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Maintenance Planning Based on Computer-Aided Preventive Maintenance Policy

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***Abstract*-In the present work, maintenance planning based on computer-aided preventive maintenance policy are introduced. The focus of this paper is on preventive maintenance activities. Preventive maintenance involves the repair, replacement, and maintenance of equipment in order to avoid unexpected failure during use. The aim of this study is to build the preventive maintenance program and is to improve system availability and maintenance resources. The preventive maintenance program results indicate that the availability and reliability have increased for three specifications M/C under investigation. For first Longitudinal Seaming machine, the result shows that the machine availability increases from 75.6 % to 90.34 %. While, machine reliability improves around 3.97 % for the proposed preventive maintenance. In case of second Longitudinal Seaming machine, as global results, about 14.4% and 4.31% of the machine availability and reliability are increased for the proposed preventive maintenance, respectively. In addition, the Rotary machine availability improves from 86.287 to 92.21 % and the machine reliability improves from 3.95% for the proposed preventive maintenance. Moreover, obtained results showed that using such preventive maintenance program will eliminate the six big losses; time losses, setup and adjustment losses, idling and minor stoppages losses, lowering machine operational speed losses, scrap & rework losses and production start up losses.**

***Index Terms*- Preventive Maintenance, Availability, Reliability.**

I. INTRODUCTION

Preventive maintenance (PM) is a schedule of planned Maintenance actions aimed at the prevention of breakdowns and failures. The primary goal of preventive maintenance is to prevent the failure of equipment before it actually occurs. It is designed to preserve and enhance equipment reliability by replacing worn components before they actually fail. Preventive maintenance activities include equipment checks, partial or complete overhauls at specified periods, oil changes, lubrication and so on. Optimal maintenance strategies for systems with partial repair options and without assuming bounded costs are introduced by Peter Bruns [1].

The PM is an important policy of a maintenance planning. Within a maintenance organization, it usually accounts for a major proportion of the total maintenance effort. There are seven elements of the PM as shown in Fig.1 [2]. Optimal maintenance scheduling of power producers considering unexpected unit failure is proposed to minimize the risk associated with unit unexpected failure [3].

Scheduled maintenance or maintenance performed based on the condition of an item conducted to ensure safety, reduce the likelihood of operational failures, and obtain as much useful life as possible from an item. The PM consists of actions intended to prolong the operational life of the equipment and keep the product safe to operate. This manual defines two types of the PM: Scheduled and Condition-based. In both cases, the objectives of the PM are to ensure safety, reduce the likelihood of operational failures, and obtain as much useful life as possible from an item [4], [5].

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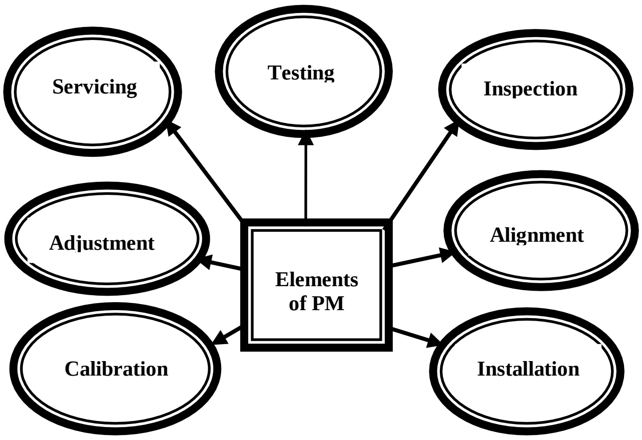

Fig. 1. Elements of the PM.

Also, the PM will result in savings due to an increase of effective system service life. Long-term benefits of the PM include:

- Decreased system downtime (MDT).
- Decrease failure rate (λ).
- Improved system reliability (R).
- Improved system availability (A).
- Decreased cost of replacement.
- Better spare parts inventory management.
- Improve maintenance resources.

Yang [6] studied a condition-based preventive maintenance arrangement for thermal power plants". Also, a hybrid Petri net modeling method coupled with fault-tree analysis (FTA) are used. The PM, reliability centered maintenance (RCM) and total productive maintenance (TPM) to maintenance problems all aim at enhancing the effectiveness of machines to improve the maintenance productivity(see Ashayeri [7]). A model for preventive maintenance planning by genetic algorithms based in cost and reliability (see Lapa et al [8]).

Badia and Berrade [9] have discussed the optimal maintenance policy of a periodically inspected system under imperfect repair. Sayed et al [10] studied computer aided reliability for optimum maintenance planning. The optimized preventive maintenance plan was obtained through the computer program at minimum cost by determining maintenance intervals. The PM policy optimization for multipurpose plant equipment is introduced by Dedopoulos and Shah [11]. Amir et al, [12] used fuzzy rules as an artificial intelligence (AI) tool used to determine priority of activities.

In this paper, a computer-aided preventive maintenance planning (CAPMP) will proposed. Mathematical model will used to calculate maintenance labor force, maintenance downtime, maintenance resource, reliability and availability within this context. In the final section, applicability of the PM policy is examined on the practical case for three specifications M/C.

II. PREVENTIVE MAINTENANCE ANALYSIS

Preventive maintenance will generally run the equipment more efficiently resulting in maintenance cost savings. While we will not prevent equipment catastrophic failures, we will decrease the number of failures. Minimizing failures translate into maintenance. Preventive maintenance is a schedule of planned maintenance actions aimed at the prevention of breakdowns and failures, since the primary objective of preventive maintenance is to prevent the failure of equipment before it actually occurs. Preventive maintenance parameters are:

1. Maintenance labor force.
2. Maintenance downtime.
3. Maintenance spare parts.
4. Total maintenance cost.
5. Maintenance Tasks.
6. Maintenance W/O.

A. *Modelling of the PM labor force*.

In the model, a specific formula is present to define the size of preventive maintenance labor force (L_{PM}) as:

$$L_{PM} = md_{annual} / LOC \quad (1)$$

Where, md_{annual} is the total preventive maintenance annual man-day, and LOC is the workers operating conditions (day/year).

The total preventive maintenance annual man-day can be calculated as:

$$md_{annual} = f_{annual} * T_{du} * L_{number} \quad (2)$$

Where, f_{annual} is the annual frequency per preventive maintenance type, T_{du} is the duration time, and L_{number} is the number of workers per preventive maintenance type.

B. *Modelling of availability (A)*

Availability is a measure of the degree to which an item is in an operable state and can be committed at the start of a mission when the mission is called for at an unknown point in time [13]. The relationship between the concepts of availability from mean time between failure (MTBF), mean downtime (MDT), Mean response time (MST)) and mean time to maintenance (MTTM) are presented in Fig. 2. The machines are reliable when their MTBF are higher. As contrast, the lower is better for MDT.

$$A = \frac{N_f * (MTBF)}{N_f * (MTBF + MDT)} \quad (3)$$

$$MDT = MST + MTTM \quad (4)$$

$$MTBF = \frac{AT - N_f * MDT}{N_f} \quad (5)$$

$$\text{Failure Rate } (\lambda) = \frac{N_f}{AT - N_f * MDT} \quad (6)$$

Where, N_f is the number of failure and AT is the available time.

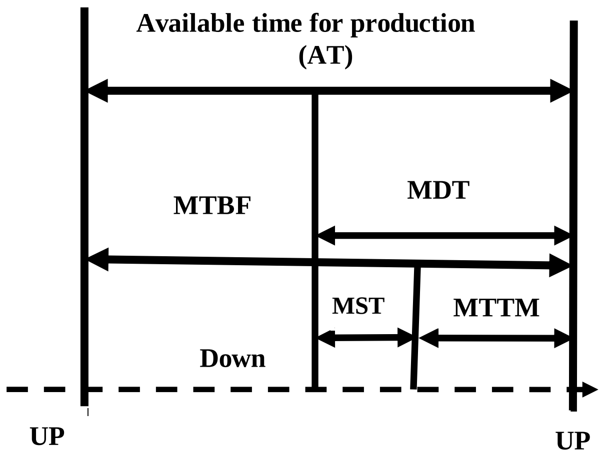

Fig. 2. The relationship between A, MTBF, MDT, MST and MTTM.

C. *Modelling of reliability*

Reliability is the probability of survival under a given operating environment. For example, the time between consecutive failures of a refrigerator where continuous working is required is a measure of its reliability [13], [14].

$$R(t) = \exp(-t/MTBF) = \exp(-\lambda t) \quad (7)$$

Where, λ is the constant failure rate and MTBF is the mean time between failures. MTBF measures the time between system failures and is easier to understand than a probability number. For exponentially distributed failure modes, MTBF is a basic figure-of-merit for reliability (failure rate, λ, is the reciprocal of MTBF).

D. *Modelling of the total maintenance cost*

Maintenance cost (C_m) can be calculated by the follow equation:

$$Cm = CSp + DT*Cv \quad (8)$$

Where, CSp is the spare parts cost, DT is the down time, and Cv is the variable cost per hour of down time, its include labor rate and crew size.

The production losses cost (Cp) is estimated using the following formula:

$$Cp = DT* P_{Los} *S_{Price} \quad (9)$$

Where, P_{Los} is the production loss in unit per hour, and SPrice is the unit selling price of the product.

III. PM SOFTWARE OVERVIEW

The goal of the software program was to establish general machines preventive maintenance program that would machine minimize downtime (DT) and improvement machine availability. It is a multi-plate form (visual basic

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language) oriented object program, compatible with windows.

As in Fig. 3, maintenance program data flow from the input phase and output phase are introduced. The PM for the building program after the data collected from the plant, now the time to build a program according to this data by extracting it and making analysis for it.

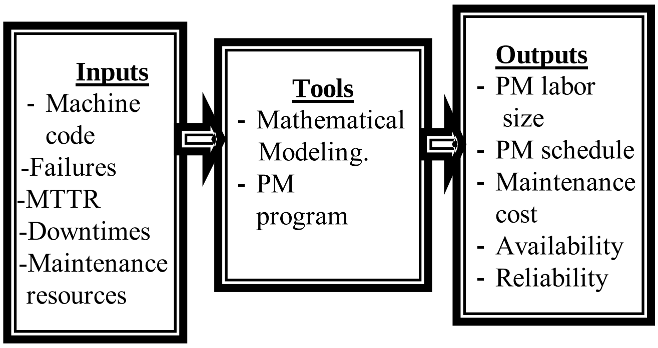


Fig. 3. Maintenance data flow from the input phase to the output phase.

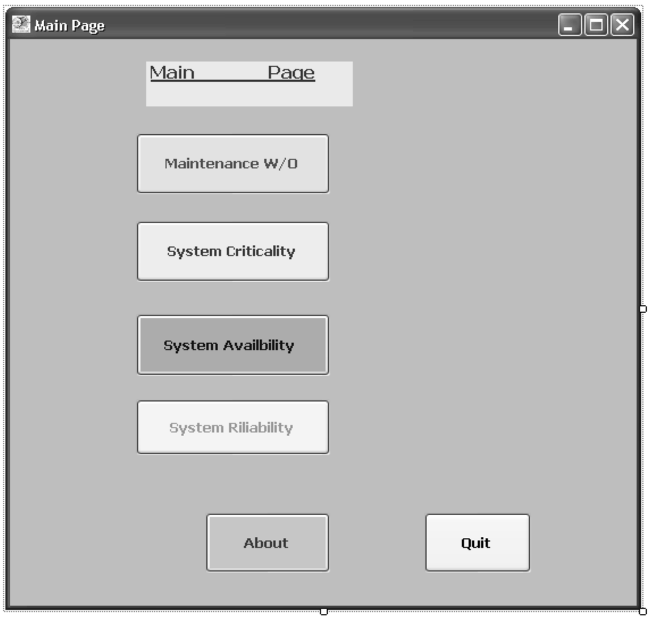
The main page (see Fig. 4) of the program is considered the main engine to move to all parts of program because it has the buttons that go to the all forms of program, also button to quit the program and button to show form of program designer.

A. Software functions

Conceptually, the functions to be performed are as following:-

1. Maintenance labor size force.
2. Spare parts cost.
3. Availability.
4. Reliability.
5. Maintenance resource analysis.
6. The maintenance work order (W/O).
7. Total maintenance cost.

As in Fig. 4, the W/O form is presented. The figure shows the maintenance W/O forms of the plant and by it is available to add, delete and save of the W/O number by the main task bar.



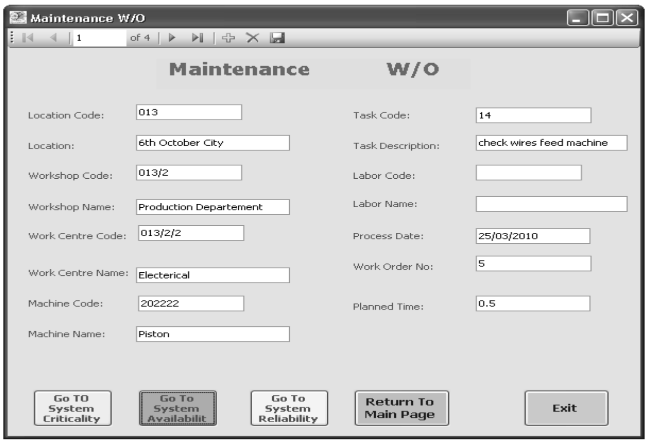


Fig. 4. Main page and maintenance (W/O) of the PM program.

System reliability and availability forms are introduced in Fig. 5. The Figure shows availability and reliability forms for the system and it has the ability of adding, removing and saving for any data related to system.

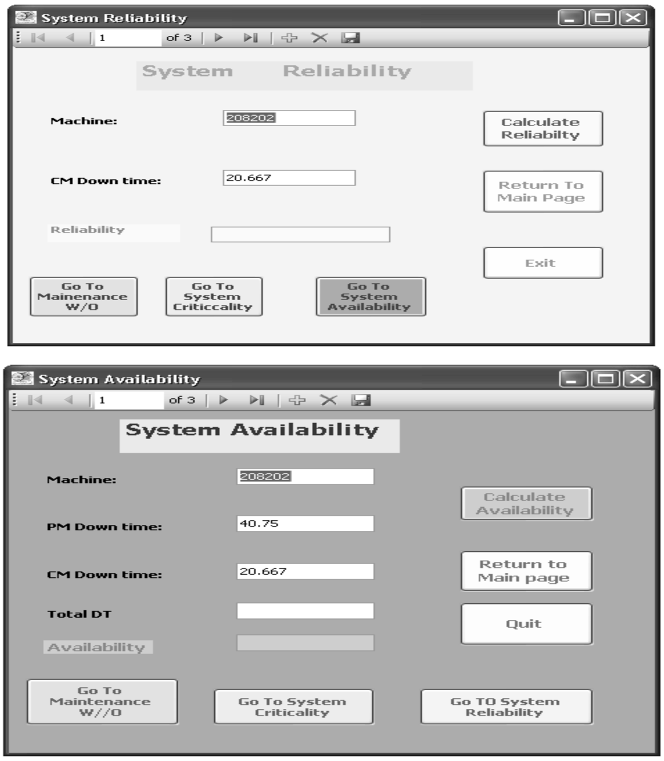


Fig. 5. System reliability and availability forms of the PM program.

V. CASE STUDY

The present research has been applied for Automotive Exhaust Systems of the Abu El -Yazeed Group, Egypt. The main product for company is the Exhaust systems. The main components of the muffler are introduced in Figure 6. The design capacity of the Muffler assembly is about 400 per hour. The different stages to form the muffler and our study will be on the linear seaming machine in muffler assembly shop are presented in Fig. 7.

A. Problem statement

In Egyptian manufacturer of Automotive Exhaust Systems, the current policy in this company is the corrective maintenance policy (CM). The production loss (muffler/hour) of the process is caused mainly by the stoppage of the company production line. Thus, the

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production loss costs are usually concentrated on the random breakdown events for Longitudinal Seaming and Rotary machines. So, the application of (CAPMP) is applied to obtain the optimum preventive maintenance interval.

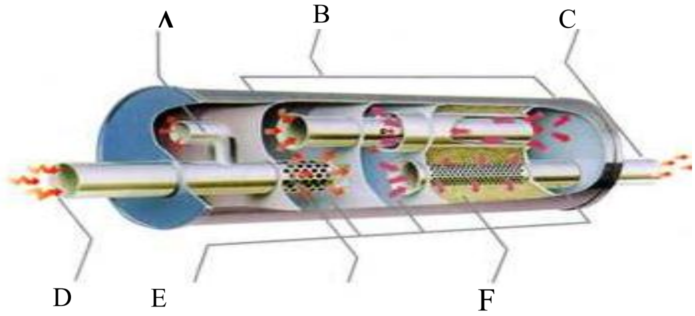

Fig. 6. Muffler components.

Fig. 7. The Longitudinal Seaming machine.

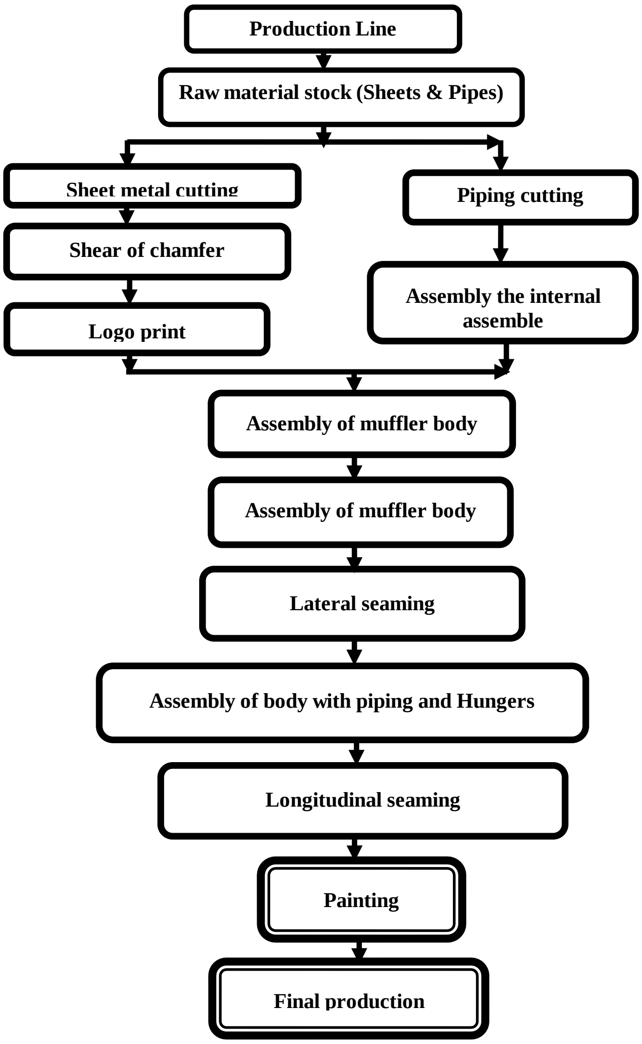

Fig. 8. Company production line.

B. Data collection

The data collections of the item for the Longitudinal Seaming machines have been collected. The data have been collated from the following sources:-

- Maintenance records.
- Operation logbooks.
- Labor working with or maintaining.

C. Results

The PM schedules and maintenance tasks for machines are presented in Table I. This table shows yearly, six monthly and three monthly maintenance tasks.

TABLE I
PM schedules for machines.

Yearly maintenance tasks	Six monthly maintenance tasks	Three monthly maintenance tasks
Replacement of oil seal.	Replacement of coupling	Filter cleaning
Replacement of orifice.		
Change oil trunk.	Motor bearing greasing.	Cleaning the electrical circuit by dry air.
Bearing replacement.	Pump vibration analysis (900RH).	
Change the hydraulic oil after 5000 work hour.	Motor vibration analysis.	Current analysis
Appling the six-monthly maintenance.	Oil analysis.	Appling the weekly maintenance.

In Table II, main downtime and current availability for Longitudinal seaming and rotating machines are presented. Also, main downtime and proposed availability for Longitudinal Seaming and Rotating machines are shown in Table III.

TABLE II
Results of availability (A_C) analysis for Longitudinal Seaming and Rotating machines for the corrective maintenance (current policy).

Item	Machine Name	Machine Code	N_f (Failure /year)	MDT (Day)	A_C (%)
1	Longitudinal Seaming machine1	208201	16	3.975	**75.6**
2	Longitudinal Seaming machine 2	208202	16	4.25	**74.24**
3	Rotary machine	M05B	17	2.115	**86.287**

As in Fig. 9, the availability analysis for Longitudinal Seaming and Rotating machines is introduced. This figure shows that Longitudinal Seaming machine1 availability increases from 75.6 % to 90.34 %. Also, it is found that Longitudinal Seaming machine 2 availability increases from 74.24% to 88.64% for the proposed preventive maintenance. On other hand, the rotary machine availability improves from 86.287% to 92.21% for the proposed preventive maintenance.

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TABLE III
Results of availability (A_p) analysis for Longitudinal Seaming and Rotating machines for the preventive maintenance (proposed PM).

Item	Machine Name	Machine Code	N_f (Failure /year)	MDT (Day)	A_P %
1	Longitudinal Seaming machine1	208201	9	2.845	**90.34**
2	Longitudinal Seaming machine 2	208202	8	3.75	**88.64**
3	Rotary machine	M05B	8	2.573	**92.21**

TABLE V
Results of reliability analysis for Longitudinal Seaming and Rotating machines for the preventive maintenance (proposed PM).

Item	Machine Name	Machine Code	N_f (Failure /year)	Average MTBF (day)	λ_P (Failure /day)	R(t) %
1	Longitudinal Seaming machine1	208201	9	26.5	**0.03775**	**96.3**
2	Longitudinal Seaming machine 2	208202	8	29.25	**0.0349**	**96.57**
3	Rotary machine	M05B	8	30.43	**0.03287**	**96.77**

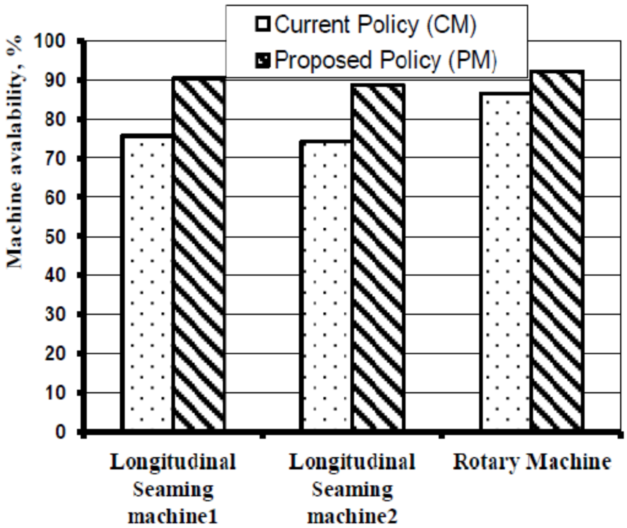

Fig. 9. The availability analysis for longitudinal seaming and rotary machines.

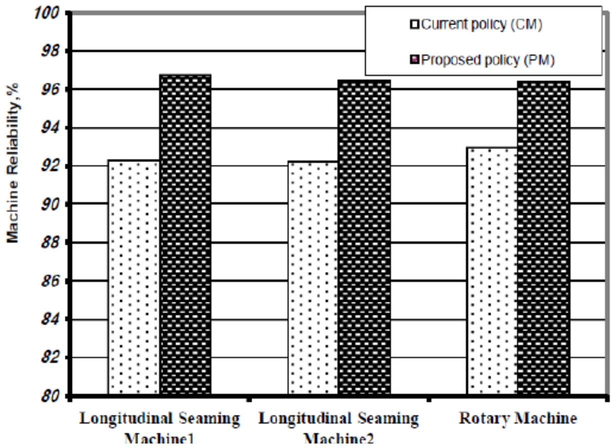

Fig.
10. Fig. 10. The reliability analysis for the Longitudinal seaming and Rotary machines.

In Table IV, the MTBF and failure rate for Longitudinal seaming and rotating machines for current policy are listed. Also, main downtime and proposed reliability for Longitudinal Seaming and Rotating machines are presented in Table V.

As in Fig. 10, the reliability analysis for Longitudinal Seaming and Rotating machines is presented. It is found that first Longitudinal Seaming machine reliability increases from 92.33% to 96.3 % for the proposed PM and it is found that second Longitudinal Seaming machine reliability increases from 92.26% to 96.57 % for the proposed PM and Rotating machine reliability improves from 92.82% to 96.77%.

TABLE IV
Results of reliability analysis for Longitudinal Seaming and Rotating machines for the corrective maintenance (current policy).

Item	Machine Name	Machine Code	N_f (Failure /year)	Average MTBF (day)	λ_C (Failure /day)	R(t) %
1	Longitudinal Seaming machine1	208201	16	12.525	0.07984	**92.33**
2	Longitudinal Seaming machine 2	208202	16	12.25	0.08163	**92.26**
3	Rotary machine	M05B	17	13.4	0.07455	**92.82**

The annual downtime cost for machines is introduced in Fig. 11. The results show that the annual downtime cost for first Longitudinal Seaming machine decreases from $305*10^6$LE to $123*10^6$LE for proposed the PM. On the other hand, the annual downtime cost for second Longitudinal Seaming machine decreases $326*10^6$LE as compared to $144*10^6$LE for proposed the PM. Moreover, about 42.8 % of the annual downtime cost for rotary machine is saved when proposed the PM other corrective maintenance once

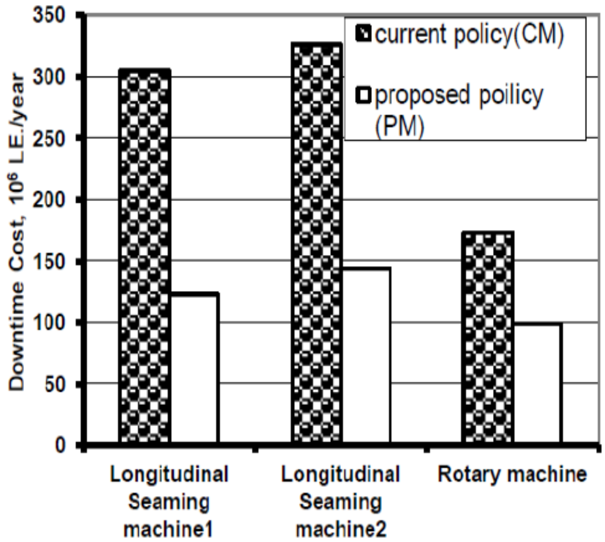

Fig. 11 . Annual downtime cost for Longitudinal Seaming and Rotary machines

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VI. CONCLUSION

This paper described a preventive maintenance program tool which was designed to calculate the size of maintenance labor force, spare parts cost, total maintenance cost, number of work order, reliability, and availability). By applying the proposed preventive maintenance program, it is possible to find preventive maintenance policies which provide a high level of availability and reliability for all machines (Figures 9 and 10). The improvement in availability and reliability for indicates the explicit benefit of the PM policy.

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