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Use of Spaghetti Diagram for Identification and Elimination of Waste Movements in Shop Floor for OEE Improvement: A Case Study

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***Abstract*— Business objectives are mainly, long term growth and profitability that can happen only by increasing in the productivity. Frequent machine breakdown, high changeover time, and high manufacturing cost are becoming great threat. The author's main aim to keep up the Research is to improve OEE to meet customer's increasing demands without addition of capacity thus meeting business goals. This document demonstrates the need to overcome most of bottleneck of equipment's unavailability for resources utilization and to run the process more effectively. Improvement in OEE was possible through reducing the changeovers and cycle time and developing the workforce culture align to the focused improvements. The outcome of this Research may expect to have marked improvement in productivity with best utilization of the capacity along with right quality product, at right time.**

Keywords*— Equipment downtime, Productivity, Losses, Cycle time.

I. INTRODUCTION

In all the manufacturing industries delivering the quality product at the right time has become more challenging in today's market situation . The paper Use of Spaghetti diagram for identification and elimination of waste movements in shop floor for OEE Improvement Maintenance has become more challenging in the current dynamic business environment. The manufacturing sector has been experiencing tremendous challenges in ensuring all products are delivered to customers on time. However, the current business environment and pressures from various parties such as customers, suppliers, governments and so forth have put manufacturing sectors under severe pressure. To operate efficiently and effectively, manufacturing sectors need to ensure no disruption due to equipment breakdown, stoppages and failure.

Manufacturing systems in particular often operate at less than full capacity, with low productivity, and the cost of producing products are high. Recent study (Mobley,1990) shows that 25-30% of total production cost is attributed to maintenance activities in the factory. The quality of maintenance significantly affects business profitability. The importance of maintenance functions has increased due to its role in keeping and improving the availability, product quantity, safety requirements, as maintenance costs constitute an important part of the operating budget of manufacturing firms (Al-Najjar and Alsyouf 2003:85-100). In response to maintenance problems encountered in manufacturing environment, the Japanese developed and introduced the concept of Total Productive Maintenance (TPM), in 1971. TPM is a maintenance system defined by Nakajima (Nakajima 1988) in Japan, which covers the entire life of equipment in every division including planning, manufacturing, and maintenance. It describes a synergistic relationship among all organizational functions, but particularly between production and maintenance, for continuous improvement of product quality, operational efficiency, capacity assurance and safety.

II. LITERATURE SURVEY

A. SPAGHETTI DIAGRAM:

A spaghetti diagram is a visual representation using a continuous flow line tracing the path of an activity through a process. The continuous flow line enables process team to identify redundancies in the work flow and opportunities to expedite process flow.

The intent of this in literature review was to identify ways to shorten the walking time from one activity to another for frequently performed tasks. Another benefit to know areas where many walks paths overlap are caused of delay. Waiting is one of the wastes of organisation as discussed above, as is unnecessary motion. [9]

Author's view: Best tool to use when it is required to modify the current state of workplace into the future improved state. This tool will help author in this project by following ways:

- ✓ To identify the wastage in work flow.

- ✓ Way to shorten the walking time for frequent operations.
- ✓ To identify the critical path that causes delays. And lastly
- ✓ To increase the morale of the workforce.

III. IMPROVEMENT OF BANDSAW PRODUCTIVITY

In this section, the TPM implementation is demonstrated through a case study in an automobile manufacturing organization. Section A gives a brief review of case organization and then the TPM implementation procedure is discussed in section B.

Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

A. ABOUT XYZ COMPANY:

XYZ is the country's largest manufacturer and exporter of automotive components and leading chassis component manufacturer in the world. With significant global market share, it is ranked among the leading forging companies in the world.

The company manufactures a wide range of safety and critical components for passenger cars, commercial vehicles and diesel engines.

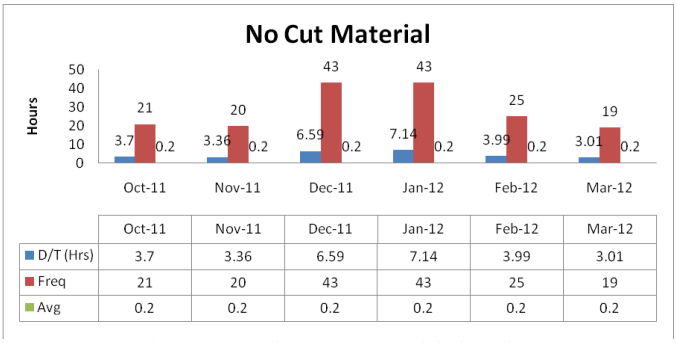
Author had considered forging line for Project work, situated in XYZ**.** This forging line was established in July 2006, to forge automobile components mainly Axle Beams and Crank Shafts.

XYZ has four big press lines having forging weight capacity of 45 to 250Kg.

B. IMPROVEMENT OF OEE

Band saw machine are at initial stages of production line for cut billet supply. Shortage or delays for supply of cut billet are booked under the category of General downtime as shown in figure 3.7a that is linked to the Equipment availability and thus affecting the OEE value.

The data is collected for 6 months for 'no cut material' as shown in figure



	Oct-11	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12
D/T (Hrs)	3.7	3.36	6.59	7.14	3.99	3.01
Freq	21	20	43	43	25	19
Avg	0.2	0.2	0.2	0.2	0.2	0.2

Figure : Pareto for 'No cut material' downtime

Down time for 'no cut material' is almost 4.5 hours every month in average and occurences are 28 times average every month. The average time loss is 0.2 hours (12 minutes) per occurrence.

Scenario: There are 6 nos of bandsaw machine that have enough capacity to supply as per the demand against the planned cycle time. At present each individual operator has to handle two bandsaw machines at a time. One bar of 6 meter length is infeeded in the machine to cut into the required length pieces called as billet (ranging from 3 to 7 pieces depending on cut length, cross section cut and cut feed rate). Cutting operation is automatic but the bar feeding and first and last trim cut process is manual controled by operator.

PROBLEM STATEMENT:

To increase the productivity of the band saw machine, interview carried out with the operators and voices of workforce are as follows:

- Single operator has to handle two band-saw machines, throughout the shift.
- Frequent travel from one machine to other for controls.
- Space between two adjacent machines is confined and frequent climbing of walkway stair in between two machines.
- Operators feel this work as more fatigue and as punishment.
- Main operating panel is at RHS of machine and secondary panel (similar in functionality to main panel) is at backside found not ease for performing.

The problem identified in the Band saw cutting operation was more unsafe, fatigue and ergonomically incorrect for an operator to operate two band saw machines.

C. Critical Analysis

Study carried out by the author after understanding the problem statement from the operators. Movements of operators were critically examined using tools like Spaghetti diagram, Why-Why analysis to find root cause and corrective actions.

The approaches to find solutions are explained as follows:

1. Why-Why Analysis:

More fatigue for machines operation (Why?)

↓

Frequently required to cross over walkway for both machines operation

↓

Main operating panel at RHS of machine and secondary panel at LHS backside frequent movement for operation

↓

Secondary panel at backside is critical to operate machine

2. Root cause:

a. The location of the secondary panel at the backside of the band-saw is critical to operate as confined space between two machines.

b. Hard and fatigue to climb the walkway stair steps frequently, to operate the other adjacent machine main panel.

3. *Spaghetti Diagram:* Author had used spaghetti diagram to identify the wastage movement of the operators during performing repetitive tasks. Method used for this are as follows:

   a. CAD drawing used (showing two band saw machines and the operator basic standing position).

   b. Examine operator movements through Path A and Path B options, using measuring tape to know actual distances and stop watch to measure the walking time, as shown in Figure

   c. Examine and counted frequently performed movement between Path A and Path B.

   d. After brainstorming derived the alternative for relocating the secondary panel from backside to front (based on above Why-Why and root cause analysis).

   e. Modified the CAD drawing accordingly for new location for secondary panel.

   f. Again used Spaghetti diagram for new Path C as shown in Figure to measure new walking distance and time.

   g. Compared the calculated walking distance and time of new Path C with respect to Path A and Path B as shown in calculation work sheet in Figure

➢ New Path C is validated with almost 70% reduction in walking distance with respect to Path A, and 65% reduction with respect to Path B, this is classic example of application of Spaghetti diagram tool.

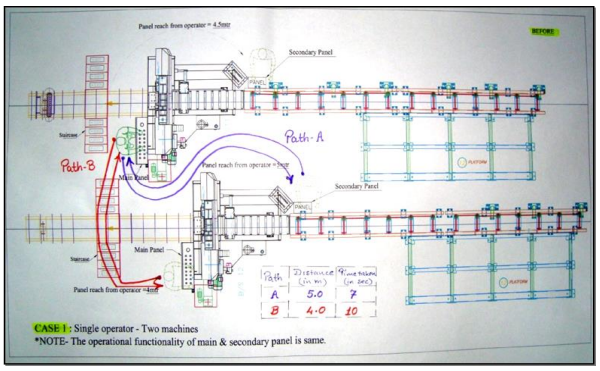


Figure: Spaghetti diagram for old Path A and B

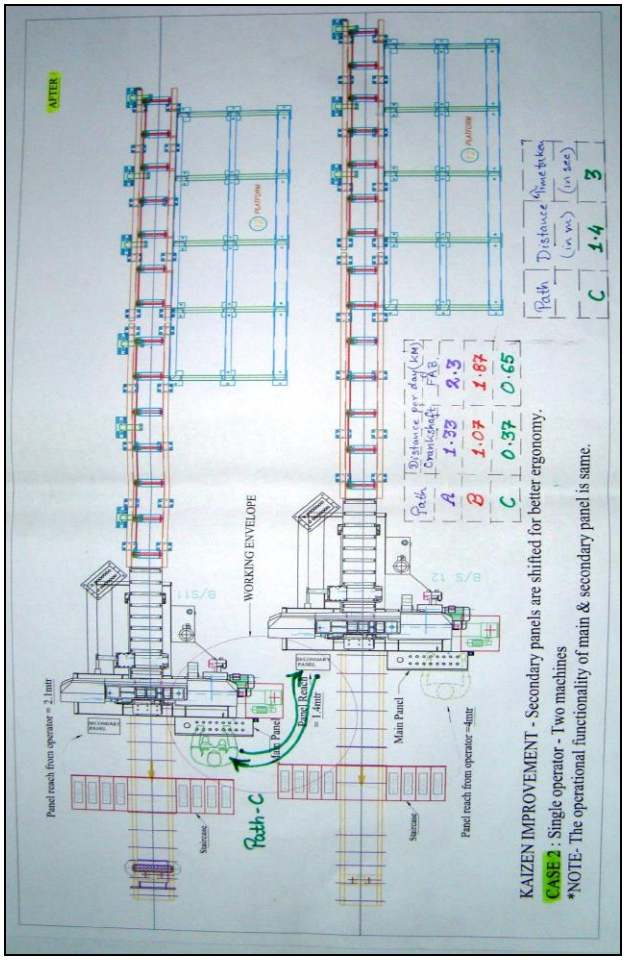


Figure : Spaghetti diagram for new Path C

Spaghetti Diagram for Man movement at 1250OT line Band saw

Number of Operators	3	(1 person operates 2 bandsaws)			
Number of Bandsaws	6				
Target for the day (Crankshaft)	1400			Total distance (in meters)	
Target for the day (FAB)	1400		Path A (La)	10	
			Path B (Lb)	8	
Number of billets / bar of 6 m (crankshaft)	7		Path C (Lc)	2.8	
Number of billets / bar of 6 m (FAB)	4				
Total number of bars (6 m) per day				Total time taken (in seconds)	
Number of bars used for Crankshaft	200				
Number of bars used for FAB	350		Path A (Ta)	14	
			Path B(Tb)	20	
Number of bars (6 m) per operator per day			Path C (Tc)	6	
Number of bars for Crankshaft	67				
Number of bars for FAB	117				

For Crankshafts

S.N.	Particulars	Before	After	Percentage improvement	Remarks
	Option 1	*Path A*	*Path C*		
1	Number of Movements / day (twice/ bar) (M)	133	133		
2	Distance travelled (M * La) (m)	1333	373	72%	Reduced
3	Time taken (M * Ta) (sec)	1867	800	57%	
	Option 2	*Path B*	*Path C*		
1	Number of Movements / day (twice/ bar) (M)	133	133		
2	Distance travelled (M* Lb) (m)	1067	373	65%	Distance Reduced
3	Time taken (M * Tb) (sec)	2667	800	70%	

For Front Axle Beams

S.N.	Particulars	Before	After	Percentage improvement	Remarks
	Option 1	*Path A*	*Path C*		
1	Number of Movements / day (twice/ bar) (M)	233	233		
2	Distance travelled (M * La) (m)	2333	653	72%	Reduced
3	Time taken (M * Ta) (sec)	3267	1400	57%	
	Option 2	*Path B*	*Path C*		
1	Number of Movements / day (twice/ bar) (M)	233	233		
2	Distance travelled (M* Lb) (m)	1867	653	65%	Distance Reduced
3	Time taken (M * Tb) (sec)	4667	1400	70%	

Note :

1 *Due to shifting of the panel to new location, a potential safety hazard (staircase) is eliminated*
2 *Operational functionality of the main and secondary panels is the same.*

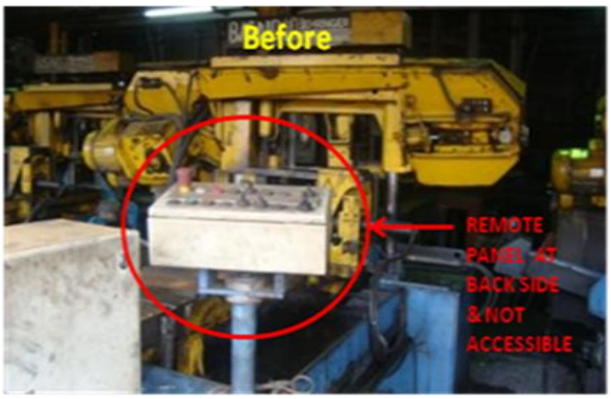
Figure: Calculation Work sheet

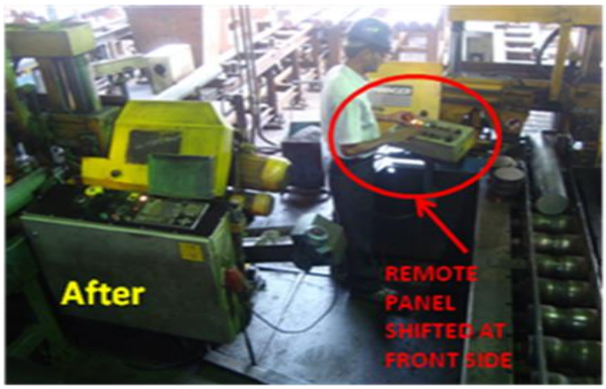
Corrective action suggested:

1. To shift the secondary panel at front side of the band-saw machine for less movement, (refer to path C new method) having travel distance of 1.4 meter reduction in movement of operator by 70%.

2. To remove the walkway stairs having long steps with small steps structures.

Team had carried out the kaizen activities based on above suggestion by authors. The secondary panel is shifted to front side of the machine. Operator able to handle both machine as both main and secondary panel came in his near vicinity, the working envelope is also reduced as shown in figure .





IV. RESEARCH RESULT OVERVIEW

Benefits due to improvement in Band saw machines:

Improvement in band saw machines was more related to reduce the operators fatigue for extra movements and was possible using Spaghetti diagram and its calculation work (as shown in Figure). Due to new method, remarkable reduction achieved as shown in below table 4.1.

The other intangible benefits are as follows:

- Less fatigue and more safety to operate the band-saw machine.
- Elimination of excess movements (waste) thus quick control.
- Increase in productivity and morale of the operators.

Even though these are intangible benefits but it is more to critically listening to the voices of workforce.

Table 4.1: Spaghetti diagram

For Crank shaft	Path A	Path B	Path C	Reduction using Path C
Distance (M) travelled per operator per day	1333	1067	373	72% (w.r.t Path A) 65% (w.r.t Path B)
Time taken for movement per operator per day(S)	1867	2667	800	70% (w.r.t Path B) 57% (w.r.t Path A)

For Front Axle Beam	Path A	Path B	Path C	Reduction using Path C
Distance (M) travelled per operator per day	2333	1867	653	72% (w.r.t Path A) 65% (w.r.t Path B)
Time taken for movement per operator per day(S)	3267	4667	1400	70% (w.r.t Path B) 57% (w.r.t Path A)

V. CONCLUSION

The research objective was to investigate the ways and means for improving the OEE values. OEE measuring tool found to be very effective to see all the potential barriers and to find corrective solutions for improving the productivity, findings from this Research:

- ✓ Improvement of Band saw productivity helped to reduce the cut billet shortage which was booked under the category of general downtime.

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