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Improving Line Efficiency & SMED Study

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***Abstract*— This work deals with the analysis and identification of factors affecting assembly line efficiency based on the case study of a shock-absorber assembly line. After evaluation of line efficiency and identification of factors, few methods for the improvement of efficiency are provided.**

The focus is laid on the reduction of setup-time of different work station during the change of production from one model to another; for this Single Minute Exchange of Dies (SMED) technique is being suggested for a workstation in the assembly line under observation, along with its implementation technique.

Keywords*— *Assembly Line, Line Efficiency, Factors Affecting Line Efficiency, SMED.

I. INTRODUCTION

In the time of sustainable development, one of the major concerns for manufacturing industries is to improve the assembly line efficiency to fulfil the customer orders with the limited resources. For this purpose various factors affecting the assembly line efficiency are to be identified and eliminated; but the factors which affect the performance of assembly lines are difficult to be assessed and solved by mathematical models.

This study aims at identification of such factors which lowers the assembly line efficiency and few solutions are provided based on the observations which might improve the line efficiency.

Along with solutions, SMED technique is applied to reduce the setup time which contributes to the efficiency improvement.

II. LITERATURE REVIEW

A brief literature review related to line balancing and SMED which formed the basis of this work.

- *Hafezalkotob et al. (2014)* presented a case study about balancing a production line with the help of simulation and statistical technique. They presented two improvement scenarios. In the first scenario, the layout design of the factory was improved with regard to production process and bottleneck station. In the second one, an essential improvement was carried out by reduction in wastages [1].
- *Subramaniam et al.* considered the manpower utilisation and machine efficiency as the factors contributing to production line efficiency. They emphasized that management should look for relevant production data and accurately interpret those data in order to identify the various faults at production level and immediately take steps to improve efficiency. They also suggested the use of accurate OEE charts [2].
- *Sathish and Lakshmanan (2015)* calculated assembly line efficiency based on a case study of automobile cluster assembly line according to the existing layout and a new improved layout. The efficiency value showed a large improvement [3].
- *Sivasankar et al. (2011)* performed the experimental verification of SMED and concluded that the improvement techniques may be assessed both in terms of their allocation to the methodology's stages and in terms of their collective representation of a full range of potential improvement options [4].
- *Joshi and Naik (2012*) applied SMED to battery assembly line and concluded 20% decrease in total time and 30% reduction in cost. They showed, not only is it imperative to focus on reducing the amount of productive time that is lost when a machine is being set, but also to eliminate errors, with the application of poka-yoke principles to the setting equipment and procedures [5].

III. PROBLEM STATEMENT & METHODOLOGY

The process of balancing assembly line is a continuous process and cannot be achieved with 100% efficiency, so steps are to be taken continuously in a manufacturing plant to overcome various limitations and factors for the smooth functioning of production line.

This work is based on the calculation of Assembly line efficiency and thereafter identifying and analyzing the factors affecting the line efficiency and also SMED technique has been used.

In the assembly line under study there were certain workstations which were acting as bottlenecks in the assembly operation thereby reducing its efficiency. The line was not able to produce according to the consumer demand or order placed.

The various steps of the methodology adopted for studying assembly line of a shock-absorber assembly are as follows:

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A. Data Collection

In the case study undertaken following data related to task time of individual workstations was collected by performing time study using Stop-watch method.

TABLE I. TASK TIME OF WORKSTATIONS

		Observations in seconds						
Elemental Activity	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*Avg.*
Piston Valve Mounting	4.98	5.21	5.42	6.01	5.54	5.20	5.31	5.38
Piston rod riveting	7.69	8.23	8.24	8.17	8.80	8.75	9.20	8.44
Piston rod assembly	10.1	9.83	9.17	9.8	10.23	8.63	10.23	9.71
Bottom valve pressing	4.35	4.84	4.56	5.21	4.87	4.10	3.90	4.54
Oil filling	5.76	5.54	6.66	5.80	6.88	7.58	4.69	6.13
Guide disc pressing	3.21	3.35	3.7	3.74	4.34	3.8	3.6	3.67
Damping force testing	8.51	8.25	7.98	7.92	8.76	8.10	8.54	8.29
Sealing	10.72	9.62	10.01	10.25	9.97	10.38	9.83	10.1

Based on the above readings taken a graphical representation of the various workstation times is presented below in *Fig.1*.

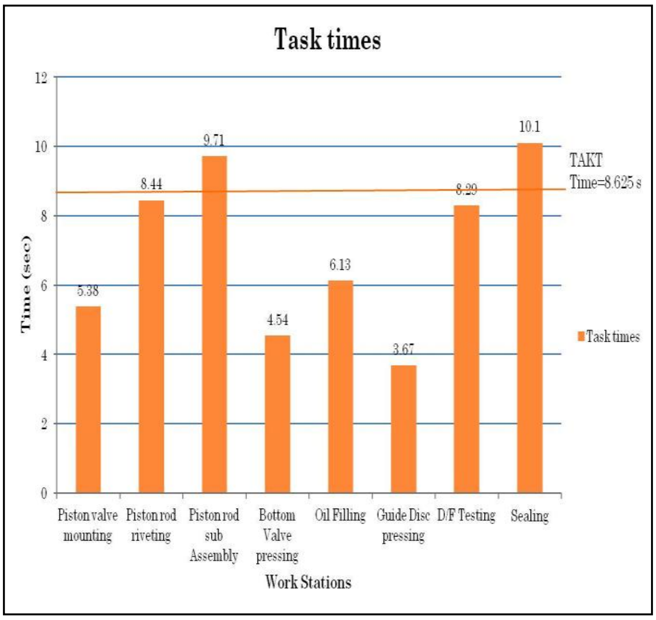

Fig. 1. Task Time of Workstations with Takt Time

B. Calculations

Line cycle time = 10.1 s

Total work content
=5.38+8.44+9.71+4.54+6.13+3.67+8.29+10.1 = 56.26 s

Total available time for production per shift = 27600 s

$$\text{Line Capacity} = \frac{\text{available time per shift}}{\text{cycle time}} \times \text{operator efficiency}$$

= (27600÷10.10) × 0.9 = 2460 units per shift

$$\text{Line efficiency} = \frac{\text{Total work content}}{\text{no of workstation} \times \text{cycle time}} \times 100$$

= (56.26 ÷ (8×10.1)) ×100 = 69.63 %

Required production per shift as per demand = 3250 units

Takt time required for line to meet the target

$$= \frac{\textit{available time per shift}}{\textit{required production per shift}}$$

= 27600÷3250 = 8.625 s

C. Identification of Factors affecting Line Efficiency

The *Fig. 2* shows the time lost due to various factors such as non-availability of material, non-availability of operator, machine break down etc at 'Sealing' workstation.

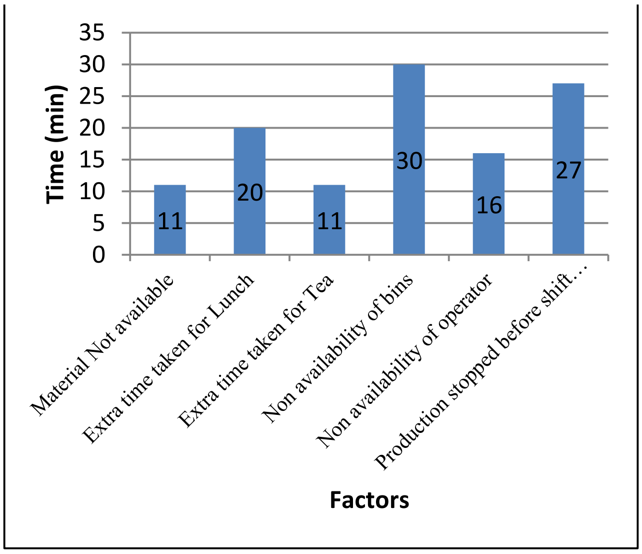

Fig. 2 Loss Study of 'Sealing' Workstation

Based on the loss study performed for the 'Sealing' workstation following factors are identified and solutions are provided along with them.

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i. Material Unavailability

The main factor which affects most of the assembly lines' efficiency is unavailability of material at right time, at right place in required quantity.

At the line under study was also the same situation; the material was not available at right work station when required, even if the material was in inventory.

Solution: To avoid such situations there can be certain steps which can be followed or implemented.

a) Implementation of Supply Chain Management techniques

b) Better Production Planning and Scheduling

c) Improvement in Material Handling system

d) Proper Inspection of incoming material

e) Implementation of Economic Order Quantity models

f) Implementation of Just-in-Time methodology

ii. Machine under Breakdown

It is the second most important and frequently occurring factor which influences the productivity or efficiency of every manufacturing industry. It is worse in the case of process layout type industries or straight type assembly lines; where breakdown of any single machine will halt the production process of the entire line or industry.

Solution: For avoiding these kinds of factors from influencing efficiency these precautions or steps can be taken.

a) The first step is to have Preventive maintenance for machines which will increase machine life.

b) Autonomous maintenance by operators before operating the machine will avoid most of the faults or failures and will also help technicians in finding out any fault, if there is any breakdown.

c) Overhauling of machines at specific periods by the machine manufacturers will improve its functioning and life span.

d) Flow of information should be smooth and quick between maintenance department and production department.

e) The operators and technicians should have proper training and knowledge of machines.

f) Implementation of TPM (Total Productive Maintenance)

iii. Non-Availability of Operator

Human factor is also one of the important factors for having varied productivity or efficiency of an assembly line. It is most of the times that the operator is not available at his workstation due to various reasons which cannot be accounted for.

But there are few which can be enlisted on the basis of study of assembly line during this project. These may be as extra time taken for lunch, extra time for tea break, social needs and some personal issues.

Solution: These factors are generally of random type and are difficult to avoid from occurring but certain measures can be taken to reduce such issues.

a) Employing motivation techniques such as employee of the month, rewards, better appraisal on the basis of employees' productivity.

b) Taking strict actions against reckless or careless employees' after giving warning.

iv. Quality Issues

Quality of products produced can also interfere with the efficiency of an assembly line as sometimes for improving quality of products the process may become slow or there may be rework due implementation of tight process control techniques.

This should not be an issue for lower productivity and can be resolved by implementing quality improvement techniques from the beginning to avoid rework or defective products. Few of the techniques might be:

a) Implementing Total Quality Management (TQM) principles

b) Implementing Six Sigma

c) Use of KAIZAN

v. Setup Time loss

This type of problem is generally faced in multi model assembly lines where changes or different setup of tools or jigs & fixtures is required for production of different models of a certain product.

This problem is faced in assembly line under study as it is a multi-model deterministic type of assembly line where different models of shock-absorber are assembled on the same line.

Solution: For reducing setup times many scientific techniques can be employed. The technique used here is the SMED method.

a) Single Minute Exchange of Die method includes videography of the entire process and is then analysed & external (setup before machine is running) and internal (setup while machine is running) factors are identified and the setup time is optimised accordingly.

Apart from above technique few general methods are:

a) Automation of machining centres.

b) Use of CNC & DNC systems

c) Universal Jigs & Fixtures can be used

IV. Application of SMED

SMED, also known as Quick changeover of tools, is a scientific approach for the reduction of setup times, and which can be applied in any industrial unit and by any machine. SMED was defined as the minimum amount of time necessary to change the type of production activity considering the moment in which the last piece of a previous lot was produced the first piece produced by the subsequent lot (Shingo, 1985) [6].

The Single Minute Exchange of Dies technique has four stages involved to make setup reductions which are [7]

- Preliminary stages, (Observe current methodology or process under study)
- Separate internal and external setup,
- Convert internal to external setup and
- Streamlining all aspect of setup
- Continuous training

A. Videography of Sealing workstation

Major operations carried out during Sealing:

- Mounting of damper assembly in bottom fixture
- Upward motion of bottom fixture
- Sealing process by sealing roller

Now the process time of sealing operation can be broken down into

- Operators working time
- Machine processing time

These two times are reduced or improved separately by studying each motion with the help of video graphing of operator and machine.

Based on the videography operator's left and right hand movement can be categorised separately.

TABLE I. OPERATOR'S HAND MOVEMENTS

Left Hand Movement	Right Hand Movement
Pick the damper assembly	-
Put it on the bottom fixture	-
Press the Push Button	Press the Push Button
-	Unload the damper assembly & put it on trolley

The time taken by operator for performing all the operations with proper movements and 100% engagement is 5.3s (approximately). For obtaining the machine processing time and studying its elemental operations machine videography has to be performed; it is found out to be 5s (approximately).

This time can be improved by bringing about some changes in the machine component motion i.e. movement of bottom fixture, sealing roller (Quick Return Mechanism) etc at improved speeds; for this the machine manufacturer or the maintenance department can be contacted to implement the changes.

B. Separating Machine Operations

All the operations of 'sealing' during setup or changeover time are to be classified into Internal and External operations based on videography performed for vertical sealing machine.

TABLE II. CLASSIFICATION OF SETUP OPERATIONS

Internal operations (Machine has stopped)	External operations (Machine working)
1. Clamping/Unclamping of bottom fixtures.	1. Machining
2. Changing of Sealing roller	2. Maintaining pressure setting
3. Changing of supporting rollers	-
4. Adjusting new pressure settings according to the model	-
5. Diameter adjustments between supporting and sealing roller	-

The changeover time (till 1st piece approval) of Vertical Sealing machine was found out to be 2 hours based on the videography done.

C. Converting Internal to External operations

The next step of SMED is to convert as much internal operations into external operations as possible to reduce the setup-time.

So the following steps are taken to convert internal operations to external and to improve internal operations i.e. work to be completed when machine is running.

1. Use of intermediate jigs & fixtures which avoided changing of bottom fixture every time when the model is changed.
2. Standardization of 'Allen bolts' used for various clamping purposes in the machine i.e. for rollers, fixtures (earlier two separate Allen keys of 8' and 10' were used).
3. Use of pneumatic spanners instead of manual for opening & tightening of screws & bolts.
4. Supporting rollers used in sealing are arranged along a turret so that they should not be unclamped or clamped every time model change occurs.
5. Uses of digital or programmable pressure setting meters which automatically change the pressure required for sealing just by entering the diameter settings and are fitted in front of machine to be easily viewable to operator.
6. Maintaining tool cabinet along with pallet of other accessories near the machine in-order to reduce unnecessary wastage of time in search of different tools when machine has stopped working and ready for changeover.
7. Work sheet availability at workstation to provide pressure readings and other help in case of troubleshooting.
8. Shadow board are used to make the operator aware of any tool not available at his station.
9. Pre-informing the line in-charge about the change of model as all other processes like inspection and quality check of 1st piece can be completed within minimum time.

TABLE III. COMPARISON OF OPERATIONS BEFORE &AFTER SMED

Operations during Sealing	Before SMED	After SMED
1. Clamping/Unclamping of bottom fixtures.	Internal	External
2. Changing of Sealing roller	Internal	Internal
3. Changing of supporting rollers	Internal	External
4. Adjusting new pressure settings according to the model	Internal	External
5. Diameter adjustments between supporting and sealing roller	Internal	Internal

As from the above table it is clear that few of the activities are converted to external from internal activities which will definitely bring down the setup time of 'Sealing' workstation.

V. RESULT & CONCLUSION

As a result of analysis of various factors affecting the assembly line efficiency of case study assembly line and the various solutions suggested for these factors the line efficiency has been improved slightly as shown below.

Improvement in cycle time of 'Sealing' workstation from 10.1s to 9.2s

Total Work Content = 55.36s

New cycle time of line = 9.71s

So, line efficiency = 55.36÷ (8×9.71) ×100 = 71.27%

Hence there is an increase in the line efficiency from 69.63% to 71.27% due to the reduction in the cycle time of 'Sealing' workstation. There is also reduction in setup time of the workstation as a result of application of SMED process.

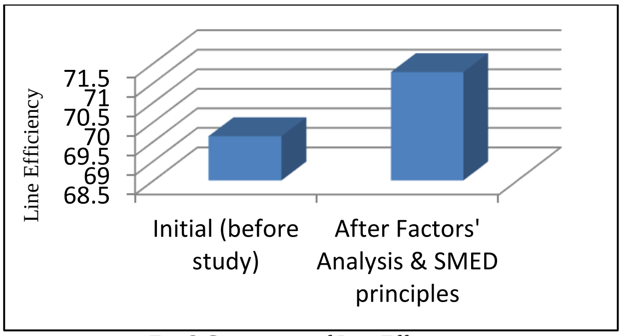

Fig. 3 Comparison of Line Efficiency

The purpose of this study was to identify and analyze various factors affecting assembly line efficiency of a multi model straight type manual assembly line. From the study it has been observed that there are several factors like machine breakdown, material unavailability, absenteeism or non-availability of operator at workstation, setup time losses etc were few of the problems encountered by the assembly line. Apart from these there are several other factors or 'waste' which reduces the efficiency of production lines in various medium and small scale industries.

Various solutions under lean manufacturing techniques are provided in this work which can be implemented by all the manufacturing firms facing these types of problems.

Also an attempt is made to reduce the cycle time of 'Sealing' workstation with the help of performing videography of the workstation. With the application of SMED principles and suggestions made based on machine videography; the cycle time gets reduced to 9.2s from 10.1s. This decrease led to an increase in line efficiency from 69.63% to 71.27%.

Although the increment is not quite large enough but as line balancing is a continuous process and steps should be taken at regular intervals to further improve the efficiency.

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