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# Implementation of Lean Manufacturing with Application of Taguchi Methodology in Cement Industry

Joshi Chirag D.[1], Prof. P. S. Puranik[2]

[*1]P.G. Student, Mechanical Engineering Dept., A.I.T.S, Rajkot, India,
[2]Asst. Professor, Mechanical Engineering Dept., A.I.T.S, Rajkot, India,

***Abstract***- *The Implementation of lean helps many organizations to improve their productivity and efficiency; on the other hand many organizations could not get the benefit of lean. The case of not achieving the expected results of implementing lean is not because of limitation of lean to specific organizations type, but the misconception of the lean philosophy is the main failure's factor. The cement industry is the example of the continuous industry and it will be used to convey that the lean philosophy is applicable to any type of organization. There are many problems facing the cement industry in today's cut throat competition; one of the major challenges is the capability of the cement industry to adopt new techniques with the help of which the overall performance of production line can be improved.*
*The developed transition steps have ability to:*

- *Understand the cement manufacturing process in order to identify value added and non-value added activities in production line through applying the process mapping technique.*
- *Determine and examine the interrelationships between the variables by developing Cause-Effect matrix.*

***Keyword***-*lean methodology, wastes, value added and non-value added activities;*

## I. INTRODUCTION

The manufacturing's philosophy has realized fundamental changes since the elimination of batch production in to mass production system. New era has started when lean manufacturing philosophy is introduced. Idea of lean production was originated at Toyota Company in early 1950s. The main concept of lean philosophy is to use less but achieve more through eliminating or minimizing non-value added activities and wastes within the system. Now days organizations are under pressure to reduce their cycle time, cost, customer lead-time and increase quality and productivity. Many organizations have realized the essential need to adopt the lean philosophy instead of the traditional mass production concepts in order to stay competitive and survive in the recent situation. This research will attempt to show that the lean methodology is not only limited to specific type of industry, but it can be applied successfully to all types of organization as long as the right steps are applied effectively. The research here will study and develop standard steps which can be used as guidelines in implementation of lean methodology for different organizations. Production line's data of cement industry is used to examine the validity of the proposed methodology.

## II. PROBLEM DEFINITION

The cement is mostly found universally in daily life and it is not possible to imagine a society without it. In construction major role of cement is found as it is the basic input in infrastructure. Cement is produced in all over world but about 75 % of it is produced and used in developing country. The cement industry can be a successful sector in the areas where cheap fuels are available. The main problem with cement industry is to reduce the waiting time to overcome the demand of market and to reduce all other waste to improve the productivity. The cement industry is characterized by intensive energy and raw materials, high breakdowns, large Work-In-Progress inventories, and the need to increase the productivity in order to meet high demands of their customer. The situation of not achieving the expectation of high machine utilization and production rates, low breakdown rates in the cement production line has motivated me to design an integrated framework by which the cement production line will be improved.

## III. METHODOLOGY

In methodology to implement lean manufacturing in cement industry there are mainly 6 steps as under.

1. Data collection of all three processes to evaluate variables of each process.
2. Developing a simulation model.
3. Identifying inter-relationship between variables by orthogonal array.
4. Developing a connectivity matrix in which variables having more no. of direct relationship with other will be taken in to account.

5. Result of Taguchi orthogonal array.
6. Performance measurement.

## IV. EXPERIMENTATION

1. Data Collected for Raw milling Process:

1) The designed production rate = 250 TPH
2) Scheduled Running Time = 80 of the actual available time = 0.8 * 38880 = 31104 min / month
3) Designed cycle time = 0.5 min/ton
4) % rework (% recalculated) = 15 – 25 % of the raw feed meal
5) % scrape = 6 %
6) Inventory capacities = 80,000 tons
7) WIP capacities = 20,000 ton
8) No of Breakdowns = 4 to 6 times per month

2. Identification of inter-relationship between variables:

| RawMilling Process Varaibles | Air Flow Rate ($cm^3/min$) | Temperature ($C^o$) | Pressure (Psi) | Material Grindability | Material Moisture (% of weight) | Material Bed Depth (cm) | Particles Size | Product Fineness ($cm^3/gr$) | Recirculation Rate(% of feed materials) | Roller Number | Roller Radius (cm) | Mill Table Diameter (cm) | separator Speed (rpm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Flow Rate ($cm^3/min$) | | D1 | D1 | I | D1 | D1 | D0 | D1 | D1 | | | | D1 |
| Temperature ($C^o$) | D1 | | I | D1 | D1 | I | I | I | I | I | I | I | I |
| Pressure (Psi) | D1 | I | | I | I | D1 | I | I | I | I | I | I | D0 |
| Material Grindability | I | D1 | I | | D1 | D1 | D1 | D1 | D1 | I | I | I | I |
| Material moisture (% of weight) | D1 | D1 | | D1 | | D1 | | | | | | D0 | |
| Material Bed Depth (cm) | D1 | I | D1 | D1 | D1 | | D0 | I | I | | | | D1 |
| Particles Size | D0 | I | I | D1 | I | D0 | | D0 | D0 | I | I | I | D0 |
| Product Fineness ($cm^3/gr$) | D1 | I | I | D1 | I | D0 | D0 | | D1 | | | | D1 |
| Recirculation Rate (% of feed materials) | D1 | I | I | D1 | I | I | D0 | D1 | | I | I | I | D1 |
| Roller Number | I | I | I | I | I | I | I | I | I | | D1 | D1 | I |
| Roller Radius (cm) | I | I | I | I | I | I | I | I | I | D1 | | D1 | I |
| Mill Table Diameter (cm) | I | I | I | I | I | D0 | I | I | I | D1 | D1 | | |
| separator Speed (rpm) | D1 | I | D0 | I | I | D1 | D0 | D1 | D1 | I | I | I | |

Where; D1= Direct relationship

D2= Indirect Relationship

D3= Independent

3. Developing a connectivity matrix:

Connectivity matrix for raw milling process is shown in table,

| Raw Milling Process Varaibles | Air Flow Rate (cm³/min) | Temperature (C°) | Pressure (Psi) | Material Grindability | Material Moisture (% of weight) | Material Bed Depth (cm) | Particles Size | Product Fineness (cm³/gr) | Recirculation Rate (% of feed materials) | Roller Number | Roller Radius (cm) | Mill Table Diameter (cm) | separator Speed (rpm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Flow Rate (cm²/min) | | D1 | D1 | | D1 | D1 | | D1 | D1 | | | | D1 | 7 |
| Temperature (C°) | D1 | | | D1 | D1 | | | | | | | | | 3 |
| Pressure (Psi) | D1 | | | | | D1 | | | | | | | | 2 |
| Material Grindability | | D1 | | | D1 | D1 | D1 | D1 | D1 | | | | | 6 |
| Material moisture (% of weight) | D1 | D1 | | D1 | | D1 | | | | | | | | 4 |
| Material Bed Depth (cm) | D1 | | D1 | D1 | D1 | | | | | | | | D1 | 5 |
| Particles Size | | | | D1 | | | | | | | | | | 1 |
| Product Fineness (cm²/gr) | D1 | | | D1 | | | | | D1 | | | | D1 | 4 |
| Recirculation Rate (% of feed materials) | D1 | | | D1 | | | | D1 | | | | | D1 | 4 |
| Roller Number | | | | | | | | | | | D1 | D1 | | 2 |
| Roller Radius (cm) | | | | | | | | | | D1 | | D1 | | 2 |
| Mill Table Diameter (cm) | | | | | | | | | | D1 | D1 | | | 2 |
| separator Speed (rpm) | D1 | | | | | D1 | | D1 | D1 | | | | | 4 |

4. Raw milling process variables:

| Air flow rate | Recirculation rate (% weight) | Material moisture | Material Grind ability | Material bed depth (cm) | Product fineness (cm3/g) | Separator speed (rpm) |
|---|---|---|---|---|---|---|
| 32500 | 15 | 7 | Easy | 4 | 3900 | 70 |
| 32600 | 20 | 8 | Normal | 5 | 3950 | 75 |
| 32900 | 25 | 9 | Hard | 6 | 4000 | 80 |

5. Result of Taguchi orthogonal array:

Table demonstrate the theoretical values of the throughput and % machine utilization for the raw milling processes within the cement production line. The throughput and %machine utilization are calculated using the equations.

% Utilization = Available time – Unused time / Available time (100)

Where, Available time = monthly available time
Unused time = breakdown or maintenance time

 

| Air flow Rate (cm³/min) | Recirculation Rate (% Feed meal) | Material Moisture (% weight) | Material Grind-ability | Material Bed Depth (cm) | product Fineness (cm³/gr) | Separator Speed (rpm) | Cycle Time (min/ton) | Breakdown Time (min) | Theoretical Throughput (ton) | Theoretical % Machine Utilisation |
|---|---|---|---|---|---|---|---|---|---|---|
| 32500 | 0.15 | 7 | Easy | 4 | 3900 | 70 | 0.2 | 480 | 153120 | 71 |
| 32500 | 0.15 | 7 | Easy | 5 | 3950 | 75 | 0.2 | 480 | 153120 | 71 |
| 32500 | 0.15 | 7 | Easy | 6 | 4000 | 80 | 0.2 | 1140 | 149820 | 69 |
| 32500 | 0.2 | 8 | Normal | 4 | 3900 | 70 | 0.2 | 1140 | 149820 | 69 |
| 32500 | 0.2 | 8 | Normal | 5 | 3950 | 75 | 0.5 | 1140 | 59928 | 69 |
| 32500 | 0.2 | 8 | Normal | 6 | 4000 | 80 | 0.8 | 1140 | 37455 | 69 |
| 32500 | 0.25 | 9 | Hard | 4 | 3900 | 70 | 0.8 | 1800 | 36630 | 68 |
| 32500 | 0.25 | 9 | Hard | 5 | 3950 | 75 | 0.8 | 1800 | 36630 | 68 |
| 32500 | 0.25 | 9 | Hard | 6 | 4000 | 80 | 0.8 | 1800 | 36630 | 68 |
| 32600 | 0.15 | 7 | Hard | 4 | 3950 | 75 | 0.5 | 1140 | 59928 | 69 |
| 32600 | 0.15 | 7 | Hard | 5 | 4000 | 60 | 0.8 | 1140 | 37455 | 69 |
| 32600 | 0.15 | 7 | Hard | 6 | 3900 | 65 | 0.8 | 1140 | 37455 | 69 |
| 32600 | 0.2 | 8 | Easy | 4 | 3950 | 75 | 0.5 | 1800 | 58608 | 68 |
| 32600 | 0.2 | 8 | Easy | 5 | 4000 | 60 | 0.8 | 1140 | 37455 | 69 |
| 32600 | 0.2 | 8 | Easy | 6 | 3900 | 65 | 0.8 | 1140 | 37455 | 69 |
| 32600 | 0.25 | 9 | Normal | 4 | 3950 | 75 | 0.8 | 1800 | 36630 | 68 |
| 32600 | 0.25 | 9 | Normal | 5 | 4000 | 60 | 0.8 | 1800 | 36630 | 68 |
| 32600 | 0.25 | 9 | Normal | 6 | 3900 | 65 | 0.8 | 1140 | 37455 | 69 |
| 32900 | 0.15 | 7 | Normal | 4 | 4000 | 65 | 0.8 | 1800 | 36630 | 68 |
| 32900 | 0.15 | 7 | Normal | 5 | 3900 | 75 | 0.8 | 1800 | 36630 | 68 |
| 32900 | 0.15 | 7 | Normal | 6 | 3950 | 60 | 0.8 | 1140 | 37455 | 69 |
| 32900 | 0.2 | 8 | hard | 4 | 4000 | 65 | 0.8 | 1800 | 36630 | 68 |
| 32900 | 0.2 | 8 | hard | 5 | 3900 | 75 | 0.8 | 1800 | 36630 | 68 |
| 32900 | 0.2 | 8 | hard | 6 | 3950 | 60 | 0.8 | 1800 | 36630 | 68 |
| 32900 | 0.25 | 9 | Easy | 4 | 4000 | 65 | 0.5 | 1140 | 59928 | 69 |
| 32900 | 0.25 | 9 | Easy | 5 | 3900 | 75 | 0.5 | 1140 | 59928 | 69 |
| 32900 | 0.25 | 9 | Easy | 6 | 3950 | 60 | 0.5 | 1140 | 59928 | 69 |

 

6. Performance measurement:

| Air flow Rate (cm³/min) | Recirculation Rate (% Feed Meal) | Material Moisture (% weight) | Material Grind-ability | Material Bed Depth (cm) | product Fineness (cm²/gr) | Separator Speed (rpm) | %Waiting before WIP minimise | %Blocking before WIP minimise | %Working before WIP minimise | Cycle Time (Min/ton) before WIP minimise | Breakdown Time (min) before | Throughput (ton) before WIP minimise | %Machine Utilisation before WIP minimise |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32500 | 0.15 | 7 | Easy | 4 | 3900 | 70 | 22 | 11 | 67 | 0.27 | 135 | 114700 | 67 |
| 32500 | 0.15 | 7 | Easy | 5 | 3950 | 75 | 21 | 11 | 68 | 0.25 | 127 | 121957 | 68 |
| 32500 | 0.15 | 7 | Easy | 6 | 4000 | 80 | 32 | 14 | 54 | 0.26 | 258 | 119558 | 54 |
| 32500 | 0.2 | 8 | Normal | 4 | 3900 | 70 | 36 | 12 | 52 | 0.27 | 266 | 115932 | 52 |
| 32500 | 0.2 | 8 | Normal | 5 | 3950 | 75 | 37 | 11 | 52 | 0.53 | 266 | 57966 | 52 |
| 32500 | 0.2 | 8 | Normal | 6 | 4000 | 80 | 28 | 12 | 60 | 0.82 | 274 | 37506 | 61 |
| 32500 | 0.25 | 9 | Hard | 4 | 3900 | 70 | 40 | 16 | 44 | 0.88 | 438 | 35007 | 45 |
| 32500 | 0.25 | 9 | Hard | 5 | 3950 | 75 | 40 | 15 | 45 | 0.95 | 447 | 32135 | 46 |
| 32500 | 0.25 | 9 | Hard | 6 | 4000 | 80 | 37 | 15 | 48 | 0.92 | 429 | 33415 | 49 |
| 32600 | 0.15 | 7 | Hard | 4 | 3950 | 75 | 28 | 13 | 59 | 0.57 | 246 | 53948 | 59 |
| 32600 | 0.15 | 7 | Hard | 5 | 4000 | 60 | 29 | 12 | 59 | 0.4 | 246 | 77145 | 59 |
| 32600 | 0.15 | 7 | Hard | 6 | 3900 | 65 | 37 | 13 | 50 | 0.82 | 252 | 37809 | 50 |
| 32600 | 0.2 | 8 | Easy | 4 | 3950 | 75 | 37 | 16 | 47 | 0.58 | 405 | 52929 | 48 |
| 32600 | 0.2 | 8 | Easy | 5 | 4000 | 60 | 36 | 16 | 48 | 0.88 | 274 | 34955 | 48 |
| 32600 | 0.2 | 8 | Easy | 6 | 3900 | 65 | 38 | 12 | 50 | 0.92 | 286 | 33571 | 50 |
| 32600 | 0.25 | 9 | Normal | 4 | 3950 | 75 | 40 | 15 | 45 | 0.94 | 438 | 32763 | 46 |
| 32600 | 0.25 | 9 | Normal | 5 | 4000 | 60 | 47 | 16 | 37 | 0.92 | 445 | 33398 | 38 |
| 32600 | 0.25 | 9 | Normal | 6 | 3900 | 65 | 40 | 15 | 45 | 0.94 | 294 | 32707 | 45 |
| 32900 | 0.15 | 7 | Normal | 4 | 4000 | 65 | 41 | 15 | 44 | 0.86 | 399 | 35787 | 45 |
| 32900 | 0.15 | 7 | Normal | 5 | 3900 | 75 | 40 | 16 | 44 | 0.85 | 393 | 36301 | 45 |
| 32900 | 0.15 | 7 | Normal | 6 | 3950 | 60 | 29 | 12 | 59 | 0.85 | 264 | 36197 | 60 |
| 32900 | 0.2 | 8 | hard | 4 | 4000 | 65 | 38 | 15 | 47 | 0.89 | 417 | 34326 | 48 |
| 32900 | 0.2 | 8 | hard | 5 | 3900 | 75 | 38 | 16 | 46 | 0.91 | 423 | 33864 | 47 |
| 32900 | 0.2 | 8 | hard | 6 | 3950 | 60 | 32 | 16 | 52 | 0.93 | 435 | 32977 | 53 |
| 32900 | 0.25 | 9 | Easy | 4 | 4000 | 65 | 35 | 14 | 51 | 0.61 | 286 | 50356 | 51 |
| 32900 | 0.25 | 9 | Easy | 5 | 3900 | 75 | 26 | 15 | 59 | 0.59 | 274 | 52432 | 60 |
| 32900 | 0.25 | 9 | Easy | 6 | 3950 | 60 | 24 | 18 | 58 | 0.3 | 282 | 102060 | 59 |

Table 1: Raw Milling Process OA before Reducing Work In Progress.

 

The literature review has shown that the cement industry is characterized by high levels of WIP and inventories. Therefore; the main aim to implement lean in cement industry is to reduce WIP and level of Inventory. One of the main reasons of high WIP levels is the non-optimized batch size. Therefore, all workstations capacities have been reduced by 10% in order to minimize the WIP levels. Tables 2 illustrate the effects of WIP reduction on the system performance parameters.

| Air flow Rate ($cm^3/min$) | Recirculation Rate (% Feed Meal) | Material Moisture (% weight) | Material Grind-ability | Material Bed Depth (cm) | product Fineness ($cm^2/gr$) | Separator Speed (rpm) | %Waiting after WIP minimise | %Blocking after WIP minimise | %Working after WIP minimise | Cycle Time (min/ton) after WIP minmise | Breakdown Time (min) after WIP minmise | Throughput (ton) after WIP minimise | %Machine Utilisation after WIP minimise |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32500 | 0.15 | 7 | Easy | 4 | 3900 | 70 | 18 | 8 | 74 | 0.12 | 132 | 258100 | 74 |
| 32500 | 0.15 | 7 | Easy | 5 | 3950 | 75 | 17 | 8 | 75 | 0.16 | 125 | 188896 | 75 |
| 32500 | 0.15 | 7 | Easy | 6 | 4000 | 80 | 24 | 14 | 62 | 0.11 | 256 | 285630 | 62 |
| 32500 | 0.2 | 8 | Normal | 4 | 3900 | 70 | 27 | 12 | 61 | 0.12 | 262 | 265879 | 61 |
| 32500 | 0.2 | 8 | Normal | 5 | 3950 | 75 | 24 | 16 | 60 | 0.38 | 263 | 80736 | 60 |
| 32500 | 0.2 | 8 | Normal | 6 | 4000 | 80 | 15 | 18 | 67 | 0.67 | 271 | 45882 | 67 |
| 32500 | 0.25 | 9 | Hard | 4 | 3900 | 70 | 31 | 18 | 51 | 0.63 | 435 | 48992 | 51 |
| 32500 | 0.25 | 9 | Hard | 5 | 3950 | 75 | 30 | 17 | 53 | 0.77 | 444 | 39612 | 53 |
| 32500 | 0.25 | 9 | Hard | 6 | 4000 | 80 | 27 | 16 | 57 | 0.77 | 427 | 39944 | 57 |
| 32600 | 0.15 | 7 | Hard | 4 | 3950 | 75 | 21 | 13 | 66 | 0.22 | 243 | 139014 | 66 |
| 32600 | 0.15 | 7 | Hard | 5 | 4000 | 60 | 22 | 12 | 66 | 0.25 | 241 | 123452 | 66 |
| 32600 | 0.15 | 7 | Hard | 6 | 3900 | 65 | 23 | 14 | 63 | 0.64 | 250 | 48513 | 63 |
| 32600 | 0.2 | 8 | Easy | 4 | 3950 | 75 | 28 | 17 | 55 | 0.43 | 401 | 71402 | 55 |
| 32600 | 0.2 | 8 | Easy | 5 | 4000 | 60 | 32 | 11 | 57 | 0.7 | 270 | 43923 | 57 |
| 32600 | 0.2 | 8 | Easy | 6 | 3900 | 65 | 27 | 14 | 59 | 0.74 | 283 | 41763 | 59 |
| 32600 | 0.25 | 9 | Normal | 4 | 3950 | 75 | 31 | 17 | 52 | 0.76 | 433 | 40570 | 52 |
| 32600 | 0.25 | 9 | Normal | 5 | 4000 | 60 | 37 | 14 | 49 | 0.77 | 438 | 39930 | 49 |
| 32600 | 0.25 | 9 | Normal | 6 | 3900 | 65 | 25 | 22 | 53 | 0.69 | 387 | 44389 | 53 |
| 32900 | 0.15 | 7 | Normal | 4 | 4000 | 65 | 29 | 19 | 50 | 0.68 | 395 | 45294 | 50 |
| 32900 | 0.15 | 7 | Normal | 5 | 3900 | 75 | 28 | 20 | 52 | 0.7 | 289 | 44274 | 52 |
| 32900 | 0.15 | 7 | Normal | 6 | 3950 | 60 | 18 | 13 | 69 | 0.67 | 261 | 45897 | 69 |
| 32900 | 0.2 | 8 | hard | 4 | 4000 | 65 | 32 | 13 | 55 | 0.74 | 410 | 41255 | 55 |
| 32900 | 0.2 | 8 | hard | 5 | 3900 | 75 | 29 | 17 | 54 | 0.66 | 419 | 46776 | 54 |
| 32900 | 0.2 | 8 | hard | 6 | 3950 | 60 | 32 | 16 | 52 | 0.78 | 431 | 39324 | 52 |
| 32900 | 0.25 | 9 | Easy | 4 | 4000 | 65 | 26 | 15 | 59 | 0.46 | 282 | 66714 | 59 |
| 32900 | 0.25 | 9 | Easy | 5 | 3900 | 75 | 28 | 16 | 56 | 0.41 | 271 | 75571 | 56 |
| 32900 | 0.25 | 9 | Easy | 6 | 3950 | 60 | 28 | 14 | 58 | 0.15 | 279 | 202796 | 58 |

Table 2: Raw Milling Process OA after Reducing WIP

 

## V. RESULTS

The WIP reduction has a great effect on the production line efficiency. Figures (1 & 2) illustrate comparison picture of variables and factors values before and after reducing the WIP within the raw milling process in order to demonstrate the enhancement that obtained within the raw milling process after reducing the WIP level. The throughput and machine utilization are improved in combination with reduction of the cycle time, and breakdown time as a result of WIP reduction.

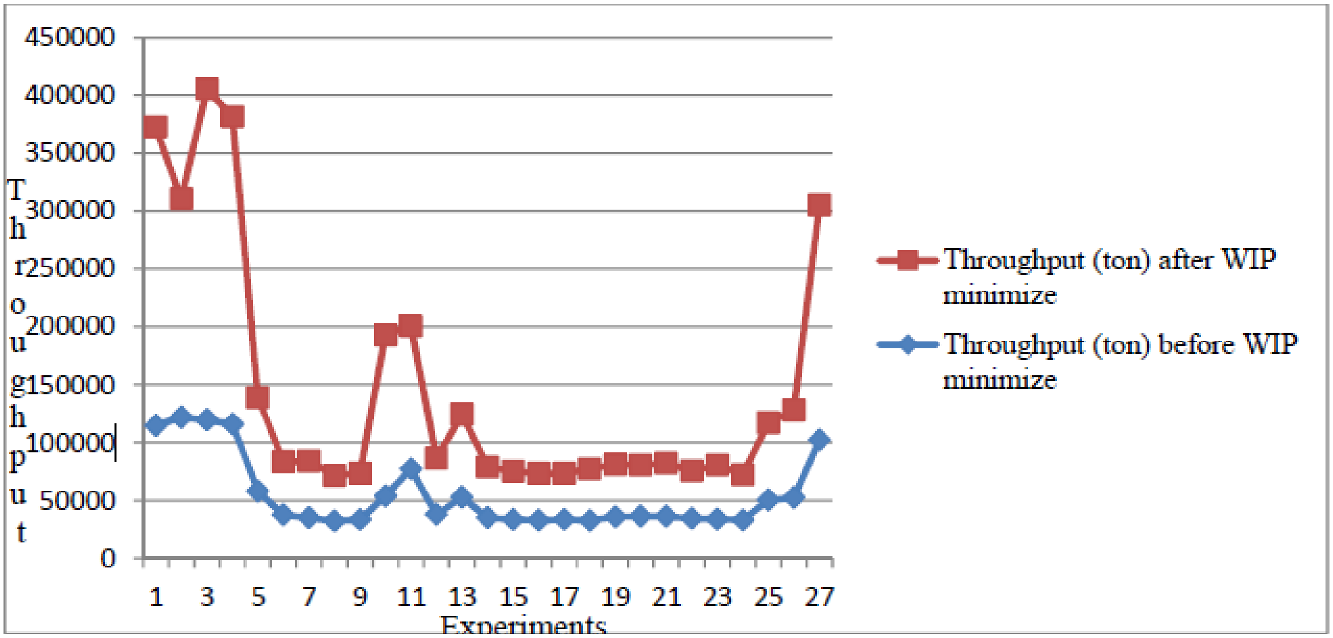


Fig. 1: Throughput Before and After Reducing WIP

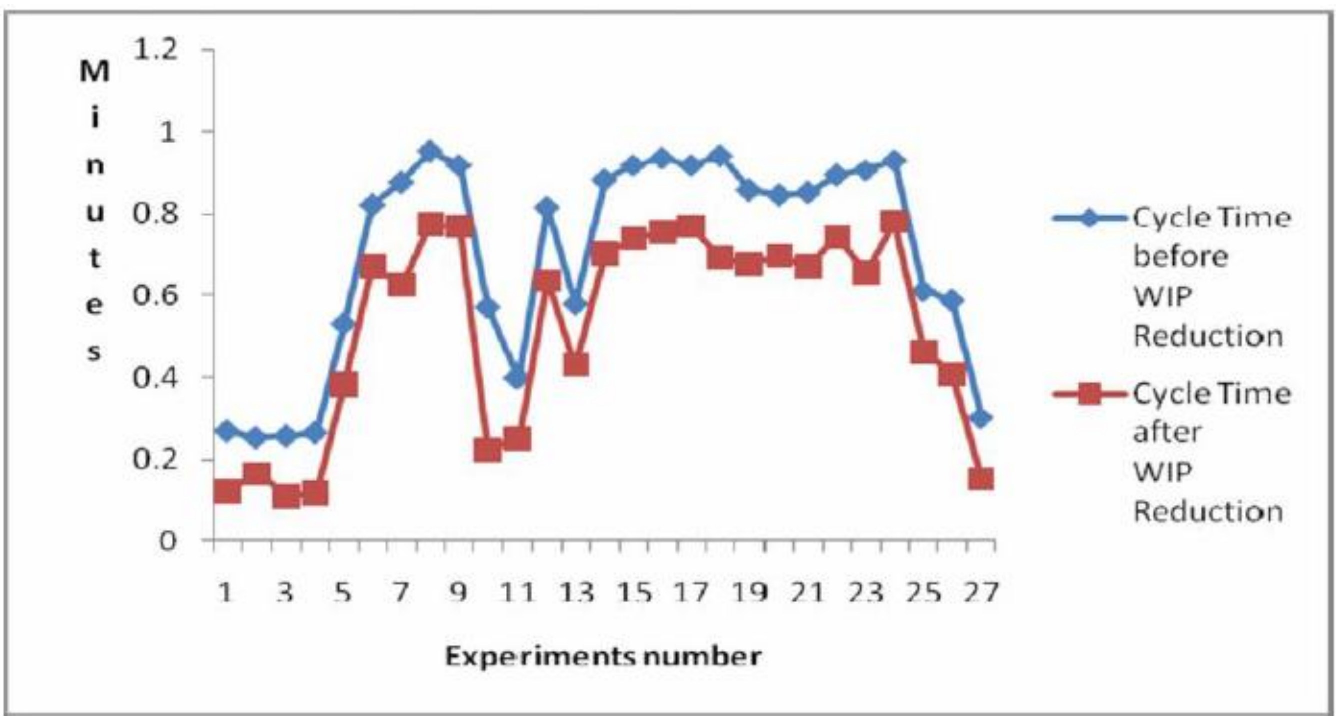

Fig 2: Cycle time before and After Reducing WIP

## VII. CONCLUSION

In the today's cut-throat competition organizations of all sizes are enforced to improve quality and reduce the costs in order to survive in the difficult environment. The cement industry is an example of the continuous process manufacturing; however the research has studied the cement industry through dividing the cement production line into three main processes such as raw milling process, thermo-chemical process, and finish grinding process. The research has handled each process as single process aiming to identify the interrelationships between the variables that associated with each process, and to determine the effects of these variables on the chosen performance parameters for each process. The research has highlighted some of the barriers that may cause the gap between the desired and the actual results, and prevent the cement industry from achieving any improvement.

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