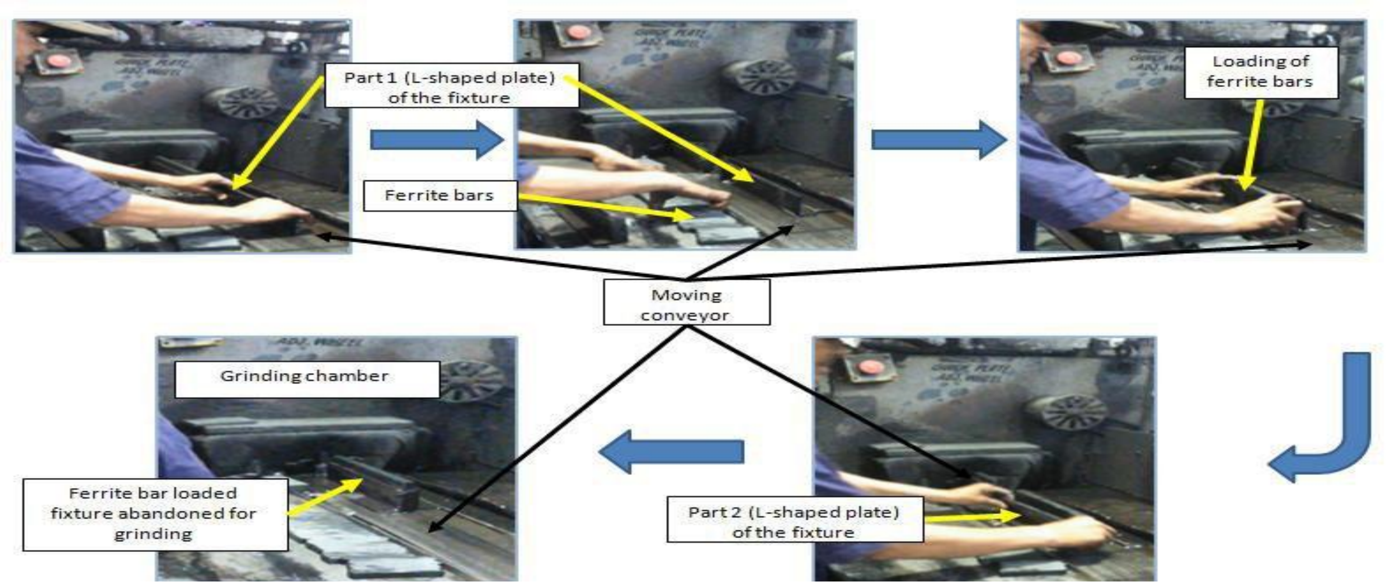


Fig 9: Present case loading activity (online) at the grinding machine

violated the principle laid down by International Labour Office.

3.2.3 Need

Thus, it was required to convert the online loading activity into offline. This would make the provision to increase the grinding feed of the machine by deploying an extra fixture loader (if required). Thus, there would be an added provision of incremental capacity escalation in the machine. Also, this would increase the job satisfaction on the personnel side.

3.2.4 Proposed Case

It was argued with the shop floor manager as to why the loading activity can't be made offline with the present fixture? It was answered that as the present fixture set has a structure which is open from the bottom, the ferrite bars would fall during the travel of the loaded fixture from the loading table to the conveyor. Thus, the fixture design needed to be changed.

The fixture design procedure went through exhaustive iterations which are as shown in the figures 10 to 15.

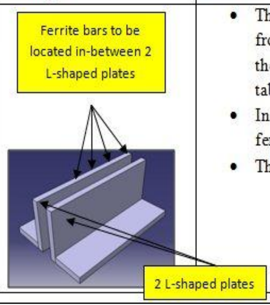
New Design Concept Generation Process		
Iteration	Concept	Remarks
0 (Present fixture)	 	• The fixture set had a structure which was open from the bottom, the ferrite bars would fall during the travel of the loaded fixture from the loading table to the conveyor. • Insufficient grip in-between the fixture and the ferrite bar. • Thus, infeasible.

Fig-10: Snapshot of the Iteration 0 of the concept generation process

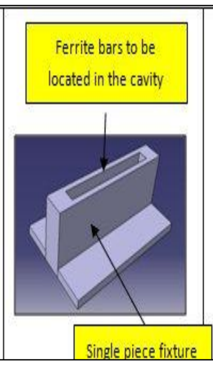
1	 	• The ferrite bars would not fall in transit from loading table to the conveyor. • But, all types of ferrite bars would not be accommodated in the same fixture due to variation in width and thickness of the ferrite bar. • This required a separate fixture for a separate type of ferrite bar which would increase the cost. • Thus, infeasible.

Fig-11: Snapshot of the iteration 1 of the concept generation process

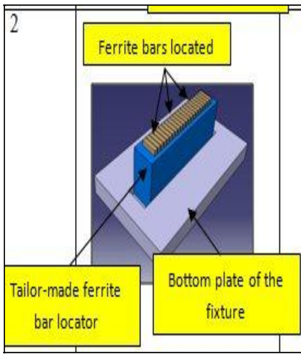
2	 	• The ferrite bars would not fall in transit from loading table to the conveyor. • This required a partial change in the fixture for an individual model of ferrite bar which would again increase the cost. • Incompetent and thus infeasible.

Fig-12: Snapshot of the iteration 2 of the concept generation process

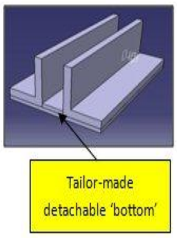
3		• Better than the previous versions. • The concept is similar to the present version i.e concept 0. • But, it also required partial change in the fixture for an individual model of ferrite bar by using a tailor-made for each ferrite bar detachable 'bottom'. • Incompetent from handling point of view. • Not up to the mark.

Fig - 13: Snapshot of the iteration 3 of the concept generation process

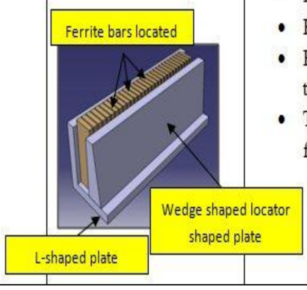
4		• It was a near-feasible design. • Better among all the previous versions • But, this fixture required a direct contact between the ferrite and metal under the grinding force. • This would lead to 'chipping' phenomenon in the ferrite bar which was non-conformity.

Fig - 14: Snapshot of the iteration 4 of the concept generation process

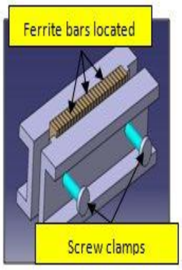
5		• This design ironed out all the non-conformities in the previous design. • The two-piece design with other provisions in the fixture would accommodate all models of ferrite bars. • Screw clamping would enable sufficient grip in-between the ferrite bar and the fixture. • The C-shaped design would do away with the handling problems. • Thus, feasible and was given a "go-ahead".

Fig - 15: Snapshot of the iteration 5 of the concept generation process

The newly designed fixture converted the online loading activity (i.e. loading activity on a conveyor) into an offline activity. The proposed offline activity is as shown in figure 16. Thus, this decoupled the worker/machine system and allowed an increase in the grinding feed (i.e. grinding conveyor speed) which was previously dependent on the speed on manual loading activity. This was already being followed at another 2-spindle length grinding machine with a conveyor speed of 630mm/min. Thus, potentially, it was proposed that the speed of the grinding conveyor could be increased from 400 mm/min to 630 mm/min.

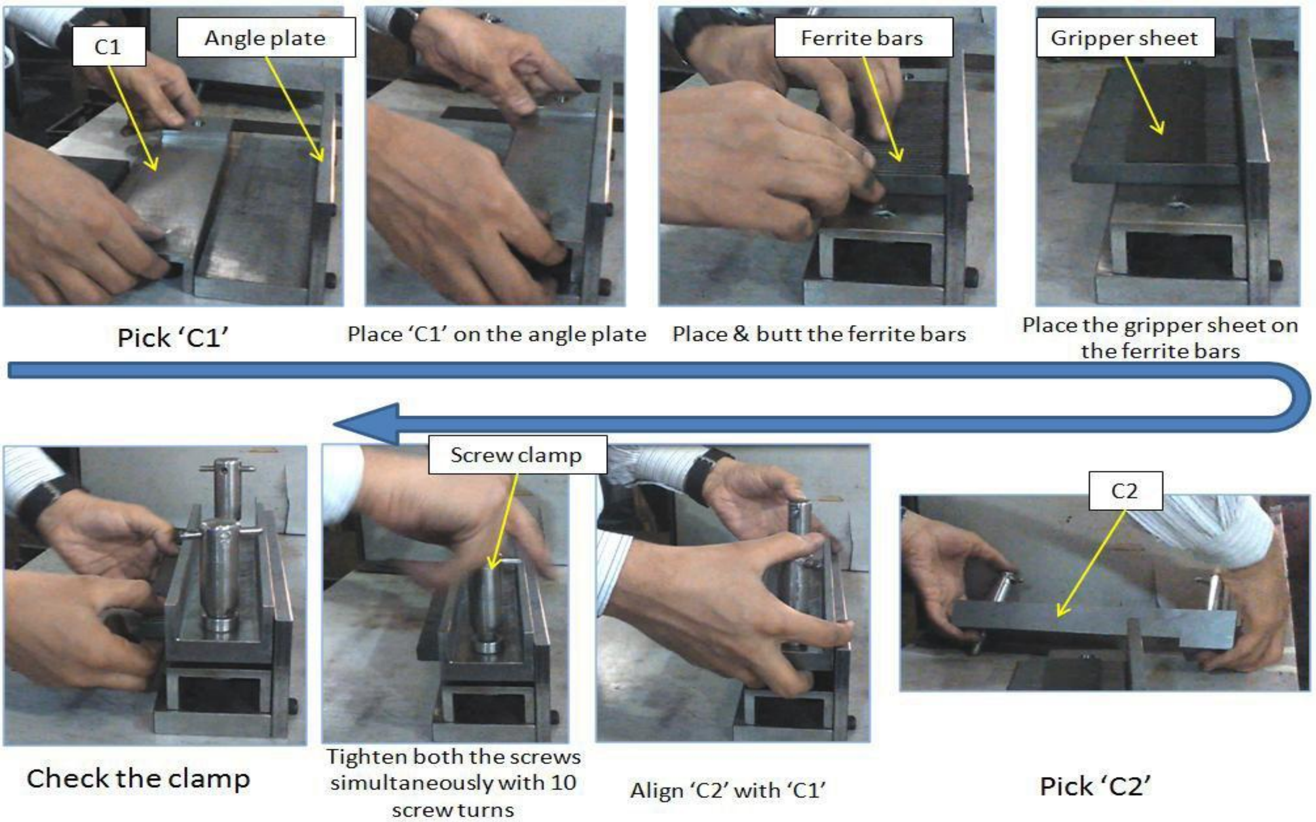


Fig - 16: Proposed case loading activity at LA1 grinding machine

ELEMENTS	Sequence model	Time (tmu)	Time (Sec)
Pick 'C1' and place it on the angle plate	A1 B0 G3 A1 B0 P1 A0	60	2.16
Reach the stack of ferrite bars and slide it outside	A3 B0 G3 M1 X0 I0 A0	70	2.52
Pick the stack and place it on 'C1'	A0 B0 G0 A3 B0 P6 A0	90	3.24
Butt the stack with the angle plate and the fixture	A0 B0 G1 (M1 X0 I1) A0 (8)	170	6.12
Pick the gripper sheet and place it on the stack	A1 B0 G1 A1 B0 P3 A0	60	2.16
Pick 'C2' and place it on 'C1' with care and precison	A1 B0 G3 A1 B0 P6 A0	110	3.96
Tighten the clamp with 10 screw turns	A0 B0 G0 A1 B0 P1 F24 A1 B0 P0 A0	270	9.72
Check the clamp	A1 B0 G1 M1 X0 I0 A0	30	1.08
Pick and place the fixture on the conveyor	A1 B0 G3 A1 B0 P1 A0	60	2.16
NORMAL TIME			**33.12**

Fig 17: Snapshot for 'normal time' calculations

	PHYSICAL STRAINS							
	AVG. FORCE		POSTURE		VIBRATIONS		SHORT CYCLE	
ELEMENTS	STRAIN	POINTS	STRAIN	POINTS	STRAIN	POINTS	STRAIN	POINTS
Pick 'C1' and place it on the angle plate	L	6	M	6	L	0	L	0
Reach the stack of ferrite bars and slide it outside	L	0	L	4	L	0	L	0
Pick the stack and place it on 'C1'	L	0	M	6	L	0	L	0
Butt the stack with the angle plate and the fixture	L	0	L	4	L	0	L	0
Pick the gripper sheet and place it on the stack	L	0	L	4	L	0	L	0
Pick 'C2' and place it on 'C1' with care and precison	L	8	M	6	L	0	L	0
Tighten the clamp with 10 screw turns	L	0	L	4	L	0	L	0
Check the clamp	L	0	L	4	L	0	L	0
Pick and place the fixture on the conveyor	L	18	M	6	L	0	L	0

Fig 18: Snapshot for 'physical strains' of work elements

	MENTAL STRAINS							
	CONCENTRATION		MONOTONY		EYE STRAIN		NOISE	
ELEMENTS	STRAIN	POINTS	STRAIN	POINTS	STRAIN	POINTS	STRAIN	POINTS
Pick 'C1' and place it on the angle plate	L	0	L	1	L	0	L	2
Reach the stack of ferrite bars and slide it outside	L	0	L	1	L	0	L	2
Pick the stack and place it on 'C1'	M	7	L	1	L	0	L	2
Butt the stack with the angle plate and the fixture	L	1	L	1	L	0	L	2
Pick the gripper sheet and place it on the stack	L	1	L	1	L	0	L	2
Pick 'C2' and place it on 'C1' with care and precison	M	7	L	1	L	0	L	2
Tighten the clamp with 10 screw turns	L	1	L	1	L	0	L	2
Check the clamp	L	1	L	1	L	0	L	2
Pick and place the fixture on the conveyor	L	1	L	1	L	0	L	2

Fig 19: Snapshot for 'mental strains' of work elements

ELEMENTS	WORKING CONDITION					
	TEMP /HUMIDITY		VENTILATION		WET	
	STRAIN	POINTS	STRAIN	POINTS	STRAIN	POINTS
Pick 'C1' and place it on the angle plate	M	12	L	1	M	5
Reach the stack of ferrite bars and slide it outside	M	12	L	1	M	5
Pick the stack and place it on 'C1'	M	12	L	1	M	5
Butt the stack with the angle plate and the fixture	M	12	L	1	M	5
Pick the gripper sheet and place it on the stack	M	12	L	1	M	5
Pick 'C2' and place it on 'C1' with care and precison	M	12	L	1	M	5
Tighten the clamp with 10 screw turns	M	12	L	1	M	5
Check the clamp	M	12	L	1	M	5
Pick and place the fixture on the conveyor	M	12	L	1	M	5

Fig - 20: Snapshot for 'working conditions' accrued on work elements

ELEMENTS	TOTAL POINTS	TOTAL RELAXATION ALLOWANCE (%)	TIME	STANDARD TIME
Pick 'C1' and place it on the angle plate	33	16	0.35	2.51
Reach the stack of ferrite bars and slide it outside	25	14	0.35	2.87
Pick the stack and place it on 'C1'	34	17	0.55	3.79
Butt the stack with the angle plate and the fixture	26	14	0.86	6.98
Pick the gripper sheet and place it on the stack	26	14	0.30	2.46
Pick 'C2' and place it on 'C1' with care and precison	42	20	0.79	4.75
Tighten the clamp with 10 screw turns	26	14	1.36	11.08
Check the clamp	26	14	0.15	1.23
Pick and place the fixture on the conveyor	46	22	0.48	2.64
	STANDARD TIME (Seconds)			38.3076

Fig - 21: Snapshot for 'standard time' calculations

The newly designed fixture travelling on the conveyor

Fig - 22: Proposed fixture in working condition

Accordingly, time standards were established for the proposed fixture design (figure 22) and its loading activity. It included calculation of normal time through Maynard's Operations Sequence Technique (MOST®), calculations of allowances based on physical strains, mental strains and working condition.(figure 17 to 21) Finally, the total points for each work element was converted into the required relaxation allowance in percentage by using the "points conversion table" laid down by "International Labour Office". And the standard time was formulated.

3.2.5 Result

As shown in the table (1), with the new fixture design and loading activity, the grinding machine could be subjected to incremental escalation of its feed and thus it's OEE. The new design of the loading fixture and the new loading sequence was taken into consideration. Trails were conducted and found to be satisfactory as shown in the figure 22. Some more changes were suggested by the shop floor manager which was required to be addressed before bringing the new fixture and sequence into mass production.

Table 1: Proposed incremental changes in grinding feed at the grinding machine

Before		After		Reduction in grinding time (per ferrite bar)
Grinding feed	Grinding time (per ferrite bar)	Grinding feed	Grinding time (per ferrite bar)	
400	=(ferrite bar thickness)/400	450	=(ferrite bar thickness)/450	11.11%
400	=(ferrite bar thickness)/400	500	=(ferrite bar thickness)/500	20%
400	=(ferrite bar thickness)/400	550	=(ferrite bar thickness)/550	27.27%
400	=(ferrite bar thickness)/400	630	=(ferrite bar thickness)/630	36.51%

OEE enhancement calculations:
With old fixture design, the OEE was given by:
OEE1=A1*P1*Q1

(Where, A1 = Availability factor with old design, P1 = Performance factor with old design, Q1 = Quality factor with old design)

With new fixture design, the OEE was given by:
OEE2=A2*P2*Q2

(Where, A2 = Availability factor with new design, P2 = Performance factor with new design, Q2 = Quality factor with new design)

Percentage enhancement in OEE was given by:
%(ΔOEE) = [(OEE2 – OEE1)/OEE1] = [(A2*P2*Q2 – A1*P1*Q1)/ (A1*P1*Q1)]

Now, since there is no change in the availability factor i.e. A1 = A2, and there is no change in the quality factor i.e. Q1 = Q2 thus:

%(ΔOEE) = [(P2 – P1)/P1] = [(TCT2*PU2/GOT2) – (TCT1*PU1/GOT1)]/ (TCT1*PU1/GOT1)

(Where, TCT2 & TCT1 = Theoretical cycle time with new & old fixture respectively, PU2 & PU1 = Processes units with new & old fixture respectively, GOT2 & GOT1 = Gross operating time with new & old fixture respectively)

Here, the processed units is considered to be 1 fixture (47 ferrite bars), i.e. PU2 = PU1. Also, since there is change in the theoretical cycle time i.e. grinding feed only and not in the gross operating time, thus:
%(ΔOEE) = [(TCT2 – TCT1)/TCT1]

Now, with the grinding feed of 400 mm/min, TCT1 for processing one fixture of 340 mm length was 340/400 = 0.85 minutes = 51 seconds.
With, potential grinding feed of 630 mm/min, TCT2 for processing one fixture of 340 mm length was 340/630 = 0.54 minutes = 32 seconds.
Thus, %(ΔOEE) = (32 – 51)/51 = 37.25 %.

Thus, with this "large" improvement, the Overall Equipment Effectiveness (OEE) of LA1 grinding machine was increased by 37.25%.

3.3 Stage 3: Standardization and alteration of the working method by methods engineering

The layout of the machine is shown in the figure 3. As discussed, the machine had a grinding conveyor and washing conveyor which were connected to each other making a continuous flow of ferrite bars. This machine was used for length grinding of the ferrite bar. Here, feed of ferrite bars (speed of both the conveyors) was dependent on the speed of the manual loading and unloading activity of the ferrite bars. If the manual loading/unloading speed is increased then it was inferred that the feed could be increased.
This stage includes increase in manual unloading speed by standardization and change in the method of working.

3.3.1 Present case
The present unloading activity is shown in figure 23 and its analysis using Multiple Activity Chart is shown in the figure 24. As revealed from the multiple activity chart, worker 1 was loaded with the time-consuming task of "stacking" which was repeated in the subsequent period. Due to this time-consuming task for worker 1, the washing conveyor was not emptied before 13.9 s. On the contrary, worker 2 had an idle time of 3.61s.

Fig - 23: Present case unloading activity

PRESENT STATE MULTIPLE ACTIVITY CHART

Worker 1	Time (s)	Time (s)	Worker 2
Collecting the bars from the conveyor in a partial stacked way (13 nos.)	10.63	1.77	Reaching the conveyor to grasp the stacked bars
		0.5	Grasping the stacked bars
		1.19	Placing it on the table
		0.91	Re-stacking
		1.67	Reaching the final tray with the stacked
		2.03	Placing it in the final tray
		3.61	Idle
Stacking the bars and leaving it on the conveyor	1		

Bars are picked from the conveyor at this point i.e. after 13.9s

Fig - 24: Snapshot of the multiple activity chart of the present case unloading activity

3.3.2 Proposed case
The future multiple activity chart for the proposed unloading activity is shown in figure 26 and its trial snapshot is as shown in the figure 25. As shown in the future state multiple activity chart, the conveyor was emptied within 7.34s unlike 13.9s in the present state multiple activity chart. Thus, the unloading speed of the worker 1 was increased by 47%

In the proposed method, the attempt was to reduce the variety of work for worker 1 thus reducing his/her cycle so that he/she can return to the conveyor at a high frequency and unload the conveyor at a faster rate. The idle time of worker 2 is transferred to worker 1. This idle time can be utilized to pick more number of ferrite bars if the feed is increased in the near future. The proposal went through many trials. Also, during the trials, minor changes such as modification in the tray 1 was done so as to prevent the ferrite bars from getting collected haphazardly.

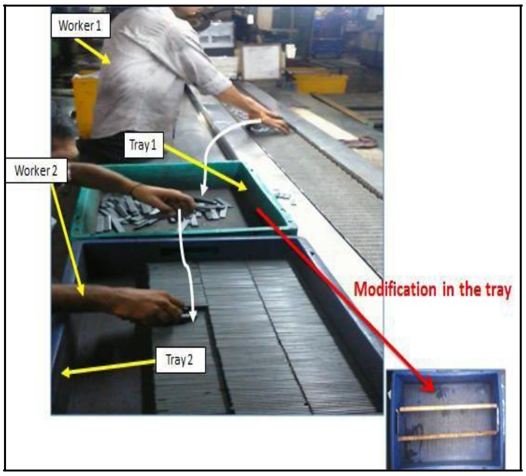


Fig - 25: Proposed case unloading activity

FUTURE STATE MULTIPLE ACTIVITY CHART			
Worker 1	Time (s)	Time (s)	Worker 2
Collecting the bars from the conveyor NOT in a partial stacked way and keeping them AS IT IS inside the bin which is located in-between both the workers	7.34	1	Reaching the bin in-between the workers
		2	Collecting the bars from the bin in a partial stacked way
		1	Reaching the final tray
Idle time for present cycle (this time is utilized by the worker in picking up the bars of the forthcoming cycle and also in helping the worker 2)	7	10	Placing the stacked bars in the final tray

Bars are picked from the conveyor at this point i.e. after 7.34s

Fig – 26: Snapshot of the multiple activity chart of the proposed case unloading activity

4. CONCLUDING REMARKS

Thus, stage 1 increased the productivity by addressing the losses in the system; stage 2 increased the productivity by making a radical change in the system i.e. by increasing the pace of the machine. In order to cop up with proposed increased grinding feed at the unloading end, stage 3 was proposed.

In a nut shell, this paper initially streamlines the process by ironing out the sub-optimal situations by increasing just the length of the present fixture. Then, on the principles of Lean SixSigma, after ironing out the losses (wastes), radical changes in the form of enhancement of overall equipment effectiveness (OEE) was done. Then, some new working methodologies were proposed.

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