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PRODUCTIVITY IMPROVEMENT OF AUTOMOTIVE INDUSTRY USING LEAN MANUFACTURING

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ABSTRACT

Lean manufacturing is defined as a systematic approach to identifying and eliminating waste through continuous improvement, flowing the product at the pull of the customer in pursuit of perfection. The identification and measurement of best practices, in Lean Production implementation, followed by the evaluation of its usage level, in the organizations, are the adequate way through the elimination or minimization of waste. However, the lack of a coordinated and structured roadmap, in the Lean Production implementation, may result in poor and disappointing results. In that sense, it is important to identify the steps required to assess the stages of companies toward the Lean Production system.

The automotive industry under study includes assembly, testing and pre-dispatch inspection department. Kaizen improvements and 5S are the two lean tools that are taken into consideration for improvements. The data is collected for the time study and analyzed with the lean metrics. Line balancing of production line is done in order to remove the unnecessary steps and thus shorten the lead time. The lean manufacturing reduces the lead time and also increases the quality of the product.

INDEX TERMS: Productivity, Lean Manufacturing, Line balancing, Kaizen, 5S.

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1. INTRODUCTION TO LEAN MANUFACTURING

Lean manufacturing is one of the initiatives that many major manufacturing plants in Asia, especially in Malaysia have been trying to adopt in order to remain competitive in an increasingly competitive global market. The focus of the approach is on cost reduction through eliminating non value added activities via applying a management philosophy which focused on identifying and eliminating waste from each step in the production chain respective of energy, time, motion and resources alike throughout a product's value stream, known as lean. Since the birth of Toyota Production System, many of the tools and techniques of lean manufacturing (e.g., just-in-time (JIT), cellular manufacturing, total productive maintenance, single-minute exchange of dies, production smoothing) have been extensively used. This activity is more towards to Toyota Production System (TPS), a systematic approach to identify and eliminate waste activities through continuous improvement. All these effort is objectively to keep cost down and stay ahead in the race.

Industrial organizations have increasingly sought to optimize the resources needed for the manufacture of its products from the competition, in order to maintain their profit margins. The search for balance of resources and balanced distribution of tasks in various types of industrial environments is called balancing. When adjustments are made and adequacy of an assembly line that is already in operation, this process is called rebalancing. Productivity of a manufacturing system can be defined as the amount of work that can be accomplished per unit time using the available resources.

Lean manufacturing has emerged relatively recently as an approach that integrates different tools to focus on the elimination of waste and produce products that meet customer expectations. It helps in reduction of resources and presents benefits such as: reduced delivery time, reduced inventory, better management and less rework [1].

1.1 LINE BALANCING

Line balancing (LB) is usually undertaken to minimize imbalance between machines or personnel while meeting a required output from the line. Line balancing is a tool to improve the throughput of a work cell or line which

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at the same time reducing manpower and cost needed. It is often used to develop product based layout. LB job description is to assign tasks to a series of connected workstations where the number of workstations and the total amount of idle time are minimized for a given output level. The line is balanced if the amount of work assigned to each workstation is identical.

Line balancing is commonly technique to solve problems occurred in assembly line. Line balancing is a technique to minimize imbalance between workers and workloads in order to achieve required run rate. This can be done by equalizing the amount of work in each station and assign the smallest number of workers in the particular workstation.

Generally, LB technique is used by many companies to improve the productivity, decreases the man power, decreases idle time and buffer or even to produce more than two products at the same time. LB technique is used to achieve the minimization of the number of workstations, the minimization of cycle time, the maximization of workload smoothness and the maximization of work relatedness.

Line balancing is commonly technique to solve problems occurred in assembly line. Basically, line balancing tries to minimize imbalance between workers and workload in order to get higher efficiency. There are some methods to solve line balancing problem; Heigesson Birnie Method, Moodie-Young Method, Immediate Update First-Fit Heuristic, and Rank-and-Assign Heuristic.

1.2 '5S' METHODOLOGY

It is one of the simplest tools of lean manufacturing. 5S is a system to have less waste, optimize quality and productivity through maintaining an orderly workplace and using visual signs to achieve operational results. The practice of 5S comes from first letter of five Japanese words and translates as: sort, set in order, shine, standardize and sustain.

i) **Sort:** is the first "S" and refers to sorting tools, equipments on the work place, relocate or remove all components that is unnecessary or not used often.

ii) **Set in order:** means "a place for everything and everything in its place". It aims to organize the work place.

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iii) **Shine:** refers to clean the work area. It involves improving the appearance of the work area and housekeeping efforts. Everything should stay clean.

iv) **Standardize:** everyone in the organization must be involved in the 5S effort. 5S should be implemented with the same way to everywhere.

v) **Sustain:** refers to making sure 5S implementation is followed by the personnel. 5S is a culture and it has to be ingrained into the organization [2].

1. CRITERIA IN LINE BALANCING

There are some criteria which should be considered in a line balancing process. These are takt time, cycle time, downtime and minimum number of workstations which can be explained as below:

A. TAKT TIME

Takt time is pre-requisite procedure in doing line balancing task. Takt time is the pace of production that aligns production with customer demand. It shows how fast the need to manufacture product in order to fill the customer orders. Producing faster than takt time results in over-production which is a type of waste whereas producing slower than takt time results in bottlenecks where the customer orders may not be filled in time. The takt time is determined by using Eq. 1.

$$TaktTime = \frac{Available\,time\ per\ day}{Customer\ demand\ per\ day} \tag{1}$$

B. CYCLE TIME

Cycle time shows how often the production line can produce the product with current resources and staffing. It is an accurate indicator to represent of how the line is currently set up to run. Cycle time is the expected average total production time per unit produced. On an assembly line or in a work cell with multiple operators, each operator will have his own time associated with completing the work he is doing.

Takt time and cycle time are definitely not the same. Takt time represents the maximum time allowed to meet the customer demand whereas cycle time is the actual time necessary for an operator to perform an activity or complete one cycle of his process. Both takt time and cycle time are determined by customer demand. Using Eq.2, we can calculate the cycle time for one engine complete assembly.

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$$CycleTime = \frac{Actual\ production\,time}{\Pr oduction\,required} \quad (2)$$

C. DOWNTIME

Downtime can be defined as that time that is non value added. It is often related with the 7 wastes that are: defects, overproduction, waiting, transportation, unnecessary inventory, unnecessary motion and inappropriate processing.

D. MINIMUM NUMBER OF WORKSTATIONS

A workstation is a physical area where a worker with tools, a worker with one or more machines, or an unattended machine performs particular sets of work together. Number of workstations working is the amount of work to be done at a work center expressed in number of workstations.

Minimum number of workstation is the least number of workstations that can provide the required production. Actual number of workstation is the total number of workstations required on the entire production line, calculated as the next integer value of the number of workstations working [3].

2. THEORIES RELATED TO LEAN MANUFACTURING

Literature is studied for lean manufacturing. Literature review gives detail information about present practices in lean manufacturing and results of advanced researches all over the world. Literature review not only gives the history of a particular problem but also provides results of recent researches on the same.

3.1 A BRIEF HISTORY OF LEAN

Mention 'lean' and most 'lean thinkers' will know that this is a reference to the lean production approach pioneered by Toyota but also the subject of The Machine that Changed the World, a book which first highlighted Japanese production methods as compared to traditional Western mass production systems, it also highlighted the superior performance of the former. The follow-on book, Lean Thinking: Banish Waste and Create Wealth in your Organization is equally a key step in the history of lean as it summarizes the lean principles which 'guide action'. It also coined the phrase 'Lean Production'.

3.2 RECENT THEORIES AND PRACTICES

The recent researches are studied for the lean manufacturing concept, line

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balancing approach and 5S implementation.

2.2.1 Lean manufacturing

Jostein Pettersen suggested that the Lean principles are applicable to any industry. If this is correct, then the Japanese should logically have distributed the knowledge of these principles throughout all domestic Japanese industry. This does not seem to be the case. The only 'true' Lean producers in Japan are confined to the automobile industry, represented by, e.g. Toyota, Honda and Mazda, whereas other areas of industry are performing at the same level as or worse than western competitors. This was pointed out that the principles constituting Lean Production have not received any wide-spread attention outside the auto-industry. He argues that the possibility to become 'Lean' through JIT in particular is highly dependent upon business conditions that are not always met, thus limiting the 'universality' of the concept [4].

3.2.2 Line balancing

R. B. Breginski et al. explained the line balancing methods for flexible manufacturing processes. It includes Heuristic Method of line balancing which normally used for balancing of number of group activities to be performed during operation and explained the problem solution which gives optimum output for such problems. This method is very easy to understand as well as implement into actual analysis is of problem. No extra expense is required to analyze the problem as well as finding solution [5].

Hudli Mohd. Rameez et al. explained main purpose of implementing lean manufacturing is to increase productivity, reduce lead time and cost and improve quality thus providing the up most value to customers. Lean Manufacturing is an operational strategy oriented toward achieving the shortest possible cycle time by eliminating waste. Lean manufacturing techniques are based on the application of five principles to guide management's action toward success. Lean production method is an effective way to improve management, enhance the international competitiveness of manufacturing enterprises [6].

3.2.3 '5S' methodology: P. M. Rojasra and M. N. Qureshi demonstrate the implementation of 5S as lean manufacturing technique in small scale

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industry. Lean manufacturing is one of the options to reduce non-value-added-activity or waste and improve operational efficiency of the organization. The efficient implementation of 5S technique leads to subsequent improvement in productivity of the manufacturing plant. The 5S improves environmental performance and thus relate primarily in reduction of wastes in manufacturing. It promotes neatness in storage of raw material and finished products. The 5S implementation leads to the improvement of the case company organization in many ways [7].

3. CASE STUDY- LEAN IMPLEMENTATION

In order to increase the productivity, the automotive industry decided to take initiative of lean implementation. The Greaves Cotton Limited is one of the leading industries to manufacture single cylinder diesel engines. The case study in this paper is regarding the manufacturing of 3-wheeler TML engine. The different departments include assembly department, testing department and pre-dispatch inspection department. The data is collected and analyzed for all departments.

The following assumptions are used to define the problem:

a) The assembly line is never starved,

b) Set-up times are not taken into consideration. Because in a real system the setup process is usually accomplished at the end of the working time,

c) No maintenance process is performed during the working period,

d) Transportation of raw materials is performed by workers who aren't used for assembly operations.

The method used for improvements is shown in following Fig-1.

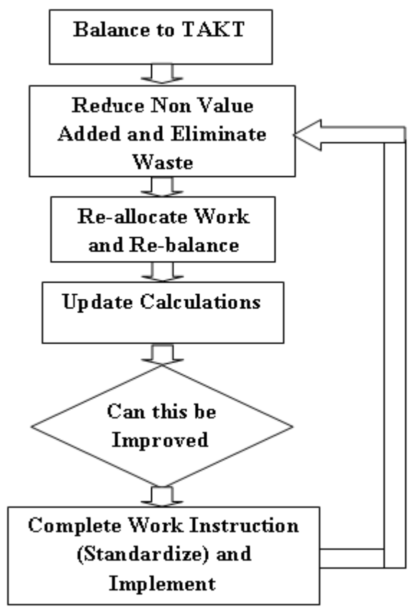

Figure 1: Process Improvement Flow Diagram

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4.1 COMPANY AND PROCESS BACKGROUND

The Industry currently is one of the leading industries to manufacture single cylinder diesel engines. The industry is heading towards becoming the world class leader. They have current peak capacity of assembly of 225 engines/shift, testing of 154 engines/shift and PDI of 200 engines. The industry is seeking to increase its capacity so that it can satisfy the increased demand of the existing customer in the future and also seeks the other customers to bring towards them.

In automotive industries, the main aim while increasing productivity is found to be the increase in number of output units that are manufactured. The lean implementation also takes care of quality of the product that is manufactured. The line balancing of the assembly line is the initiate towards this fulfillment.

Some of the tools used are kaizen improvements, pokayoke, motion reduction, transportation reduction, line balancing, 5S implementation, takt time etc. The steps include process review and data collection, data analysis, observations and data collection after the improvement, results and discussions.

4.2 ENGINE FLOW DIAGRAM

This diagram shows which sequence the product, engine, flows from one department to another department. The engine is assembled in the assembly department on the conveyor. The assembled engine is tested in engine testing department. The torque settings are done in this testing and also the engine is checked for any leak while actual running of the engine. The OK engine from testing department then transferred to pre-dispatch inspection (PDI) department. In this department, all the accessories, markings are added to engine and also the tappet settings are done.

Figure 2: Engine Flow Diagram

Engine Assembly Department

This is the first and the main area of concern towards the lean implementation. There are 30-Online workstations and 9-Offline workstations on the conveyor. The conveyor available

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is power and free conveyor which is already installed. From the data analysis, the target in the productivity improvement is set for assembly of engines, which is 16% improvement.

Process review and data collection Prior to Lean Production implementation, a process review on TML was conducted to investigate the existing method of its actual assembly processes through direct observation. Hardcopy information on actual manufacturing activities is based on their Operations Manuals and the Standard Operating Procedure (SOP). The Cycle Time or Processing Time measured is observed by the video taken from the ongoing process of the assembly in order to establish the baseline for data analysis. Further to that, line observation was conducted to monitor and to grasp full understanding on the current practice at the assembly line as well as to identify types of wastes in the process.

The engine is assembled on conveyor which is already available. The conveyor used is power and free conveyor. The following data is collected as before improvement data. The issues that are found out from the present assembly line are as follows:

a) The activities contain value-added as well as non-value-added activities. Non-value-added activities are taking time that adds no value to the final product. So the time required is more and again there is motion loss. It leads to low production rate.

b) Line is not balanced and one station is taking too much time to complete the set of activities that are subjected to be done on that workstation only. That leads to bottlenecks and the next station is idle for the remaining time.

c) There are idle stations present in the line that are not adding any value to the product, thus leads to take more time to assemble the engine and leads to low production rate.

d) The activities are taking too much time than the actual time they have to take, since they contain various non-value added motions. Thus the time taken for completion of the work for a particular station is more.

Table-1 shows the detailed operations in the assembly line with the processing times at respective stations. The observations before the improvements for assembly line related to total workstations, total capacity of the line

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and the output per man are made which are as below:

a) Number of workstations: 40

(Online- 30, Offline -10)

b) Capacity (Engines/Shift) = 225 Engines

c) Output/Man: Total Team Associate (TA) = 35

Hence, Output/TA = 225/35 = 6.42 Engines/TA

As it can be seen from the above data, there are 30 online workstations. Out of these, five stations are without Team Associate. Out of these, on the two stations there is In-Process Verification (IPV) setup is installed as a quality check point and three stations are idle/man-less stations.

a) DATA ANALYSIS

For the data analysis, total shift time is taken 8Hour and 30minutes, i.e. 510 minutes. Excluding the unproductive time like lunch and other time, the available productive time is 450 minutes.

Table-1: G600WIII Operations Details

WS No.	Operations to be done	Time in seconds
01	Loading of crank case, History card scanning and locate at identified location	74.4
02	Crankshaft fitment, starter plate, retainer plate	94.2
03	IPV-01 (Axial Play Measurement)	52
04	Fitment of camshaft, roller tappet & PRT support, FWE cover	123.6
05	Fitment of cylinder head stud & PTO cover fitment	126
06	Barrel fitment, Piston & con. rod fitment	88.8
07	Fitment of strainer, stud on adaptor for filter fitment	122
08	Fitment of oil pan with loctite & pressure switch on adaptor	68

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09	Oil pan tightening, LOF adaptor fitment	80
10	Positive lubrication pipe fitment	114
11	Stud fitment on starter plate	86
12	FWE tightening in sequence, alternator bracket stand, engine feet trolley	85
13	IPV-II (Torque to turn)	-
14	Flywheel & crankshaft pulley fitment	81
15	Fitment off water pump & water feed pump pulley	81
16	Fitment of FIP, check BDC with dial gauge	126
17	Bumping clearance &TDC marking	75
18	PRT, Push rod, Cylinder head fitment	68
19	Cylinder head tightening, DCNR torquing, Tappet setting	85
20	Water feed pump pulley, inlet and exhaust stud fitment	120
21	Thermostat cover with sealant and stop bracket fitment	79
22	Fuel feed pump and rico valve fitment	79
23	Rocker lubrication pipe, oil return pipe fitment	73
24	Feed pump to FIP pipe and overflow pipe fitment	87
25	Rocker cover, Intake manifold fitment	78
26	Idle station	-
27	Engine air leak test, high pressure pipe fitment	121

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28	Idle station	-
29	Idle station	-
30	Breather cap, name plate fitment, oil dispensing, register entry, barcode scanning and declare engine for	84

From Eq. 2, the cycle time is calculated and which is found to be 2 minutes. This means that there is assembly of one engine for every 2 minutes that is 120 seconds. The time taken for pallet movement from one station to another station is found to be 13 seconds. This shows that the available time for working on the each station is 107 seconds.

Based on this, the target is set for 16% improvement which gives 262 engines per shift and with the takt time of 103 seconds. Excluding the prior available pallet movement time between stations, the time available for completing the work at each station is found to be 90 seconds, i.e., the assembly line should be balanced for 90 seconds. This is the takt time for assembly department.

b) IMPROVEMENTS IN ASSEMBLY LINE

The improvements done are done by kaizen improvements and 5S implementation on the assembly line. These improvements reduce the motion losses, waiting losses, transportation losses, etc. Apart from these improvements, pokayoke improvements are also done as quality improvements.

KAIZEN IMPROVEMENTS:

These are done for reducing fatigue and motion losses. These improvements help to reduce the time for completing the task. The non-value-added activities or motions are eliminated/reduced with the help of proper kaizen improvements.

Rebalancing is done by the proper shifting or distribution of activities at various workstations such that identical time is required at all workstations to complete the activities distributed on them.

These are continuous improvements. The basic idea of improvement is got form actual walking on the assembly line. The operator on the station provides the idea of the improvement.

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This helps to reduce the fatigue to the worker.

Some of the kaizen improvements are as shown in following Tables.

Table-2: Kaizen Improvements (1)

Kaizen Objective: To reduced time and fatigue	Idea: To provide location arrangement for gasket and TDC plate
Problem/Present status: More time and fatigue during taking of material	Countermeasure: Gasket and TDC plate bin provided in right side of operator
Before	After
	
Description: Material taking on back side (Time required= 11 sec)	Description: Material taking on right side (Time required= 7 sec)

As shown in Table-2, the location for the bin is changed. This reduces the fatigue to the worker. The location of the bin is also placed at the good height and distance.

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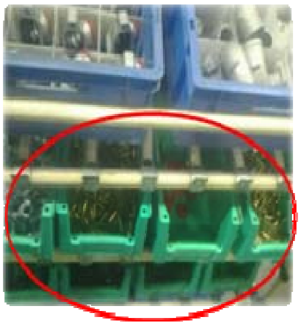
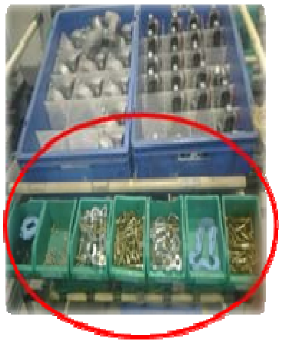
Table-3: Kaizen Improvements (2)

Kaizen Objective: To reduced time and fatigue	Idea: To provide arrangement for FIFO rack
Problem/Present status: More time and fatigue during taking of material	Countermeasure: Small bin attached over FIFO rack at comfortable level
Before	After
	
Description: Material bin is not at comfortable level (Time reqd= 09 sec)	Description: Small bin provided at comfortable level (Time reqd= 3 sec)

As shown from Table-3, it is seen that the bin before was not at the comfortable level. The comfortable level of bin reduces fatigue to the worker.

Table-4: Kaizen Improvements (3)

Kaizen Objective: To reduced time and fatigue	Idea: To provide arrangement for FIFO rack
Problem/Present status: More time and fatigue during taking of solenoid bracket	Countermeasure: Slant tray provided in the side of operator
Before	After

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Description: Solenoid bracket taking from back side (Time reqd= 8 sec)	Description: Solenoid bracket taking from side of operator (Time reqd= 4 sec)

Table-4 shows that before kaizen improvement, the solenoid bracket has to be taken from the back side of the worker. After, the tray is provided by the side of the operator.

Table-5: Kaizen Improvements (4)

Kaizen Objective: To reduced time and fatigue	Idea: To provide arrangement for back plate & air shroud
Problem/Present status: More time & fatigue during BOM issue	Countermeasure: Hanger type trolley provided for back plate & air shroud
Before	After
 	

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Description: Before BOM issue for back plate, it is in box (Time reqd= 09 sec)	Description: Trolley for Air shroud & back plate (Time reqd= 6 sec)

Table-5 shows before kaizen improvements, the back plate was provided in box on the assembly line which causes fatigue during BOM issue. The trolley is provided for air shroud And back plate, reduces fatigue and time during BOM issue.

5S IMPROVEMENTS

These are workplace related improvements. These cause the best utilization of the workplace.

Table-6: 5'S' Improvements (1)

5S Objective: To improved 5's' and increase working space	Idea: To provide location arrangement for s/a of EGR valve
Problem/Present status: 5's' not maintained and difficulty for working	Countermeasure: Hanger provided for s/a of EGR valve
Before	After
	

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Description: S/a of EGR valve on working table	Description: S\a of EGR valve on hanger

Table-7: 5'S' Improvements (2)

5S Objective: To improved 5's'	Idea: To provide location arrangement for oil return pipe fitment gauge
Problem/Present status: 5's' not maintained	Countermeasure: location change and separate stand provided for gauge
Before	After
	
Description: Gauge location and material bin location is same not separate	Description: separate location provided for gauge location

As shown in Table-6 and Table-7, these are 5'S' improvements. The right location is set for all the materials. After usage, same is placed to its respective location. These are out of some of the 5'S' improvements.

Table-8 shows the time before (P) line balancing and the time required after (Q) line balancing at all workstations. Action taken to reduce the timing at each workstation is also included in the table. All the time study is done in seconds.

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Table-8: Time Before and After the Improvements and the Actions Taken

WS No.	P	Q	Actions Taken
01	74.4	85	Activity rebalanced for 90 sec
02	94.2	88	Activity rebalanced for 90 sec
03	52	52	IPV-1 (End Float) Man-less
04	123.6	82	Layout changed & rebalancing done
05	126	81.4	Motion loss reduced
06	88.8	81.6	Motion loss reduced
07	121.2	69	Motion loss reduced
08	67.2	82	Activity rebalanced for 90 sec
09	79.2	67.8	Activity rebalanced for 90 sec
10	124.8	82.2	Activity rebalanced for 90 sec
11	85.2	81.6	Activity rebalanced for 90 sec
12	85.2	85.8	Activity rebalanced for 90 sec
13	62	62	IPV-2 Torque To Turn (Man-less station)
14	81.6	79.2	Motion loss reduced
15	81	84	Activity rebalanced for 90 sec
16	126	72	Motion loss reduced
17	81	66.6	Activity rebalanced for 90 sec & motion loss reduction

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18	67.8	87	Activity rebalanced for 90 sec
19	85.2	75.6	Activity rebalanced for 90 sec
20	120.6	69	Motion loss reduced
21	78.6	90	Activity rebalanced for 90 sec & motion loss reduced
22	78.6	78	Activity rebalanced for 90 sec
23	73.2	82	Activity rebalanced for 90 sec
24	86.4	85	Activity rebalanced for 90 sec
25	0	82	Idle station used to utilize conveyor & Activity rebalanced for 90 sec
26	77.4	83.4	Activity rebalanced for 90 sec
27	121.2	73.2	Motion loss reduced
28	0	0	Idle station
29	0	0	Idle station
30	84	72.6	Motion loss reduced

Thus, the total task time required before line balancing is 2426.4 seconds and that required after line balancing is 2180 seconds. Fig-3 below shows the graph for above data for Online WS-01 to WS-30. WS-28 and WS-29 are idle stations. The activities at all workstations are balanced for 90 sec by using motion losses, changed layout and rebalancing of activities.

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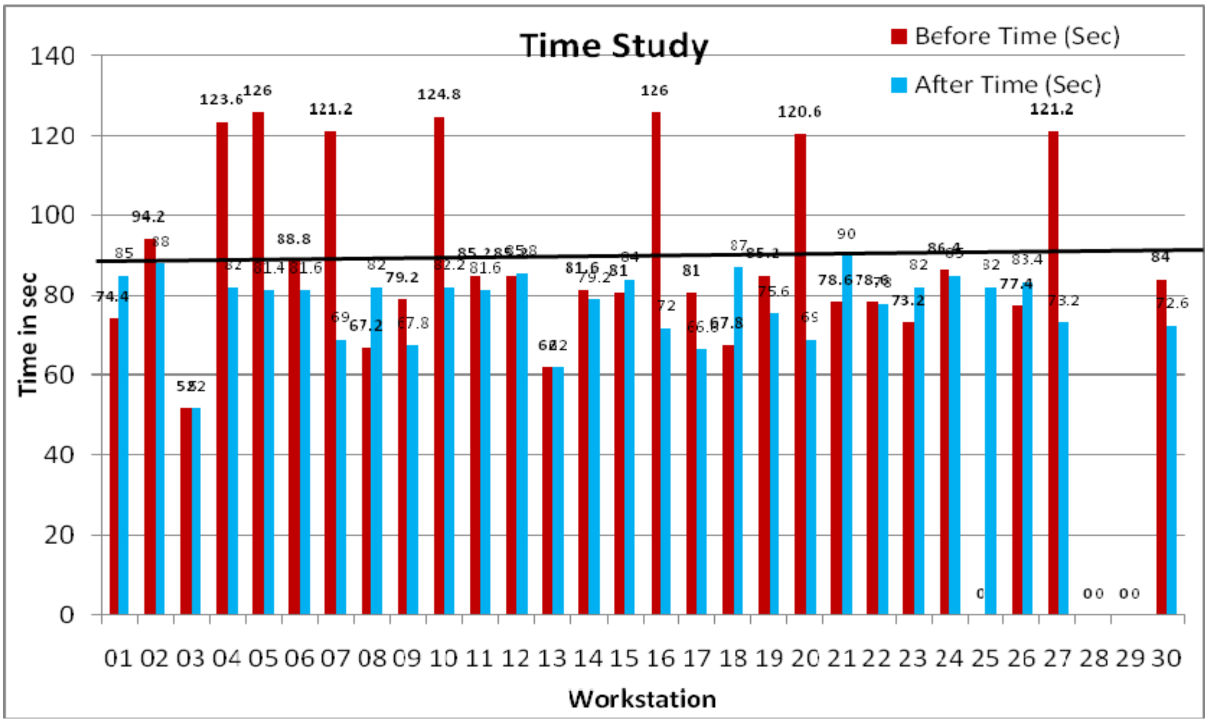

Figure 3: Time study and Takt Time

As shown in above Figure 3 , the cycle time is rebalanced for 90 seconds at all workstations, which is takt time.

c) DATA AFTER LEAN IMPLEMENTATION

i) Production capacity:

Before Improvement = 225 Engines/Shift

After Improvement = 262 Engines/Shift

Percentage Improvement = (262-225) / 225×100

= 16% improvement.

ii) Production lead time: Time from start of physical production of first sub-module/part to production finished (ready for delivery).

From Table-7, the production lead time before was 2426.4 seconds and that after line balancing is 2180 seconds. Thus production lead time is also found to be reduced.

iii) Product yield per employee or Output/Man = 262/34 = 7.71 engines, which was 6.67 engines before improvement.

iv) It determines optimize use of labor. It measures effectiveness of manufacturing process and productivity of employee. Thus, in this case study, it is found to be increased.

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v) Additional 925 (= 37×25) engines can be made in one shift basis only.

vi) With 225 engines/shift we can ran single shift up to maximum 5625 engines/month but with 262 engines/shift, we can achieve 6550 engines per month with the same manpower.

d) Results Observed after Lean Implementation

i) Productivity Improvement

Increase in the number of engine assembly leads to increase in the productivity. Here, the number of engines assembly is increased from 225 to 262 engines per shift. Percentage improvement observed is 16% improvement. This shows that the lead time is also reduced since there is increase in the number of engine assemblies in the same amount of time.

ii) Line Efficiency

Eq. 3 below shows the formula for calculating the efficiency of the assembly line. From Table-7, adding the data for before line balancing, the equation gives the line efficiency before improvement [7].

$$Line\ \ Efficiency = \frac{\sum Task\ \ Time}{(Number\ \ of\ \ Workstations \times Largest\ \ Cycle\ \ Time\ )}$$

.... (3)

Line Efficiency = 2426.4 / (30 × 126) = 64.19%

Now, adding the data for after line balancing, Eq. 3 becomes,

Line Efficiency = 2180 / (30 × 90) = 80.74%

Thus, it can be seen that there is improvement in line efficiency from 64.19% to 80.74%.

I. G600WIII Engine Testing Department

In this department, every assembled engine is tested for its performance and the various settings are also done while testing of the engine. Some of these settings includes maximum RPM setting, low RPM, idle RPM settings, rico valve setting, etc. Testing of engine includes loading of engine on the testbed then running the engine and setting the different engine specifications and then again unloading of the engine. Testing department consists of total 11 testbeds on which engine is tested.

Following roadmap is prepared for the improvement in the testing department.

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i) Video to be taken from Loading + Connection + Removal of connection to unloading.

ii) Conduct time study (Loading + Running + Unloading).

iii) Identify wastages/Improvement opportunities.

iv) Implement kaizen.

v) Check results.

a) Data Collection before and after Improvement

The data included the activities to be performed along with the time require for those activities before and after improvement. The improvement actions taken are also included in the Table-8. The improvements done are mainly kaizen improvements. The data collection is done for the three steps, loading of engine, running in cycle of engine and unloading of the engine.

Table-8: Engine Testing Department Summary

Terms	Before	After	Improvement
Loading(sec)	419	153	266
Running cycle(sec)	1166	982	184
Unloading (sec)	344	139	205
Total time (sec)	1929	1274	655
Cycle time (min)	32.14	21.23	10.55
Total hr working (min)	450	450	
Output per engineer(engine/engineer)	14	21.19	7
Testing capacity (engines/day)	447	670	223

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b) Data Analysis for Observations Before and After the Improvements

Manpower required for 447 engines/day = 2.8 shifts/day.

Before required = 447/14= 32 TA (approx.)

After required = 447/21.19 =21 TA(approx.)

Benefit it can be seen that, after the improvements, required 11 Team associates (TA) less than previous.

Investment for test-bed improvement:

Per test cell investment (Rs. in lacs) = Rs. 0.5 lacs.

Total test bed (11nos.) investment = 11×0.5 = Rs. 5.5 lacs.

The required investment is regained back with the reduction in TA.

II. G600WIII PDI DEPARTMENT

This is the last department under study. This includes the per-dispatch inspection of engine. It also includes the addition of OK tags, markings, final tappet setting, and applying anti-rust. The data collection, data analysis, observations and data collection after the improvements are the major steps included in this study.

a) Data Collection and Improvements

There are 10 Workstations, Operation-10 to Operation-100. The following Table-9 shows time taken at various workstations before and after rebalancing and actions taken to rebalancing the PDI line.

Table-9: Engine PDI Department Summary

WS No.	Time Required (sec)		Actions taken
	Before	After	
OP-10	88	110	Line balanced for 110 sec
OP-20	85	0	Retorquing eliminated
OP-30	128	100	Motion eliminated
OP-40	112	105	Motion eliminated

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OP-50	100	100	-
OP-60	135	101	Motion eliminated
OP-70	135	106	PTO retorquing eliminated
OP-80	132	103	Motion eliminated
OP-90	70	102	Line balanced for 110 sec
OP-100	105	109	Paint marking eliminated for one place

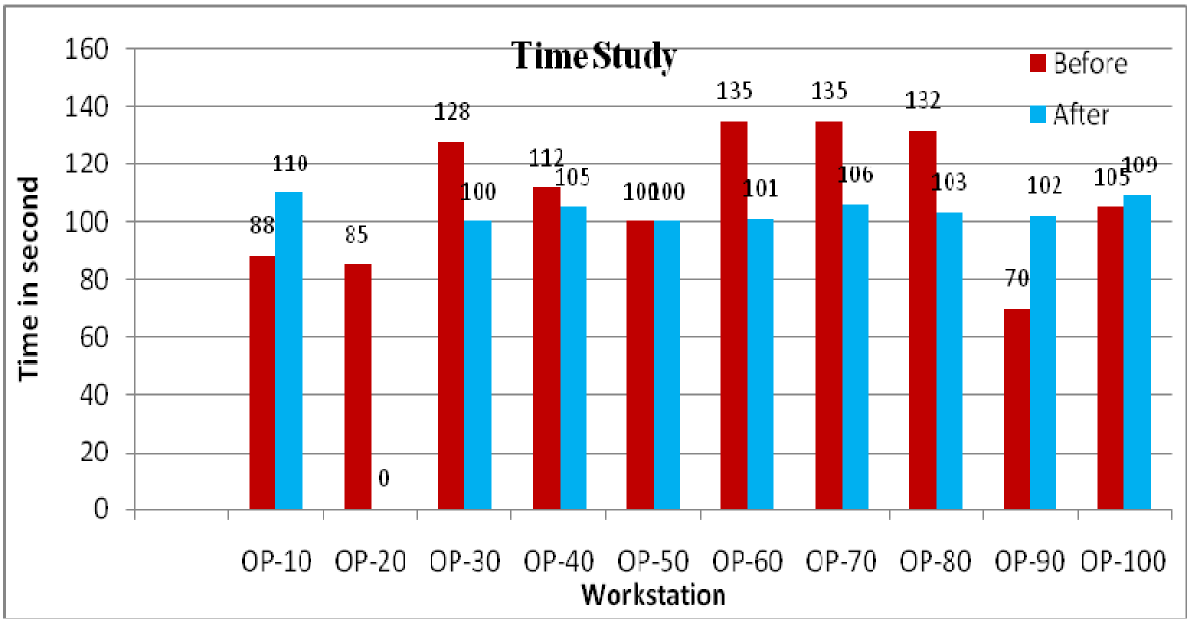

Figure 4: Time study and Takt Time

Fig-4 shows the graph for the time study for various workstations in PDI department. It can be seen that, all the workstations are balanced for the takt time of 110 seconds. The operation-20 is eliminated after the improvements [8].

b) Observations after the Improvements

i) Capacity improved to 270 engines/shift from 200 engines/shift.

Percentage improvement = (270-200)/200×100

= 35 % improvement.

ii) Output per man is improved from 20 nos. engines to 27 nos. engine.

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iii) Additional 1750 nos. of engines per month can be made in one shift basis only.

iv) With 200 nos. engines/shift, we can run a single shift upto max. 5000 engines/month, but with 270 nos. of engines/shift, we can achieve 6750 nos. of engines/month with optimum manpower.

5. CONCLUSIONS

This is concluded that the assembly line balancing is one of the major step to be taken into consideration while increasing productivity of automotive industries. Line balancing is done with taking in account the takt time, cycle time and downtime and thus reduces the production lead time with increased number of output engines. Continuous improvement is the step to reduce unnecessary downtime losses. The productivity of engine assembly line is thus found to be increased. The testing department and PDI department also have some non-value-added activities. Those are also reduced or eliminated by the kaizen improvements and 5'S' changes and the operation are rebalanced taking in account the takt time. The productivity of both testing and PDI departments is also found to be increased. Thus lean manufacturing concept when deployed increases the productivity. The primary lean tools used are kaizen improvements and the 5S implementation. By using line balancing and Lean techniques, practitioners can better calculate the time and effort needed to complete their products or services, and also utilize their resources to the fullest to produce the output demanded by the customer.

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