Productivity Improvement in Engine Assembly Line at GM India Ltd. Pune, India

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Abstract- Productivity is a measure of the rate at which outputs of goods and services are produced per unit of input (labour, capital, raw materials, etc). It is calculated as the ratio of the amount of outputs produced to some measure of the amount of inputs used. GM India Pvt. Ltd. (power train department) management planned about capacity planning and scheduling of engines as per demand. But because of the some areas where bottleneck happens they failed to implement existing plan. The productivity improvement process uses basic data to identify bottlenecks. Production counts, overtime, buffer monitoring, blocked and starved, downtime and cycle time analysis these are the techniques used alone, or in combination to identify bottlenecks. By observing and collecting previous data some areas are identified where bottlenecks happens. In this paper, main focus is to reduce the bottleneck areas by applying necessary techniques. It is found that main areas where bottleneck happens are, head sub-assembly keyup station, tappet line and hot testing of the engines. Engine head sub assembly is semiautomatic intake and exhaust key installation station. In which keys are used for locking the spring with retainer in it. There are two machines separately working on petrol engine head and diesel engine head. FTQ (first time quality) for diesel engine was 60% to 70% and for petrol engine it was 0%. We design and modified manually operated tool for the system which improved FTQ 100% for petrol engines. For improvement in hot testing area line balancing is necessary, means leveling the workload across all processes in a cell or value stream to remove bottlenecks and excess capacity. We found out various NVA (non-value added) activities and with the help of pareto principle we sorted out most probable causes i.e. Traffic problems of cart, unwanted movements and handling of equipments etc. By applying these all techniques the productivity is increased from 210 to 233 i.e. 9.8% improvements in engine assembly line.

Keywords – Productivity, Bottleneck, FMEA, Engine head, Line balancing.

I. Introduction

GM India Pvt. Ltd. Pune India (Power train department) management planned about capacity planning and scheduling of engines as per demand. But due to some areas where bottleneck happens they failed to implement existing plan. The productivity improvement process uses basic data to identify bottlenecks. Production counts, overtime, buffer monitoring, blocked and starved, downtime and cycle time analysis these are the techniques used alone, or in combination to identify bottlenecks (Roser, Nakano, Tanaka, 2001). From the previous data collected and observations some areas are identified where bottlenecks happen and our main focus to reduce the bottleneck areas by applying necessary techniques. It is found that main areas where bottleneck happens are, head sub-assembly keyup station, tappet line and hot testing of the engines. Engine head sub assembly is semiautomatic intake and exhaust key installation station. In which keys are used for locking the spring with retainer in it (Instruction manual of Head sub-assembly). In engine head assembly keyup station for implementation of new techniques it is very important to do the FMEA (Failure mode effect analysis) for problem solving purpose**.** Tappet line sub-assembly is semiautomatic assembly station where cam bore and cam shaft are measured (Instruction manual of Tappet line). However since the dimensions were not measured properly may results in wrong tappet selection. So it is necessary to find out root-cause, implement action plans and troubleshooting of different possibilities for wrong tappet selection.

For improvement in hot testing area line balancing is necessary, means leveling the workload across all processes in a cell or value stream to remove bottlenecks and excess capacity (Moberly and Wyman, 1973). Installation for the new test cell involves the planning for new area required for the involvement process. But first of all it is necessary to have the information about the existing area is enough for the existing test cell or not. Also the time study of the existing area is necessary with help of the method study. Critical examination of the information recorded about the process in charts is the most important phase of the method study. Each element of the work, as presently being done and recorded on the chart is subjected to a systematic and progressive series of questions with the purpose of determining true reasons for which it is done (Toyota Production System Handbook).

Productivity measures are used at the level of firms, industries and entire economies. Depending on the context and the selection of input and output measures, productivity calculations can have different interpretations such as bottleneck detection, FMEA, lean manufacturing, line balancing, etc.

1.1 Bottleneck Detection: (Hopp and Spearman, 2000) stated that utilization of a machine is defined as the ratio of arrival rate of parts to be processed to effective production rate. Also the percentage of utilization is calculated for each machine in the system and the machine with the largest percentage of utilization is considered to be the bottleneck resource. The author does not discuss about the % of time spent by a machine in blocked state when they illustrate this technique with an example. (Roser, Nakano, Tanaka, 2001) have categorized all possible states of a machine into two groups: active and inactive states. A machine is said to be in active state when the current state of the machine is aimed at improving the system throughput. Starving, blocking and waiting for services are classified under inactive states.

1.2 Failure Mode Effect Analysis : (Liu, Liu and Liu, 2013) stated that risk evaluation approaches in failure mode and effects analysis (FMEA) is a risk assessment tool that mitigates potential failures in systems, processes, designs or services and has been used in a wide range of industries. The conventional risk priority number (RPN) method has been criticized to have many deficiencies and various risk priority models have been proposed in the literature to enhance the performance of FMEA. (Yesmin, Hasin and Proma, 2013) conducted research work in pharmaceutical company using a very effective tool named FMEA, consisted of observing the works at different sections, breaking them down into sequential steps, noting the surrounding variables of each task, and using these data to perform risk analysis. to find out the most hazardous works for the workers.

1.3 Lean Manufacturing: (Womack, Jones and Roos, 1990) stated that Lean Manufacturing is a production philosophy that targets the identification and elimination of any waste in the production processes; especially reduce waste in human effort, inventory, time to produce and production space etc. The concept of Lean was originally developed by Toyota (TPS) for their automobile manufacturing replacing mass production. (Czarnecki and Loyd, 2001) mentioned that waste is generally caused due to unnecessary delays, processes, costs and errors. The seven types of wastes associated with Lean are overproduction, transportation, processing, inventory (work-in-process and finished goods), waiting, motion and defects. The main focus of Lean is to address the value-added and non-value added activities.

1.4 Line Balancing : (Moberly and Wyman, 1973) proposed the approach of using simulation two compare two assembly line configurations. According to Moberly, the study of production line configurations along the length of the line is called assembly-line balancing. The set of work stations along the line that results from this balancing is the generated line configuration. They demonstrate splitting the assembly line width wise rather than length wise i.e., one workstation is replaced by two identical parallel stations and they named it as dual production line. (Becker and Scholl, 2006) done survey of the simple assembly line balancing problem and several mathematical techniques that can be applied to solve this problem. They give an integer and dynamic programming approach to solve an assembly line balancing problem.

II. METHODOLOGY

A. Head Sub-Assembly Keyup Station Improvement –

To find out the failure modes (What could go wrong?) different online readings for the different series of engines are to be taken in slandered format considering the no. of defects appeared. The comparison is done with comparing defects in different manners. Various defects presents are RH key up, RH key incline, RH key miss, LH key up, LH key incline, LH key miss. After taking readings of 89 SDE and 337 xSDE engines, it is found that the main defect is due to right dolly and defects found are shown in table (See Table 1).

Table I Defects for SDE and xSDE Engines

Comparison of dolly		
Dolly	No. of defects SDE	No. of defects SDE
Right	308/356	549/1011
Left	7/356	11/1011

With these observations and by checking different systems it is found that most of the defects are related to the right dolly and pneumatic system used for feeder system, vertical slide assembly, pallet with lifter assembly, drive assembly, etc. Figure (Fig. 1) shows various components of air preparation units from newly installed systems. Action taken and check points made for these systems are shown in table (See Table II).

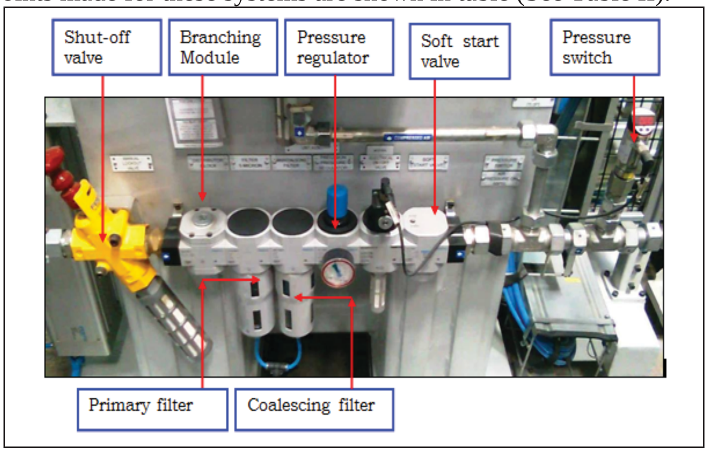

Fig.1 New Installed Air Preparation Unit

Table II Action Taken for Troubleshooting of Vertical Slides Failure

Observation	Cause	Action taken and check points
Vertical slide fails to operate	Air supply failure	Check the air supply pressure and air leakage from the pneumatic fittings or pipes. Replaced damaged part.
	Failure of seals Failure of pneumatic cylinder to advance or retract will cause a cycle fault, shutting down the machine and stopping the production	Seals are rated for 1000000 cycles. Seals are rated for appropriate chemical composition. Seals were prematurely fail due unmatched chemicals are introduced to the process. Inspected the seals for pre-mature wear and expected time to failure. This is done by the skilled person.
	Failure of LM block	Checked the LM blocks and LM rail. LM blocks are recommended to use at below 80^0C. Checked the cycle for which LM blocks is running.
	No electrical signal at proximity sensors or reed switch	Checked the electrical supply to sensors. Checked the mounting of sensors in the bracket. Tighten the mounting hardware.

B. Tappet Line Troubleshooting

According to the measurement of the cam bore and cam shaft dimensions selection of the tappet is to be carried out. After tappet is fixed there is manual inspection is done for checking that the selection of tappet is correct or not for that following specified filler gauges are used. For tappet line sub-assembly we found out defects for intake and exhaust valve which is shown in detailed in table (See Table III) and problem and cause for lubrication module is resolved shown in table (See Table IV).

Table III Comparison for the Measure Defects of Tappet Failure

SIDE	GO/NOGO	DEFECTS
INTAKE	GO GAUGE	123
	NOGO GAUGE	29
EXHAUST	GO GAUGE	139
	NOGO GAUGE	112

Table IV Causes and Troubleshooting for Lubrication Module

Problem	**Cause**
Lubricating oil not reaching at the parts to be lubricated.	Electrical supply to lubricating oil motor with pump failure.
	Air pressure low or leakage.
	Oil pressure very high or very low.
	Oil level low in the oil sump.
	Lubrication motor trip.
Quantity of oil at the lubricating points cannot be controlled.	Blockages in the supply line. Foreign particles in the circuit.
	Metering cartridge failure.

Tappet thickness verification machine installation is going on for revaluation that the tappet which is selected by operator is wrong or right.

C. Hot Test Cell Area-

Time Study at Hot Test Station has showed that major deviations from STDS exist, and such identifying related issues has become simpler. The following graph represents the actual time in seconds required by the operators working at the station to complete the cycle over a period of time. We take readings it was found that actual time required and ideal time given for completing engine's rigging is shown in figure (Fig. 2) and figure (Fig. 3) shows de-rigging station.

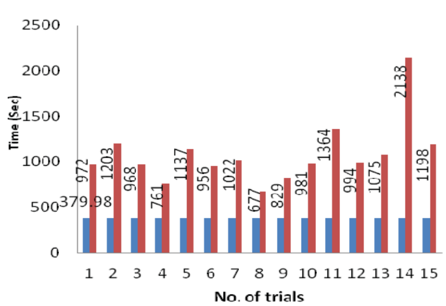

Fig. 2 Steps Charts of Rigging

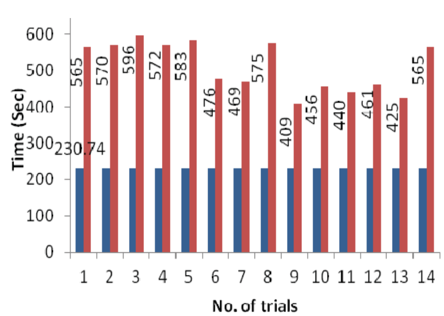

Fig. 3 Steps Charts of Derigging

IV. RESULTS AND DISCUSSIONS

A. Head Sub-Assembly Keyup Station

New designed tool for HS50 is installed, that needs some changes in the layout of head sub-assembly station. Old layout of head sub-assembly is shown in figure (Fig. 4) and modified layout is shown in figure (Fig. 5). After installation of manual tool the process is as shown in figure (Fig. 6).

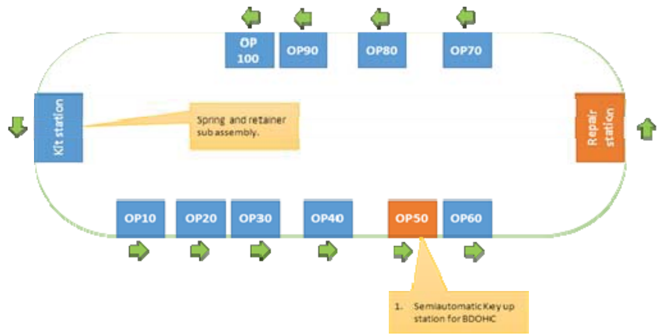

Fig. 4 Layout of Head Sub-Assembly

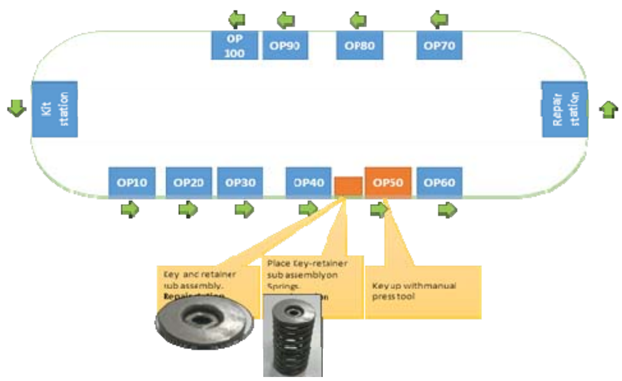

Fig. 5 Layout of Head Sub-Assembly with New Station

Fig. 6 Photograph of Manual Operating Process with New Tool

The manual operating process shown in figure (Fig. 6) is installed for BDHOC engine by installing this tool and troubleshooting related to head sub-assembly line the observations noted are:

- By installing manual new tool, rework for BDHOC engine is reduced to 0%.
- By applying troubleshooting noted in Table II efficiency is improved to 20% (from 60% to 80%).

B. Tappet line troubleshooting

Tappet line causes main downtime while processing BDOHC engine.

- By implementing trouble shooting noted in table (See Table IV) it is found out that efficiency of the tappet line is nearly improved by 15 to 20%.
- Tappet verification gauge is used to reduce the time required for revolution of engine which saves 70-80 sec. per engines.

C. Hot test cell area

We found out different various NVA (Non-value aided) activities and with the help of Pareto principle we sorted out most probable causes i.e. traffic problems of cart, unwanted movements, handling of cart etc. and we identified waste what are actions taken to resolve these waste are shown in table (See Table V).

Table V Waste identification and elimination

Waste Identified	Lost Time (in Sec.)	Waste Type	Action Taken To Eliminate
Improper location of turbo adopter	10	Over motion	Proper location made available on test cart to avoid the over motion, time required and bending.
Engine dip stick not at proper location	05	Over motion and Defect	Proper location is made available at test cart itself to avoid the over motion and dip stick damage issue.
Coolant and fuel evacuation pipes kept on floor in mixed condition	06	Over motion	Proper location is defined so that TM over motion and bending avoided
TM has to bend for handling the fuel pipe horse collar and bolts	02	Over motion	Proper location is defined so that TM over motion and bending avoided
Wrong plier location leading to excess searching time.	09	Over transport	Plier location defined on engine lifting tackle itself to avoid the searching time.
Extra effort requires to push/pull the engine test cart	10	Fatigue +Over transport	Test cart handle modification done so as to reduce the pull and push force/ Efforts bending movement of TM.
No provision for keeping ok and NOK bolts on engine transfer/rework trolley.	12	Over transport	Provision of separate green and red bins made available on rework trolley to avoid the over transport
Engine masking plastic caps misplace and extra/unnecessary searching time.	15	Over motion + fatigue	Proper box arrangement made available to avoid the searching time and cap missing issue.
Improper location of hot test consumables.	20	Over transport + fatigue	Fixed location defined with proper labeling on each box
Engine mounting plate tool having wrong location	6	Over transport+ fatigue	Location defined on engine lifting tackle itself to have ease in handling the tool.
No locations for oil pressure switch connector.	2	Over motion	Fixed location with proper arrangement for oil pressure switch made available.
Battery operated gun misplaced condition.	10	Over transport+ Over motion	Proper fixed location defined to avoid the searching time.

Waste eliminated:

After implementing and actions taken to eliminate waste motion, transport, bending motion and time reduced are:

- Over Motions reduced by 1,260 KM per Year,
- Over Transport reduced by 1,320 km per Year
- Bending Motions reduced by 2,40,000 nos. per Year
- Over processing time reduced to 307 Hrs. per Year.

D. CASE STUDY

i. Cart Modification**:**

The cart handling in hot test cell extra effort requires to push/pull the engine test cart so it was not significant job for the operator to handle it and results in fatigue of operator and turning moment requires for operation was more resulted in over motion. Test cart handle modification done so as to reduce the pull and push force, bending movement of operator.

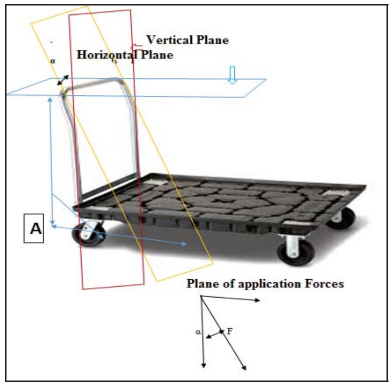

Fig. 7 Cart with Different Plane

By mathematical analysis (classical mechanics approach), and by selecting different planes as in figure (Fig. 7) we calculate forces required using translational and rotational motion to handle cart accordingly cart before implementation and after implementations photos shown in figures (Fig. 8~9) respectively.

Fig. 8 Cart Handle Before Implementation

Fig. 9 Cart Handle Improvement After Implementation

Waste eliminated:

By making these improvement in handle of test cart following wastes are eliminated,

- Time saved by these cart handle improvement is 10 sec per engine.
- Bending moment and fatigue saved for 200 engines per day.

ii. Layout modification:

In hot test area Hot test cell- 03 is newly installed so as to it is essential to make changes in layout of hot test area. In existing area it is found that though the equipment are enough for testing but there was unnecessary walking of operators, excess material handling and traffic problems were main issues.

The layout of hot test area was shown in figure (Fig. 10) and newly modified layout of hot test is shown in figure (Fig. 11).

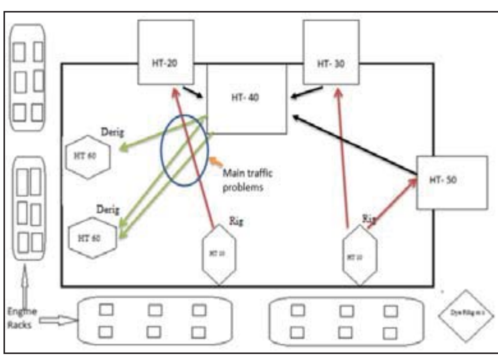

Fig.10 Old layout of hot test cell area

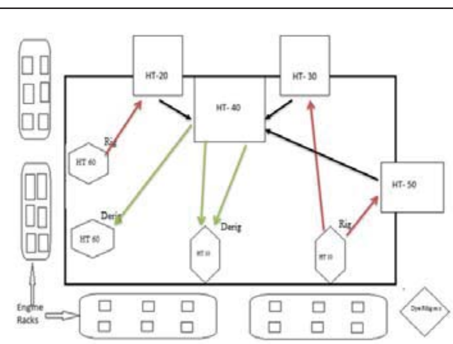

Fig.11 New layout of hot test cell area

Main area of where traffic issue was occurred is shown in figure (Fig. 10). The occurrence of problem is because of improper layout designing. So that we shifted one rigging station to derigging station and vice-versa. Modified layout is shown in figure (Fig. 11).

Waste eliminated:
By making these improvement layout of hot test cell following wastes are eliminated, and time saved by hot test cell area modification is 20 sec per engine.

V. CONCLUSIONS

Based on the installation of new tool and troubleshooting for head sub-assembly, tappet line sub-assembly also action taken in hot test cell are, following conclusions are drawn.

- Productivity improvement in one sub-assembly system causes improvement in other sub-systems too.
- Implementation of new manual tool for the head sub assembly results 100% improvement in BDOHC engine.
- Substantial reduction in operator’s efforts causes due to new tool implementation and improvement in efficiency by 25 to 30% by causes and troubleshooting in lubrication module.
- NVA reduction by proper sequence of arrangement in activities and by applying different Kaizen techniques in hot test cell area (65 sec) time is saved for testing engines.

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