INSPECTION MODEL DEVELOPMENT FOR PRODUCTION MACHINES BASED ON DOWNTIME RECORD

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Inspection Model Development For Production Machines Based On Downtime Record

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ABSTRAK

Di bahagian pengeluaran, objektif utama mesin untuk menghasilkan produk yang berkauliti pada masa yang ditetapkan dan mengikut keperluan pelanggan untuk mencapai kepuasan pelanggan. Untuk mencapai objektif, bahagian pengeluaran perlu beroperasi dengan lancar tanpa atau kurang kerosakan pada mesin. Walau bagaimanapun, pengeluaran sebenar dengan strategi penyelenggaraan yang tidak berkesan menjadi halangan kepada pencapaian matlamat. Secara munasabah, masalah ini menyumbang kepada kerosakan kepada pengeluaran, kecacatan pengeluaran (jika kerosakan berlaku sewaktu mesin beroperasi) dan meningkatkan kos penyelenggaraan. Pemeriksaan merupakan salah satu strategi Penyenggaraan Pencegahan yang boleh digunakan untuk mengurangkan masalah kerosakan mesin di dalam bahagian pengeluaran. Sebaliknya, permohonan pemeriksaan dalam tempoh berapa kali pemeriksaan yang perlu dilakukan pada sesuatu tempoh (seperti sekali sebulan) adalah isu utama. Untuk menjawab soalan ini, analisis penyelenggaraan yang mencukupi berdasarkan pemeriksaan mesti dicapai. Kebanyakan kajian sedia ada adalah fokus kepada pemeriksaan Mesin pada keadaan kadar kegagalan yang berterusan. Tiada pertimbangan untuk mesin dalam kadar kegagalan yang menurun. Oleh itu, strategi pemeriksaan diperkenalkan pada kadar kegagalan yang menurun kepada sesuatu mesin untuk memberi nilai tambahan kepada mesin-mesin pengeluaran dengan mengurangkan kerosakan mesin kerana pemantauan berterusan yang dijalankan dan melakukan pembetulan atau penyelenggaraan jika perlu. Dalam kajian ini, analisis model pemeriksaan penyelenggaraan dengan mengambil kira masa kegagalan mesin-mesin yang dibangunkan untuk menentukan kekerapan pemeriksaan optimum mesin-mesin yang kritikal dalam bahagian pengeluaran. Di samping itu, strategi pemeriksaan yang digunakan boleh memaksimumkan output pengeluaran Mesin dari segi produk dan perkhidmatan. Untuk mengesahkan model ini, kajian kes telah dijalankan di industri automotif di Malaysia. Hasil dari analisis kegagalan telah mengenal pasti bahawa semua Mesin kritikal di peringkat mengurangkan kadar kegagalan dan maklumat ciri-ciri kegagalan adalah digunakan untuk analisis seterusnya. Keputusan menunjukkan bahawa Mesin mengikut taburan Weibull dan pemeriksaan pemodelan juga menggunakan fungsi Weibull untuk mengenal pasti kekerapan pemeriksaan untuk mesin kritikal. Oleh itu, keputusan menunjukkan bahawa hubungan di antara dua model pemeriksaan berdasarkan keuntungan dan masa henti ada persamaan.

DEVELOPMENT OF PRODUCTION MACHINES INSPECTION MODEL BASED ON DOWNTIME AND FAILURE CAUSE INFORMATION

ABSTRACT

In the production line, the main objective of the machines to provide the good quality of products at the time given and follow the customer requirement to accomplish customer's satisfaction. To reach the objective, the production line should running in smooth flow without or less breakdown. Nevertheless, the real production with the ineffective maintenance strategy becomes barrier to the production to achieving the objective. Reasonably, this problem contributes to high production lost, production defect due to reject product (if the breakdown occurs during the machine is operating) and increasing the maintenance cost. Inspection is one of the Preventive Maintenance (PM) strategies that can be used to reduce machines breakdown problem in the production line. Conversely, the application of inspection in term of how many times of the inspection should be done at the unit of time (such as per month) is the main issue. To answer this question, an adequate maintenance analysis based on inspection must be accomplished. Most of the existing study is focus to inspection of single machine at the state of constant failure rate. There is no consideration for machine in the state of decreasing and increasing failure rate. Hence, the inspection strategy introduce to the machine at decreasing failure rate state to give extra value to the production machines by reducing machines breakdown due to continuous monitoring the machine condition and do correction or maintenance if needed. In this research, an inspection model of maintenance analysis by considering the failure time of the machines is developed in order to determine the optimal inspection frequency of the critical machines in the production line. In addition, the inspection strategy that used can maximize the output of production machines in term of product and service. In order to confirm this model, a case study was carried out on the automotive industry in Malaysia. The result from failure analysis have identified that all the critical machines in the state of decreasing failure rate and the failure characteristic information was used for the next analysis. Result shows that the machine follows the Weibull distribution and for inspection modeling also used the Weibull function to identify the inspection frequency for the critical machines. Therefore, the result shows that have relationship between two inspection model base on profit and downtime.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter contains four sections that base on background of research, problem statement, objective and scope and limitation. Background of research gives overview about the research content and focus. Problem statement discusses the problems that appear in the maintenance area and need solution to solving it. The third section is an objective of research and the last section is a scope and limitation of research.

1.2 Background of Research

Machine which is used as part of manufacturing process is subject to random failure because of continuous operating. Breakdown of machine in production line will increase if maintenance activities not take as a serious aspect in the manufacturing production area. Therefore, maintenance activities are introduced to keep a system and all its components in working order. Maintenance activities can be classified into two categories, preventive maintenance (PM) and corrective maintenance (CM).

Preventive maintenance is applicable in manufacturing industry to increase the system reliability, maintainability and availability (Ahmad et al., 2006). By applying PM,

the system lifetime will be longer, performance will be better and productivity will be higher (Ahmad et al., 2006). For repairable system, unexpected failure that occurs during machining process will increase the maintenance cost and production lost (Nakajima, 1986). Failure is defined as any change of product or system from its satisfactory working condition to a condition that is below acceptable or operating standards for the system.

The one of PM strategies is inspection that are useful for a repairable system to increase the system availability by eliminating the root causes of unexpected failure. An inspection is an activity to organized examination or formal evaluation exercise. In a preventive maintenance strategy, the scheduling of periodic inspections for this machine will certainly reduce the number of breakdowns and the associated costs of machine downtime and emergency repairs. Inspection can help determine the current status of repairable system and detect minor error due to major failure (Bahrami-Ghasrchami and Mathew, 1998). There are several criteria in inspection policy (Ahmad at al., 2006):

1. Cost criterion, to generate optimal inspection policy.
2. Downtime minimization criteria.
3. Maximizing system availability criteria.

1.3 Problem Statement

Most of industries perform maintenance activity after breakdown occur (Corrective maintenance) to the machines or system; because of that activities, production flow will be stop for a while (downtime). Corrective maintenance (CM) is not the best strategy that will be use for the industries. This strategy reflects to high machine downtime (production lost) and maintenance (repair or replace) costs (Tsang, 1995). Other strategy that can be useful to replace the CM is Preventive Maintenance (PM). To apply PM strategy, the best time to perform PM and how many frequency of maintenance activities need to be considered. Inspection is one of PM strategy that will help to determine current situation of the machine or system by detecting minor or major error. By using inspection strategy, time to do inspection and frequency of inspection for the machine or system will be answered to achieving the production goal. Most inspection strategy applied at constant time interval, less depression on maintenance at the stage of decreasing time interval.

1.4 Objectives

The general objective for this research is applying inspection strategy for reducing machine breakdown problem in the production line. The specific objectives of this research are as follows:

1. To develop an inspection model for maintenance action at decreasing failure rate by considering downtime record.
2. To identify critical machines those cause major effect to the production line by using Pareto Analysis.

3. To analyze failure time data of critical machines by using parametric method and Failure time Modeling.
4. To determine the optimal inspection frequency and optimal inspection interval by using inspection modeling.

1.5 Scopes and Limitation

This research is carried out on some scopes and limitation. First scope for this research is application of Preventive Maintenance (PM) strategy is based on Time-Based Maintenance (TBM) and focus on the determination of the optimal inspection frequency and optimal inspection interval. Second scope is criteria for inspection analysis that will be considered are minimizing downtime, maximizing profit and maximizing availability. The limitation for this research is an application of this research for automotive industrial application.

1.6 Thesis Structure

The structure of this thesis are as follows; Chapter one give introduction of the research, related problem to study, objective of the research and scope and limitation of this research. Chapter two provide a literature review of research subject. Chapter three discusses development of inspection model. Chapter four presents the validation of inspection model based on application of automotive industry. Chapter five concluded the overall of this thesis and provided recommendation for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter covers on the literature review with the topic of production machine characteristics, type of failure, maintenance strategy, inspection issues and reliability issues. In the second topic (type of failure) have two sub topics that cover physical failure and functional failure. While, in the third topic (maintenance strategy) have three sub topics such as corrective maintenance, preventive maintenance and selection of maintenance strategy. In the inspection issues topic has one sub topic that is inspection model. The last topic is concluded the finding of literature review.

2.2 Machine Characteristics

A machine is a tool that consists of one or more parts or components that have been combined, and used the source of energy to meet a particular goal or a device that used energy to perform some activity or task. The source of energy come from mechanical, chemical, thermal, or electrical means, and motorized powered. Machine is complex systems that have various subsystem, component and part. In general, machine consists of three types of components such as electrical component, mechanical component and electronic component and it can be combination of all type of the components to become

one system. The electric energy was supply to electrical component to change the energy into the mechanical energy or motion to perform a task. The electronic components are the device that used to control current and voltage for the machine system.

Machine or system configuration can be classified into three types; serial configuration, parallel configuration and serial-parallel configuration. The rule of the serial system is all component need to function for the system to function. Figure 2.1a illustrated the serial system, failure of any one component will result in system failure and for system to work; all the components must work (Narayan, 2003). Figure 2.1b shows the parallel system and this system need only one components to work for the system to be effective (Narayan, 2003). The combination of serial and parallel configurations that shows in Figure 2.1c is the reality of most of the machine system.

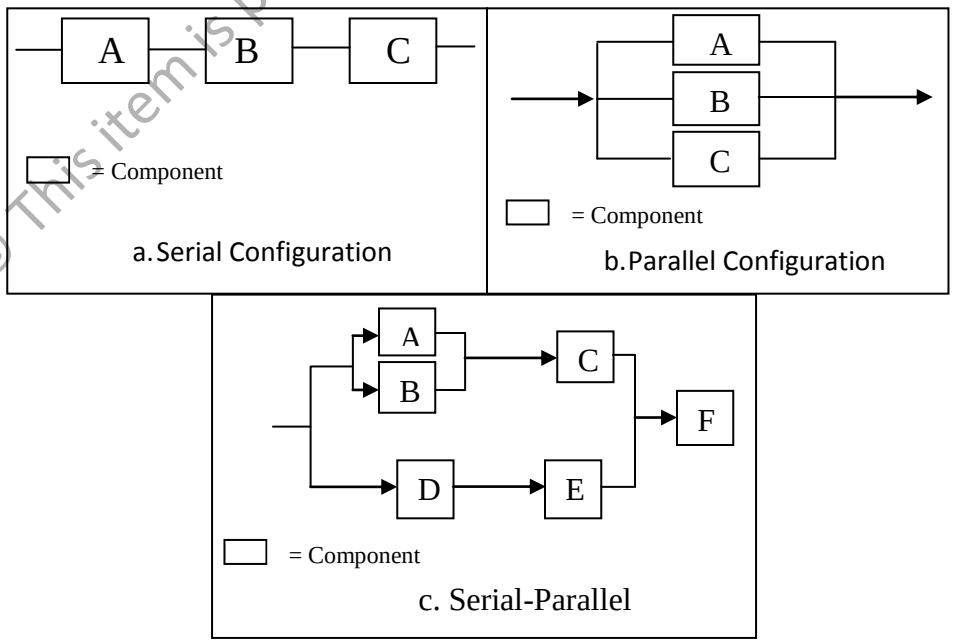

Figure 2.1: Machine configuration: a. Series configuration, b. Parallel configuration and c. Serial-Parallel configuration

2.3 Type of Machine Failure

Referring to Narayan (2003), failure is the inability of an item of equipment, a sub-system or system to meet a set of predetermined performance standards. The machine failure also related to system configuration of the machine. If the machine developed by the series configuration, it will result all the system of the machine shutdown when one of the component failed to function. The machine that developed by the parallel configuration still can continue it operation when one component failed to operated because it have another component to backup the operation of failed component. Effective machine system should have both of the configuration to balance the system operation and as the strategy to reduce the components failure.

Nowlan and Heap (1978) divided failure into two types: functional and potential. Functional failure is the inability of an item (or the component containing it) to meet a specified performance standard, whereas potential failure is an identifiable physical condition indicating an imminent functional failure. Based on Eti et al. (2004), failures usually attract attention because they can adversely affect output, safety, environmental health, quality of end-product, customer service, competitiveness or unit costs. While Ahmad and Kamaruddin (2012) stated that failures of machine component are divided by two types such as physical failure (PF) and functional failure (FF).

2.3.1 Physical Failure (PF)

The first failure is physical failure; where the component is considered failed when the function of component is terminated due to physical damage (Ahmad and Kamaruddin, 2012). Example of this failure is rotating component like bearing becomes loose because of long time of used. This type of failure usually results the operation will stop or sudden breakdown.

2.3.2 Functional Failure (FF)

The second failure is functional failure, where the component is considered failed when its performance does not reach the required level (Ahmad and Kamaruddin, 2012). This type of failure may not result in stop of operation of the component but its output (product) characteristics, such as quality (size of product) may not satisfy requirements. Failure also can be combination of PF and FF.

According to Venkata Rao and Gandhi (2002), the unplanned maintenance and random failure of the machine tool has a direct effect on the efficiency of any manufacturer or unit. In a repairable system, unexpected failure occurs during machining process will increase maintenance cost and production lost (Nakajima, 1986). In reality, the second and third failure types frequently occur because a close relationship exists between maintenance and production quality from a production machine perspective, especially because product quality depends on the condition of machine components (Arunraj and Maiti, 2007). The conclusion is FF and combination of FF and PF are critical problem in production machine.

The economic effect of these types of failure not only includes internal cost, but external cost as well (Ahmad and Kamaruddin, 2012).

2.4 Maintenance Strategy

Manufacturing industries are set up to meet the need for a particular goods or products. The main aim of such manufacturing industries is to make profit, maximize profit, or minimize cost by investing for huge amount in several aspects such as start-up capital, equipments, and machines. According to recent research on Effective Maintenance Implementation (EMI), it has been reported that the main problems faced by developing and under–developed countries is the lack of a proper maintenance culture (Martin, 2003). There is no equipment that can operate with 100% efficiency and this defense the fact that any equipment, no matter its present or recent reliability status, can breakdown (Yannis and Mackwanzie, 2003).

Referring to Najji (1995), the definition of maintenance is "A means to maintain and improve the quality of the elements involved in a production process, continuously and cost-effectively through detecting and controlling the deviations in the condition of a production process that is decided by production costs, working environment and product quality in order to interfere when it is possible to arrest or reduce component or equipment deterioration rate before the process condition and product characteristics are intolerably affected and to perform the required action to restore the equipment or process or a part to as good as new" (Al-Najja,1995). Mulugeta (2009) stated that maintenance is any activity

carried out on an asset in order to ensure that the asset continues to perform its intended functions.

According to Odeyale et al (2013), maintenance strategy is the coordination, control, planning, execution and monitoring of the right equipment maintenance activities in manufacturing and facilities operations. Consequently, the maintenance function is an important element of modern business and must be managed effectively (Murthy, et al., 2002). In a maintenance improvement programmed, the maintenance activities are analyzed to ensure that the correct blend of maintenance strategies is utilized (Kahn, 2006). The technology of maintenance today, find out and applying cost-effective ways of avoiding or overcoming performance deterioration by using failure management techniques include predictive and preventive actions, failure-finding, run-to-failure and change the way it is operated (Eti et al, 2004). However, a production system after maintenance is not as efficient as a new system and it becomes "younger" than its actual age, but does not reach age zero (Chen, 2013). Generally, maintenance can be applied based on two strategies; corrective and preventive maintenance (Ahmad et al, 2011).

2.4.1 Corrective Maintenance

The main characteristic of corrective maintenance is that actions are only performed when a machine breaks down (Bevilacquaa and Bragliab, 2000). There are no interventions until a failure has occurred. Corrective Maintenance (CM), also known as run-to-failure or reactive strategy is a traditional strategy that restores (repairs or replaces) the machine or component to its required function after it has failed (Blanchard, 1995). However, this

strategy will cause high machine downtime (production loss) and maintenance (repair or replacement) costs due to sudden failure (Tsang, 1995). The study of Kenne and Gharbi (2004) showed that optimal production and corrective maintenance policies can be estimated by combining simulation experiments to experimental design and response surface methodology. Because of disadvantaged of the corrective maintenance, the alternative ways is applying in production system such as preventive maintenance.

2.4.2 Preventive Maintenance (PM)

Preventive maintenance is based on component reliability characteristics. This data makes it possible to analyze the behavior of the element in question and allows the maintenance engineer to define a periodic maintenance program for the machine (Bevilacquaa and Bragliab, 2000). The preventive maintenance policy tries to determine a series of checks, replacements and/or component revisions with a frequency related to the failure rate. In other words, preventive (periodic) maintenance is effective in overcoming the problems related with the wearing of components. It is evident that, after a check, it is not always necessary to substitute the component: maintenance is often sufficient**.** Gertsbakh, (1977) and Lofsten, (1999) stated that PM strategy involves the maintenance activities such as preventive repair and preventive replacement that performed before equipment failure. The objective of PM is to reduce failure rate or failure frequency of the machine. It contributes to reducing costs, minimizing machine downtime (production loss), increasing productivity and improving quality (Usher et al., 1998). The main target of PM is determination of the optimal time or interval to carry out the PM's task (replacement or repair) (Jardine, 1973). PM actions will result in additional costs and are worthwhile only if