RELIABILITY SIMULATION OF SCHEDULED PREVENTIVE MAINTENANCE FOR SURFACE-MOUNT TECHNOLOGY MACHINE

by

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LIST OF ABBREVIATIONS

PM	Preventive Maintenance
SMT	Surface-Mount Technology
SMD	Surface-Mount-Device
IC	Integrated Circuit
BGA	Ball Grid Array
SPI	Solder Paste Inspection
AOI	Automated Optical Inspection
PCB	Printed Circuit Board
PCBA	Printed Circuit Board Assembly
CCD	Charge-Coupled Device
TC	Transport Controller
PCC	Placement Controller
DES	Discrete Event Simulation
R	Reliability
MTBF	Mean Time Between Failure
A	Availability
A_A	Achieved Availability
MTTR	Mean Time To Repair
MTTF	Mean Time To Failure
M	Maintainability

CM	Corrective Maintenance
MTBMA	Mean Time Between Maintenance Action
MMT	Mean Maintenance Time
MPMT	Mean Preventive Maintenance Time
FMS	Flexible Manufacturing Systems
PMOST	Preventive Maintenance Optimization Software Tool
TPM	Total Productive Maintenance

LIST OF SYMBOLS

λ	Failure rate
μ_R	Repair rate
f_{PM}	Frequency of preventive maintenance
t	Time
χ	Random variable

Simulasi Kebolehpercayaan Bagi Penyelenggaraan Pencegahan Berjadual Untuk Mesin Teknologi Peletakan Permukaan

ABSTRAK

Tesis ini membentangkan satu pendekatan penyelenggaraan yang lebih baik dalam teknologi peletakan permukaan, terutamanya penjadualan pencegahan penyelenggaraan mesin AX-501 dengan menggunakan simulasi kebolehpercayaan. Ini adalah untuk meramalkan kegagalan mesin dan menganggarkan kebarangkalian bahawa mesin tidak akan gagal beroperasi untuk mengekalkan fungsinya daripada kerosakan secara tiba-tiba, terutamanya pada masa yang kritikal. Tujuan utama kajian ini adalah untuk mencadangkan jadual penyelenggaraan pencegahan yang lebih baik daripada yang dijadualkan sekarang iaitu sekali sebulan berdasarkan kebolehpercayaan mesin. Sumber data yang dikumpul dari Julai 2014 hingga Jun 2015 untuk 24 jam (2 syif) hari bekerja dari Isnin hingga Ahad. Model matematik yang digunakan dalam kajian ini adalah berdasarkan kepada kebolehpercayaan dan model simulasi telah dibangunkan dengan menggunakan perisian Arena. Kesimpulannya, penyelenggaraan pencegahan yang terbaik dijadualkan pada mesin ini adalah sekali sahaja bagi setiap dua minggu. Kekerapan penyelenggaraan pencegahan berjadual ini sama sekali mengurangkan kerosakan mesin kerana ia akan memanjangkan kebolehpercayaan mesin dan jangka hayatnya seterusnya memanjangkan masa mesin tidak berfungsi.

Reliability Simulation of Scheduled Preventive Maintenance for Surface-Mount Technology Machine

ABSTRACT

This thesis presents an improved maintenance approach for the surface-mount technology; particularly the AX-501 machine's scheduled of preventive maintenance by using reliability simulation. This is to predict the failure of the machine and estimate the probability that the machine will not fail over some operational time in order to maintain its functional from sudden breakdown, especially during critical time. The main aim of this study is to propose a better schedule of preventive maintenance than current schedule which is once a month based on the machine's reliability. Data source is collected from July 2014 until June 2015 for 24 hours (2 shifts) of working day from Monday to Sunday. The mathematical model used in this study is based on reliability and model simulation was developed by using Arena software. In conclusion, the best scheduled preventive maintenance for this machine is once for every two weeks. This frequency of scheduled preventive maintenance totally reduces the machine's breakdown as it will extend machine's reliability and its lifespan thus prolong machine's time to fail.

CHAPTER 1

INTRODUCTION

1.1 Overview

Maintenance is the important system in operation to prevent occurrences of failure. Machine malfunction and breakdown can delay the production as well as affect the company reputation, operation, and profitability. The outcomes of a failure machine can be disorganized, uncooperative, improvident and costly. In consequence, it has far loss of profit and affecting the customers and market's goodwill.

As stated by Heizer and Render (2011), Orlando Utilities Commission (OUC), a central Florida electric utility company experienced an unexpected forced outage that cost from USD250,000 to USD500,000 per day. Its coal-fired unit requires maintenance personnel to perform about 12,000 repairs and preventive maintenance tasks a year. The value of preventive maintenance was illustrated by the first overhaul of a new generator, which revealed a crack rotor blade that could have destroyed a USD27 million piece of equipment.

There are many different ways in maintaining equipment which consists of preventive maintenance, condition monitoring and corrective (breakdown) maintenance (http://www.hansfordsensors.com/the-pros-and-cons-of-different-maintenance-strategies/). Preventive maintenance (PM) mostly features two different types of maintenance which are scheduled (periodic or time-based) maintenance and non-scheduled (predictive) maintenance (Figure 1.1).

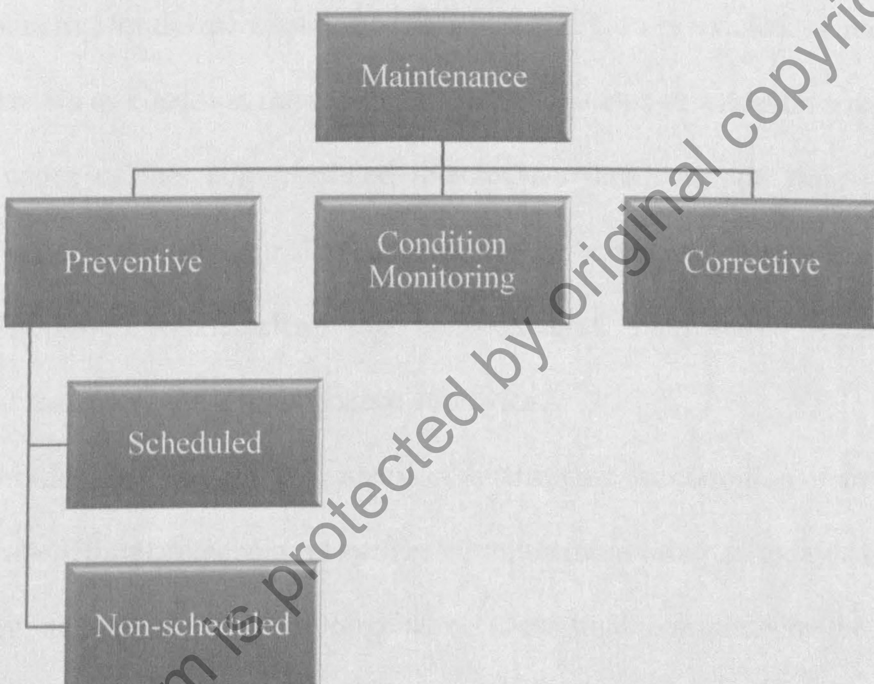

Figure 1.1: Types of maintenance strategies

Scheduled preventive maintenance is the activity based on a regular basis, which helps keep things in working order. Scheduled preventive maintenance involves performing routine systematic inspections, detection, correction, prevention of incipient failures servicing and keeping equipment in good shape. Scheduled preventive maintenance level needs planning, a high degree of coordination between different departments, allocation of the significant amount of time, and is typically initiated through a work order. The main purpose of scheduled preventive maintenance is to ensure that all equipment required is operating in parallel at 100% efficiency at all times to avoid them from malfunction and keeping them working without interruption. The cost of scheduled preventive maintenance is relatively small when compared to the cost of a major breakdown.

In a non-scheduled maintenance strategy, the person-in-charge will predict when equipment failure might happen, and then perform maintenance to keep machines in operation. This non-scheduled maintenance ensures that a piece of equipment requiring maintenance is only shut down right before forthcoming failure and allowing assets to remain productive for the most amount of time possible. Non-scheduled maintenance uses a process known as condition monitoring to check the status of assets on a regular basis. The advantages of this non-scheduled maintenance are cost and time of machine downtime is kept to a minimum. In addition, the probability of failure is reduced and reliability improved. Nonetheless, this non-scheduled maintenance requires higher upfront cost than more basic maintenance strategies.

Condition monitoring is the process of determining the condition of an asset while it is in operation, through techniques such as vibration monitoring. In today's engineering environment, monitoring the condition of assets is essential to minimising the failure and downtime of critical machinery as it allows for remedial action to be taken and productivity to be protected. The advantages of this condition monitoring are the problems with components can be identified prior to failure, repairs can be carried out on assets to keep them running with minimal disruption to productivity and long-term costs are very low compared with the cost of failure. However, this condition monitoring requires short-term investment.

Meanwhile, corrective maintenance involves fixing something that has stopped working properly. Corrective maintenance activities commenced to detect, isolate, and rectify the fault so that the failed equipment, machine, or system can be restored to its normal operable state. This remedial activity occurs when the machine fails and must be repaired on emergency or priority basis. Corrective maintenance is at variance with preventive maintenance. Corrective maintenance improves equipment and components so that preventive maintenance can be carried out reliably. Equipment with design weakness must be redesigned to improve reliability or improving maintainability.

This study will focus on the scheduled preventive maintenance which repairs are taken care of on a smaller scale with less operational costs and machinery is fixed before a failure or another downtime-causing event occurs based on the machine's reliability. It is one of the best ways to prolong the machine's life. Though, organizations should consider having an established schedule in place in order to gain the full benefits of a preventive maintenance strategy.

1.2 Problem Background

This study is about reliability simulation of scheduled preventive maintenance for the Surface-Mount Technology (SMT) machine (model AX-501) using discrete-event simulation by Arena software. The AX-501 machine is a multi-functional machine for standard SMD (Surface-Mount-Device), IC (Integrated Circuit) and BGA (Ball Grid Array) placements (Figure 1.2).

Figure 1.2: AX-501 machine

The AX-501 machine (Figure 1.3) is located in the middle of the SMT process which consists of a few machines - Board Loader, DEK, SPI (Solder Paste Inspection), AX-501, Oven Reflow and AOI (Automated Optical Inspection). Board loader machine is the initial process of inserting bare PCBs (Printed Circuit Boards) inside the loader machine and the PCBs are queuing to start the assembly process. Then, the PCBs will go through the DEK machine by piece for solder paste printing before continuing to SPI machine for solder paste inspection and measurement.

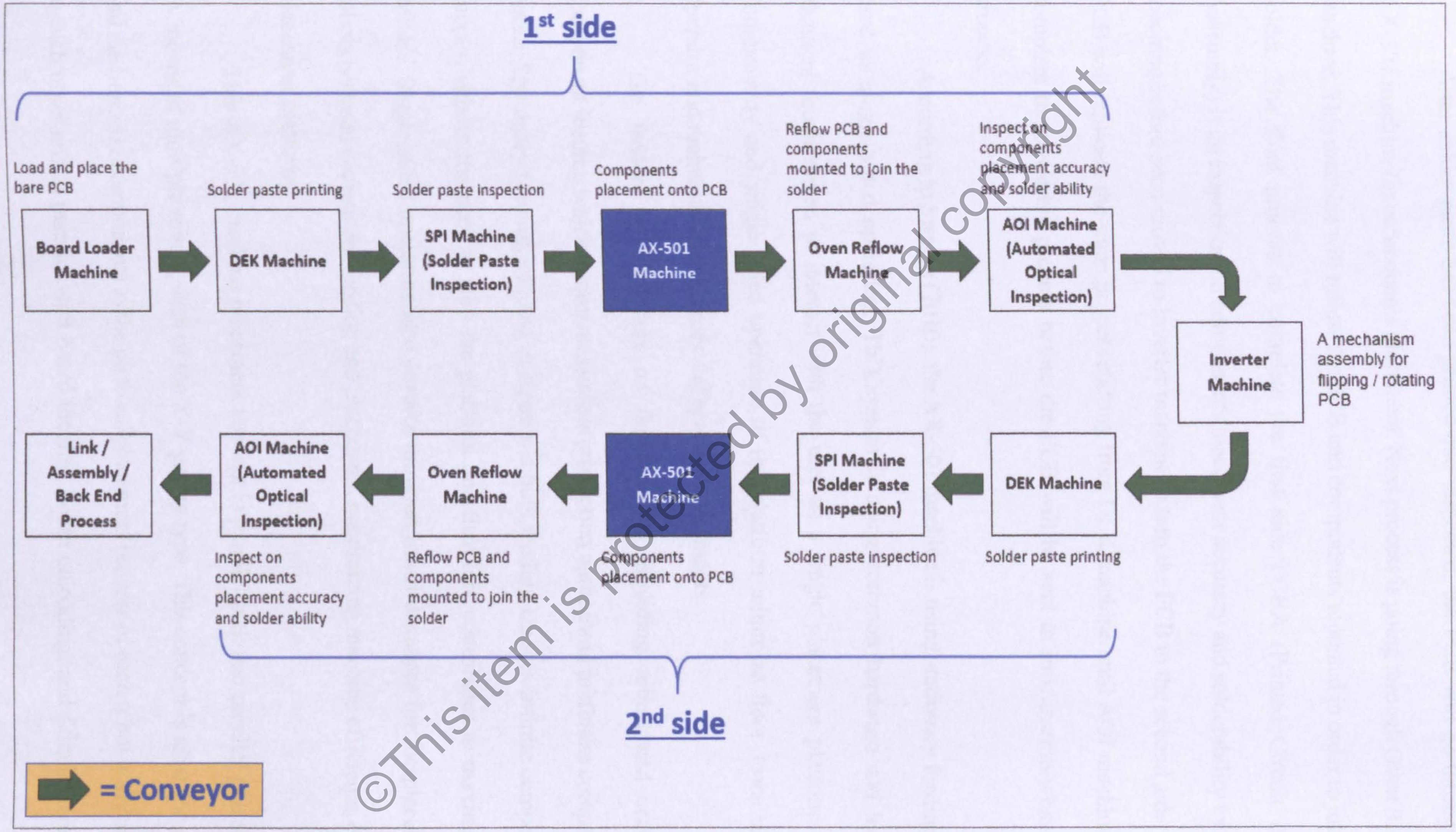

Figure 1.3: SMT process flow

After solder paste has been printed and inspected, the PCB will go through the AX-501 machine for components placement. Next process is going through Oven Reflow machine. This machine will reflow the PCB and components mounted in order to join the solder. The final process to complete the first side PCBA (Printed Circuit Board Assembly) is an inspection on components placement accuracy and solderability by AOI machine before been moved to Inverter machine to turn the PCB to the second side. This PCB will replicate the same process starting from DEK machine until AOI machine and complete the assembly process before the PCB will be sent to link/assembly/backend process.

According to Sweere (2010), the AX-501 machine is using stationary feeding and used as single sided operation. This system is using common hardware and has an identical touch screen to interact with the user as a single placement platform. The commonality and single sided operation of the platform minimize floor space usage, operator and maintenance resources and spares requirements.

The feeders are stationary on the platform providing robust and accurate component feeding which in turn maximizes production uptime and minimize component waste. Stationary feeding, splicing of tapes and bulk feeding ensures infinite component supply without the need to stop the platform and therefore contributes to maximizing uptime. Single sided operation also ensures minimal travel distances for the placement robots between component feeding and placement, maximizing machine efficiency of the placement platform.

This AX-501 machine placement concept is parallel pick and parallel placement by means of multiple robots, each of the X-Y gantry type. This concept is ideal for small and medium size components as the pick and placement process of each robot is in parallel to each other and in parallel with board loading, board unloading, and fiducial reading.

Parallel processing assures that all of the available time is used for the added value of component placements and thus maximizing machine efficiency. This concept is used to handle the majority of an application component range at the highest efficiency.

The robots are individually operating at a relatively low speed in X & Y direction only, providing robust component handling and reliable robot lifetime. The placement head uses a direct drive rotation motor, a linear motor servo system with a linear ruler, providing controlled movement of the Z-axis, and programmable placement force control. Component placement to artwork alignment is achieved using an onboard alignment camera on the placement head. After each index stroke of the transport, each of the placement robots checks for fiducials to assure accurate component to artwork alignment. Component alignment is by using laser alignment, optional upwards looking CCD (Charge-Coupled Device) cameras with digital image processing, for lead and ball inspection.

The AX-501 machine can accommodate up to 5 feeder trolleys and up to 10 standard placement robots or 20 compact placement robots. The top 4 major breakdowns recorded from July 2014 until June 2015 for the AX-501 machine are Auto Power Down, Pickup Error, Machine Hang and Fiducial Error. Auto Power Down is an error when the machine application software suddenly closed and the machine will trigger on the location (hardware) problem. Mainly issues are related to TC (*Transport Controller*) and PCC (*Placement Controller*). Pickup Error is an error that caused by machine, robot or component while Fiducial Error is due to machine unable to interpret accurately thus cause this error. Machine Hang was caused by various failures that related to Auto Power Down, Pickup Error, and Fiducial Error.

1.3 Problem Statement and Research Questions

The focus of this study is to approach further on machine's scheduled preventive maintenance using reliability simulation in order to maintain the machine functional from the sudden breakdown, especially during a critical time. The scheduled preventive maintenance can be seen as a relationship between the machine (which run assembly process through the assembly line) and the technician (who maintain the machine along the assembly process).

Hence, this research tries to have some insight to the following questions:

i. How many times the machine malfunction or breakdown? Monthly or weekly?

ii. How long the inter-arrival time from one breakdown to another breakdown?

iii. How long has the service time or repair time taken by a technician to fix the problem?

iv. What is the probability that the machine will not fail over some operational time span?

v. What is the recommendation schedule for preventive maintenance?

1.4 Research Objectives

The objectives of this study are:

i. To identify the phenomena or behaviour of AX-501 machine malfunction based on historical data;

ii. To model the malfunction behaviour by using Discrete Event Simulation (DES) generated with Arena software;

iii. To simulate periodic preventive maintenance for AX-501;

iv. To propose a better schedule maintenance model for AX-501 machine based on machine reliability.

1.5 Research Scope

The scope of this study is to analyse on the reliability system for AX-501 machine maintenance, the assumption on AX-501 machine preventive maintenance schedule and to get the assumption of AX-501 inter-arrival time from initial breakdown to next breakdown without considering cost constraint and production assembly planning process. The machine's downtime cost and operation cost are excluded in this study due to time constraint. Data is gathered from July 2014 until June 2015 for 24 hours (2 shifts) of working day from Monday to Sunday.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In the performance-based design and operation of modern engineered systems, the accurate assessment of reliability is of paramount importance, particularly for civil, nuclear, aerospace, and chemical systems and plants which are safety-critical and must be designed and operated within a risk-informed approach (Patalano, Apostolakis & Hejzlar, 2008).

The reliability assessment requires the realistic modelling of the structural/mechanical components of the system and the characterization of their material constitutive behaviour, loading conditions, and mechanisms of deterioration and failure that are anticipated to occur during the working life of the system (Schueller & Pradlwarter, 2007).

In practice, not all the characteristics of the system under analysis can be fully captured in the model. This is due to:

i. the intrinsically random nature of several of the phenomena occurring during the system life;

ii. the incomplete knowledge about some of these phenomena.