

**Implementation of Lean Manufacturing with Application of Taguchi Methodology
in Cement Industry**Joshi Chirag D.¹, Prof. P. S. Puranik²^{*1}P.G. Student, Mechanical Engineering Dept., A.I.T.S, Rajkot, India,²Asst. 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 Variables	Air Flow Rate (cm ³ /min)	Temperature (C°)	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°)	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 Variables	Air Flow Rate (cm ³ /min)	Temperature (C°)	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		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 (cm ³ /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 (cm ³ /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.

$$\% \text{ Utilization} = \text{Available time} - \text{Unused time} / \text{Available time} (100)$$

Where, Available time = monthly available time

Unused time = breakdown or maintenance time

Air flow Rate (cm ³ /min)	Recirculation Rate (% Feed meal)	Material Moisture (% weight)	Material Grind-ability	Material Bed Depth (cm)	product Fineness (cm ³ /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 (cm ³ /min)	Recirculation Rate (% Feed Meal)	Material Moisture (% weight)	Material Grind-ability	Material Bed Depth (cm)	product Fineness (cm ³ /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 ³ /gr)	Separator Speed (rpm)	%Waiting after WIP minimise	%Blocking after WIP minimise	%Working after WIP minimise	Cycle Time (min/ton) after WIP minimise	Breakdown Time (min) after WIP minimise	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.

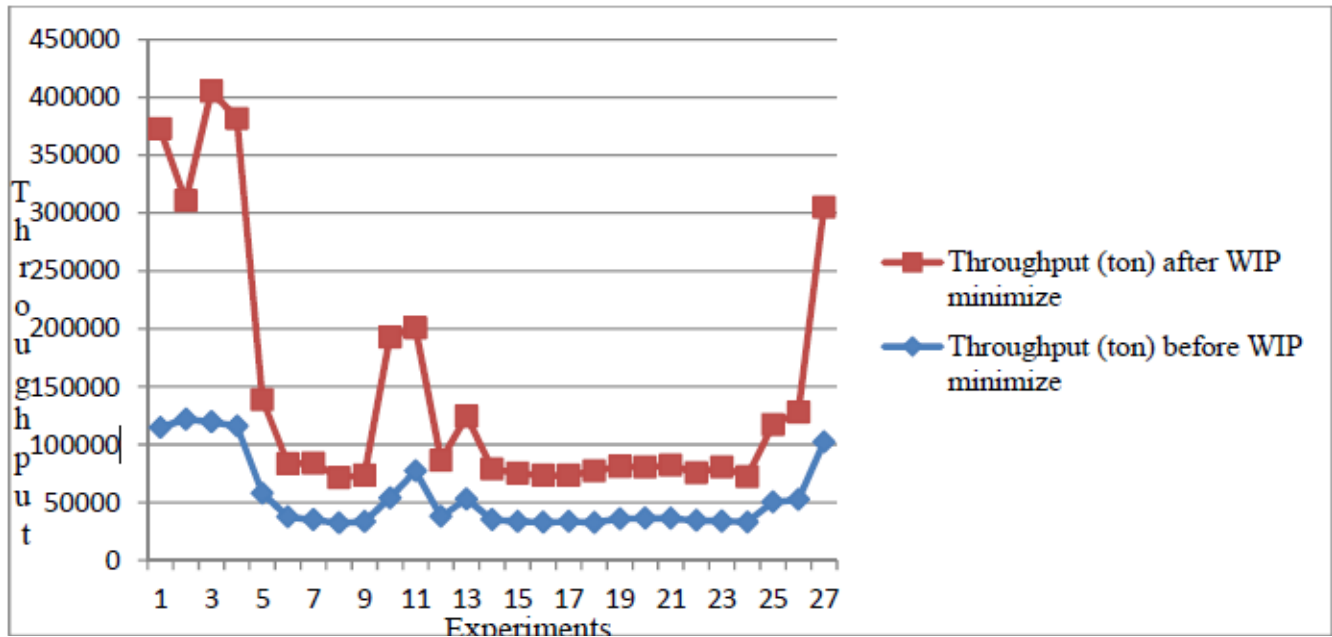


Fig. 1: Throughput Before and After Reducing WIP

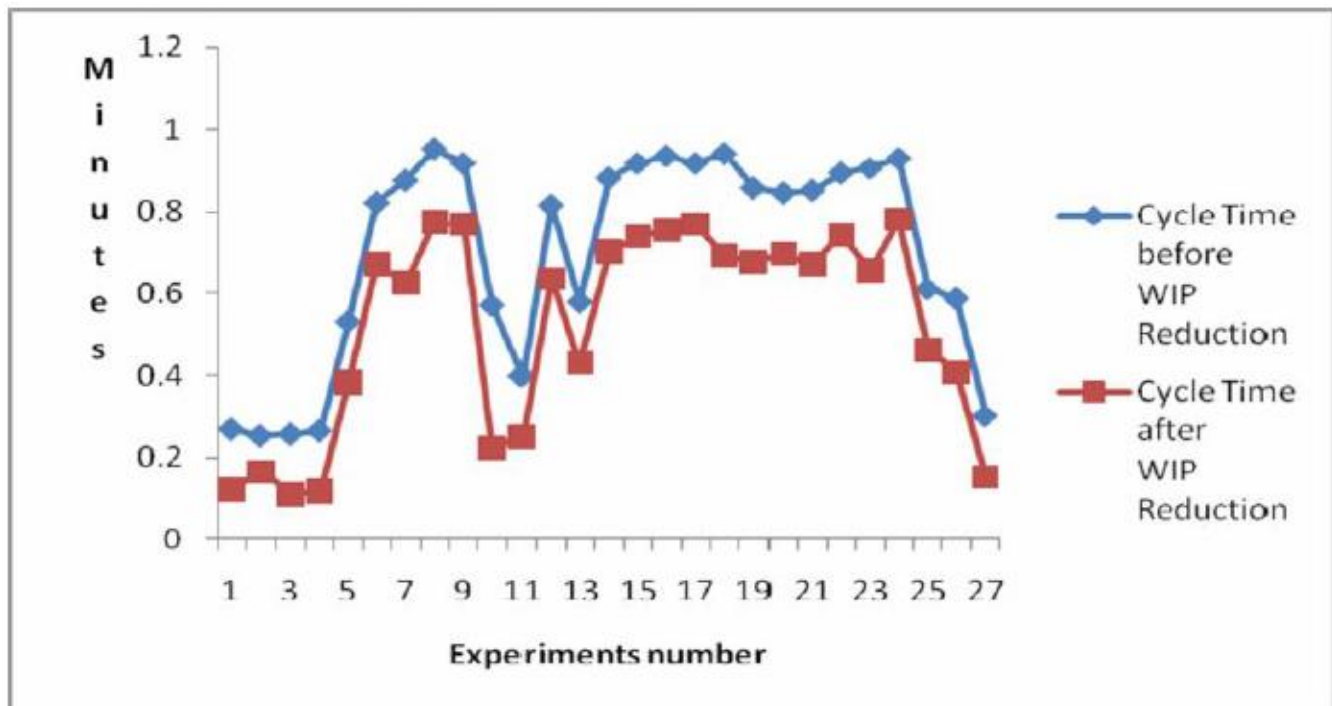


Fig 2: Cycle time before and After Reducing WIP

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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