การเพิ่มประสิทธิภาพกระบวนการผลิตจากการวิเคราะห์การซ่อมบำรุงฉุกเฉินเมื่อเครื่องขัดข้อง

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DOI: 10.14416/j.kmutnb.2015.06.005

บทคัดย่อ

ต้นทุนการซ่อมบำรุงรักษาเครื่องจักร เครื่องมือ ตลอดจนต้นทุนแรงงานที่สูงขึ้นส่งผลต่อประสิทธิภาพกระบวนการผลิตและความสามารถในการทำกำไรของบริษัท สถานประกอบการจึงมีความจำเป็นต้องนำกระบวนการวางแผนการซ่อมบำรุงที่มีประสิทธิภาพเพื่อช่วยลดต้นทุนการเปลี่ยนเครื่องจักรและการซ่อมบำรุงฉุกเฉินเมื่อเครื่องขัดข้อง ดังนั้นงานวิจัยเชิงปฏิบัติการฉบับนี้จึงมีวัตถุประสงค์เพื่อออกแบบและวางแผนการวางแผนซ่อมบำรุงเชิงป้องกันให้เครื่องจักรสามารถดำเนินงานได้อย่างเต็มประสิทธิภาพ การวางแผนซ่อมบำรุงเชิงป้องกันถูกออกแบบจากการวิเคราะห์การซ่อมบำรุงฉุกเฉินเมื่อเครื่องขัดข้องเพื่อช่วยเพิ่มประสิทธิภาพการผลิต ลดการสูญเสียเวลา และลดต้นทุนค่าเสียโอกาสในกรณีเครื่องจักรขัดข้อง การวางแผนซ่อมบำรุงเชิงป้องกันถูกนำไปใช้ในกระบวนการที่เกิดคอขวดในสายการผลิต พบว่าสามารถช่วยลดการเกิดเครื่องจักรขัดข้องอย่างมีประสิทธิภาพและช่วยให้เครื่องจักรมีชั่วโมงการทำงานที่มากขึ้น จากการนำการวางแผนซ่อมบำรุงเชิงป้องกันไปใช้ในกระบวนการผลิตสามารถกล่าวได้ว่าช่วยเพิ่มประสิทธิภาพในการผลิตและความสามารถในการทำกำไรของสถานประกอบการ

คำสำคัญ: การซ่อมบำรุงฉุกเฉินเมื่อเครื่องขัดข้อง การวางแผนซ่อมบำรุงเชิงป้องกัน การเพิ่มประสิทธิภาพกระบวนการผลิต

การอ้างอิงบทความ: ปิยฉัตร จันทิวา, วรรณลักษณ์ เหล่าทวีทรัพย์ และ สุพิชชา ชีวพฤกษ์ "การเพิ่มประสิทธิภาพกระบวนการผลิตจากการวิเคราะห์การซ่อมบำรุงฉุกเฉิน เมื่อเครื่องขัดข้อง," *วารสารวิชาการพระจอมเกล้าพระนครเหนือ*, ปีที่ 25, ฉบับที่ 3, หน้า 485–492, ก.ย.–ธ.ค. 2558. http://dx.doi.org/10.14416/j.kmutnb.2015.06.005

Improving Production Efficiency by Using Preventive Maintenance

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Received 22 October 2014; Accepted 22 June 2015; Published online: 1 October 2015
DOI: 10.14416/j.kmutnb.2015.06.005

Abstract

The costs of maintenance, equipment and labors are increasing very rapidly, affecting the production efficiency so it is crucial to implement effective maintenance programs that will be able to decrease replacement and breakdown costs. It is necessary for the factories to have the effectively preventive planning. Therefore, this operational research aims to design and plan the preventive maintenance in order to get the highest machine capacity. The preventive maintenance scheme was designed by using Preventive Planning Principles in order to enhance production activity and reduce time lost and opportunity cost in the event of machinery break down. The designed planning was exercised in the production process where the bottleneck process often bring inefficiencies. After the implementation, the preventive maintenance planning appears to increase the production capacity and improve enterprise quantifiable benefits.

Keywords: Breakdown Maintenance, Preventive Maintenance, Production Efficiency

Please cite this article as: P. Jantiva, W. Laotaweesub, and S. Cheevapruk, "Improving Production Efficiency by Using Preventive Maintenance," *J. KMUTNB*, Vol. 25, No. 3, pp. 485–492, Sep.–Dec. 2015 (in Thai). http://dx.doi.org/10.14416/j.kmutnb.2015.06.005

1. Introduction

With the fact that the current business competition has been highly competitive and also the increasing of demands from Stakeholders. The performance and manufacturing competitiveness of each companies depends on the reliability and productivity of the production facility [1]. The maintenance and effective equipment plays an important role in order to enhance high quality, dependable services, efficiency and effectiveness of business [2]. Maintenance operation has been increasing its important roles as it help to keep and improve the product availability, product quality, safety requirement and plant cost effectiveness and it is also associated with operating budget of manufacturing firms [3]. According to Salonen and Bengtsson [4] the production failures may cause high losses, e.g. lost production time or volume, negative impact on the environment, lost customers, warranty payments, etc. and downtime cost due to the corrective maintenance is higher that preventive maintenance as also mention in several researches [5]–[7].

A company case study of this research was having this kind of problem. The downtime related cost was substantial. Therefore, the preventive maintenance planning by applying management principles to plan machines maintenance system in order to make the machine work efficiently was drawn to attention for reducing the downtime, time and costs of maintenance. It was necessary to have the preventive maintenance (PM) method to organize the maintenance system planning as if the machines are maintained effectively, the machines work as planned, and less production costs. First this paper explains the maintenance function. Second, the literature review is presented to assist in designing preventive maintenance framework and process. Finally, the result and discuss is shown in the last section.

2. Literature Reviews

Starr [8] stated that the traditional practices of run-to-failure (breakdown maintenance or BM) and time-based planned preventive maintenance (PPM) are widely used in practically all industrial sectors. It has been identified, however, that: 1) BM is at best only suited to non-critical areas where the capital costs are small, the consequences of failure are slight, there is no safety risk, the failure will be identified quickly, and the repair will be quick. Unfortunately BM is widely adopted by default in areas which are not appropriate, and therefore becomes costly. 2) PPM is best suited to failures which have a clear wear-out characteristic. It is necessary to estimate component or system life. The maintenance task (whether a repair or replacement) can be made at a time which we are confident will prevent the failure occurring. Normal distributions of component life mean that it is not economical to prevent all failures, and many components and systems do not obey a wear out model. Condition Based Maintenance (CBM) uses a parameter which is indicative of machine health to trigger the maintenance activity. Regular tasks become scheduled inspections and measurements rather than repair or replacements, and actions are only scheduled when they are really needed.

Many were adopted the maintenance approach to enhance their productivity, production effectiveness and cost saving as in Oruma Gorsanan [9] mentioned that the revision of maintenance plan was done by collecting the causes of label wrapping machine damages and failures including the average lifespan - parts of label wrapping machine. The data was collected from

the operators and engineers in order to improve the maintenance plan of label wrapping machine on the new carbonated beverage PET bottles production by integrating the label wrapping machines user's manual maintenance plan with the agent original maintenance plan.

Method of preventive maintenance should maintenance machine as per the period defined from experience or the operation manual of the machine itself [10].

P. Wongwiwat [11] stated that the preventive maintenance is a concept that needs to protect the shutdown of machine as the machine would not be predictable. Unexpected machine shut down at any circumstances causes seriously damage to the industry; therefore the preventive maintenance system is necessary in order to check machine performance, oil refill, lubrication, part replacement, repair and record operation. The collected planning maintenance was exercised to find out problem causes and corrective measurements. The operation was performed repeatedly to adjust the maintenance plan in accordance with the changes of machines over the time by suitability, accuracy, reliability and keep up to date.

C. Richard Cassady and E. Kutanoglu [12] mentioned that the preventive maintenance planning, and production scheduling are individual activities and mostly perform independently. However, preventive maintenance and repair effect both productivity and opportunity cost. Therefore, the integrated preventive maintenance planning and production scheduling is worth designed. And C. M. Kelly *et al*. [13] mentioned that the utilizing preventative maintenance procedures generally results in better average flow time and % tardy performance while deteriorating the average tardiness performance in some cases.

3. Preventive Maintenance Design and Process

The company - case study was a soft drink factory which has many machines in the production lines and recently new machines had been installed but yet have not got any maintenance plan systematically. The production line 3 which is plastic bottle production line was chosen to conduct the preventive maintenance in this research. The studying and analyzing production machine of soft drink package was exercised only in size 1.25 liter only. The filler cycling speed is 400 bottles/minute. The machine operates 8 hours or 480 minutes with 100% capacity to produce soft drink at total of 16,000 cases/day by packing 12 bottles/packet and selling price is 27 baht/bottle.

3.1 The maintenance data collection was done regularly start from 08.00–16.00 hours each day. An analyzing collected maintenance past records found that the production line no.3 has the urgent problem repeatedly under same machine. Then the production capacity was lower than the target and caused the company lost a lot of money from each machine shutdown.

3.2 The machine selection for the preventive maintenance was analyzed from the previous maintenance records, the selected machine based on machine downtime as shown in Table 1.

3.3 Designing the check sheet and inspection standard, 5W1H Theory was applied by setting the standard questions before creating the check sheet in order to enhance the efficiency and suitable check sheet. Inspection standard was prepared by using the preventive maintenance and the operation manual. The designed check sheet and inspection standard were reviewed by authorized person such as maintenance engineer.

Table 1 Machine breakdown time and preventive maintenance

Machine	Down Time (Machine/Min/3months)	Safety	Maintenance System	Repairing Cost	Break Down Maintenance: BM	Preventive Maintenance: PM
D - Paratile	1,455	Y	N	H		Y
Conveyer	0	Y	N	H		Y
Air Conveyer	90	Y	N	H		Y
Labeler	705	Y	N	H		Y
Rinser	30	Y	N	H		Y
Filler	2,665	Y	N	H		Y
Capler	230	Y	N	H		Y
Date Code	20	N	N	L	Y	
Fill Tex	39	N	N	L	Y	
Warmer	35	N	N	L	Y	
Packing SM	2,091					
Bar Code	250	Y	N	L	Y	
Paratile	1,055	Y	N	H		Y
Robopack	170	Y	N	H		Y

*L = Low H = High
**Y = Yes N = No

3.4 Designing the preventive maintenance system by applying the machine operation manual and instruction to schedule the preventive maintenance plan presenting in 3 report which were individual machine report, maintenance report, and the service report.

3.5 The designed preventive maintenance system implementation and comparing pre- and post-preventive maintenance system in order to compare machine downtime and cost.

Based on breakdown time, filler machine was selected to plan the preventive maintenance system, the result shows in following session.

The preventive maintenance plan was designed as shown in Figure 1.

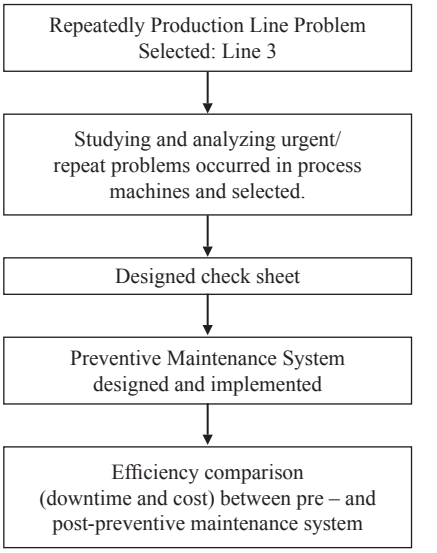

Figure 1 Preventive Maintenance Process Design.

4. Results

The designed check sheet and the preventive maintenance system was implemented in filler machine, data was collected for 3 months. It was found that the check sheet and the preventive maintenance system were able to carry out efficiently by the maintenance system and need to be regularly traced the condition of the machine's parts. The 3 months breakdown time after implementation of the preventive maintenance system shown in Table 2.

Table 2 The filler machine break down after the preventive maintenance implementation

Month	Down time /mins	Machine Operation from 8.00–16.00 hr/mins	Percentage
1	2,946	11,040	26.68%
2	2,799	11,520	24.30%
3	2,791	10,560	26.43%

The results were calculated from total time of the machine breakdown each month divided by the total

of running time each month as a percentage shown in Table 2. as in the equation (1)

Filler speeds = 400 bottles / min

100 % production per shift = 16000 boxes.

Down Time Target 100% – production of each shift. × Number of bottles per pack/ speed

$$16000 - 11000 \times 12/400 = 150 \quad (1)$$

Down time of time lost = 150 minutes/shift.

Due to the machine breakdown, the opportunity cost was calculated shown in equation (2).

The filler speed = 400 bottles / minute

100% of production per shift = 16000 crates

Down Time = 150 × filler speed / min × price / bottle.

$$150 \times 400 \times 27 = 1{,}620{,}000 \text{ Baht / shift} \quad (2)$$

If the machines break down for 1 minute, it equals to a loss of 400 bottles, and then multiply with selling price would be equal to 10,800 baht/minute (400 × 27). The preventive maintenance implementation reduced the opportunity cost as shown in Table 3.

Table 3 the opportunity cost due to machine down time

Opportunity cost after the preventive maintenance implementation	
Month	**Down Time/Baht**
1	31,817,880
2	30,232,008
3	30,139,344

The opportunity cost and the machines break down comparison between pre – and post preventive maintenance implementation based on the check sheet and the preventative maintenance system. The opportunity cost reduction was decreased and shown in Table 4.

Table 4 the opportunity cost comparison

Planning of the Preventive Maintenance		
Month	**Down Time/mins/Baht**	
	Before	**After**
1	46,629,648	31,817,880
2	45,082,494	30,232,008
3	40,838,796	30,139,344

The comparison referred to machine down time data without a plan as shown in Table 5 which shows the machine down time and the comparison of the time reduction.

Table 5 The filler machines down time comparison

Month	**Machine down time/mins**		**Machine operated from 8.00–16.00 hr/mins**		**Percentage**	
	before	**after**	**before**	**after**	**before**	**after**
1	4,318	2,946	12,480	11,040	34.60%	26.68%
2	4,174	2,799	11,040	11,520	37.81%	24.30%
3	3,781	2,791	10,560	10,560	35.80%	26.43%

5. Conclusions and Discussion

In this operational research, it can be concluded that the preventive maintenance system based on the recorded data and academic approach leads to the positive results in reducing machine down time and opportunity cost. The operational result in terms of the machines down time has shown that the time reduction was decreased very clearly and the opportunity cost was decreased abundantly. The production line 3 has been increasing in many aspects such as the machines' efficiency and effectiveness which support the customers' demand. According to the operational research result, the 3 months average of machine downtime was decreased down to 2,845 minutes which was 25.80%. The percentage of time reduction was reduced up to 10.27 per month. The opportunity cost was also decreased 30.30% due to the fact that the machine work

more efficient, the 3 months average of opportunity cost was 13,453,902 baht

This paper has shown the impact of the preventive maintenance on machine efficiency and cost. A well preparation on equipment and machines will be maximizing the production efficiency and ensuring all the necessary resources are available before the work commences. Not only machines' functions but also other aspects on planning and scheduling are involved in the preventive maintenance. To ensure that the preventive maintenance work is not left behind, the planning and scheduling elements are important [14] The important indicators for work planning are the percentage of planned work, percentage of work orders requiring rework due to planning and planning rate (percentage of time planned for work over available time). For work scheduling, the important indicators are the scheduling intensity (percentage of scheduled man-hours to the total available man-hours) and percentage of delayed work orders due to lack of material or manpower. Work execution performance indicators help monitor the effectiveness (schedule compliance, quality of work done, etc.) and efficiency (manpower and resource utilization) of maintenance in carrying out the maintenance job. Among the key performance indicators are schedule compliance (percentage of work completed within the scheduled time), percentage of reworks, percentage of completed task overall received tasks, the number of overdue tasks and manpower efficiency.

This case study employed the preventive maintenance methodology to improve the machines' efficiency and effectiveness as well as the technical skills, morale of members participated in this preventive maintenance system. The identification of various preventive maintenance tasks is directed toward preserving system function and based on a comprehensive knowledge of equipment and machine failure modes. This process ensures selection of the most applicable and cost effective.

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