UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPING PROCESS FMEA FOR CENTRIFUGAL PUMP: A CASE STUDY IN LOJI AIR BERTAM, SAMB

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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I hereby, declared this report titled "Developing Process FMEA for Centrifugal Pump: A Case Study in Loji Air Bertam, SAMB" is the result of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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ABSTRAK

Analisis Mod dan Kesan Kegagalan (Failure Modes and Effects Analysis, FMEA) merupakan satu kaedah sistematik yang digunakan untuk mengenal pasti kemungkinan kegagalan yang akan membawa risiko keseluruhan yang tinggi terhadap sesuatu produk/ sistem dengan menganalisis cara-cara kegagalan sesuatu proses, sebab-sebab kegagalan serta akibatnya. Dalam kajian ini, satu Process FMEA (PFMEA) direka untuk pam sentrifugal Loji Air Bertam di bawah Syarikat Air Melaka Berhad (SAMB) yang belum melaksanakan kaedah penilaian risiko. Antara kaedah yang digunakan untuk mengumpulkan dan menganalisis isu-isu umum yang berkaitan dengan pam sentrifugal termasuklah temu duga, tinjauan dan memeras otak. Melalui kajian penulisan ini, sebuah templet PFMEA dan skala penilaian akan direka, diikuti dengan hasil kumpulan data yang dimasukkan ke dalam templet tersebut. Satu Prosedur Operasi Standard (Standard Operating Procedure, SOP) turut dihasilkan untuk dijadikan sebagai garis panduan pada fasa pelaksanaan PFMEA.

ABSTRACT

The Failure Modes and Effects Analysis (FMEA) is a systematic method for identifying those possible failures that pose the greatest overall risk for the product/system by analysing the ways a process can fail, the possible causes of each failure, and its consequences. In this study, a Process FMEA (PFMEA) was to be developed for the centrifugal pumps at Loji Air Bertam under Syarikat Air Melaka Berhad (SAMB), who has not implemented any risk assessment methodology. Interviews, surveys, and brainstorming are among methods used to gather and analyse common issues related to the centrifugal water pump. Through literature research, a PFMEA template and ranking scale was developed, followed by the fitting of data collected into the template. A Standard Operating Procedure (SOP) was also developed during the implementation phase of the PFMEA to act as a guideline.

DEDICATION

Dedicated to my mother,

Loo Lian See,

who gave up her career to watch over her daughters;

and to my best friend,

Yeap Yee Lin,

without which I would have been sleeping throughout the COVID-19 self-isolation.

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FMEA	-	Failure Modes and Effects Analysis
FYP	-	Final Year Project
PFMEA	-	Process Failure Modes and Effects Analysis
PSM	-	Projek Sarjana Muda
SAMB	-	Syarikat Air Melaka Berhad
SOP	-	Standard Operating Procedure

CHAPTER 1
INTRODUCTION

This chapter serves as an introduction to the entire study on Process Failure Modes and Effects Analysis (PFMEA) conducted at Syarikat Air Melaka Berhad (SAMB). A brief summary on the background of the study and the company is given, followed by the problem statement, objectives, scope, and rational. At the end, the thesis organisation is provided to provide a glance through of the report.

1.1 Study Background

Failure Modes and Effects Analysis (FMEA) is currently one of the world's most widely known reliability tool used to systematically identify and prevent product and process problems before they occur. According to McDermott, Mikulak & Beauregard (2009), "FMEAs are focused on preventing defects, enhancing safety, and increasing customer satisfaction". In short, FMEAs are able to assist engineering teams anticipate and prevent issues, consequently leading to higher product and/or process reliabilities.

FMEA, then known as Failure Mode, Effects, and Criticality Analysis (FMECA), was first fully developed and documented by the United States' Department of Defence (1949; Teng & Ho, 1996). The purpose of this approved military standard was to "study the results or effects of item failure on system operation and to classify each potential failure according to its severity" (p. 19). In recent years, an increasing number of manufacturing organisations have been adopting the FMEA methodology in order to satisfy the ISO 9001:2015 Quality Management Systems' requirements, where the management is required to ensure that risks that may affect the quality of a product are determined and addressed. (International Organization for Standardization [ISO], 2015).

To this day, researchers like Kmenta (2000) and Pang (2018) continue to base their area of study on FMEAs, despite it being a 70-year old method. This proves that the FMEA remains a widely used standard in the industry, and organisations that have not incorporated FMEAs into its operations should make the effort to do so.

1.2 Company Background

Figure 1.2.1: Logo of Syarikat Air Melaka Berhad (SAMB).

Syarikat Air Melaka Berhad (SAMB) is a water utility company located in Melaka, Malaysia. Founded on 1 October 1971, the organisation was initially known as Lembaga Air Melaka (LAM) under the jurisdiction of the Melaka State Government, before rebranding it to Perbadanan Air Melaka (PAM) on 1 September 1993. Finally, on 1 July 2006, the agency was transformed into the SAMB private company in response to the Federal Government of Malaysia's aspirations.

Armed with the vision "To be a World-Class Water Provider", SAMB is a one-stop water utility company offering a variety of water-related services to the citizens of the state of Melaka. Besides preserving the quality of treated water provided, the organisation is also responsible for retaining the water supply network throughout the state, thus including the maintenance of water pipes and water meters.

Syarikat Air Melaka Berhad owns a total of nine water treatment plants throughout the state of Melaka. Among them, Loji Air Bertam shares its facilities with Loji Air DAF 1 and Loji Air DAF 2, using the Melaka River, Muar River, and Durian Tunggal Dam as a water source.

Table 1.2.1 on the following page shows the capacity, water source, supply area, and accreditation of each water treatment plant:

Table 1.2.1: SAMB Water Treatment Plant Details

Plant	Bertam	DAF 1	DAF 2
Capacity (mld.)	132	120	120
Water Source	Melaka River Muar River	Durian Tunggal Dam	Durian Tunggal Dam
Supply Area	Melaka Tengah Jasin Masjid Tanah	Melaka Tengah Sungai Udang Bukit Rambai Klebang	Melaka Tengah Jasin Masjid Tanah Merlimau Duyong
Accreditation	MS ISO 9001:2008 MS ISO 14001:2004	none	MS ISO 9001:2008 MS ISO 14001:2004

Figure 1.2.2: Main Entrance of Loji Air Bertam (DAF)

The facilities above, which uses the Dissolved Air Floatation technology, are one of the first and most advanced water treatment plants in Malaysia. Built in the 1990's under the Malacca Water Supply Project Phase 2, it includes flocculation, dissolved air flotation (DAF) and filtration plant, chemical plant, electrical plant, and various other main components in a typical water treatment plant.

1.3 Problem Statement

At present, Syarikat Air Melaka Berhad (SAMB) has not implemented the use of Failure Modes and Effects Analysis (FMEA) in the administration of the organisation. In the words of the engineers at Loji Air Bertam, the company "maintains a record of all machine maintenance and breakdowns, as well as the actions taken to counteract each problem, yet no analysis has been done on the data collected" due to a shortage of engineering personnel.

Aware of the importance of having a proper risk management system in the daily operations of the company, the Engineering Manager of Logi Air Bertam requested for a complete PFMEA system to be developed. Besides the Process FMEA template and risk priority number (RPN) scale, the developed FMEA system should also include a Standard Working Procedure (SOP). Finally, it is expected that the system be taught to the engineering team and all related personnel at Loji Air Bertam, SAMB, upon completion.

Loji Air Bertam of SAMB, as a water utility company, is mainly responsible for supplying water to the Bertam and Melaka Tengah area, which includes Universiti Teknikal Malaysia Melaka (UTeM). As a result, centrifugal water pumps, as shown in Figure 1.3.1, are heavily relied on during day-to-day operations. A centrifugal pump is a mechanical device designed to move a fluid by means of the transfer of rotational energy from one or more driven rotors, called impellers ("Useful Information on Centrifugal Pumps", 2019).

Figure 1.3.1: Centrifugal Pumps at Loji Air Bertam, SAMB

From the experience of engineers and the internal maintenance records of Loji Air Melaka, SAMB, centrifugal water pumps are responsible for up to 80% of the operating and maintenance costs. Due to the nature of the organisation, the effects of any centrifugal pump breakdown will also cause devastating loss in service quality. Based on the points mentioned above, it was unanimously agreed upon that the first PFMEA was to be created based on the centrifugal water pump.

1.4 Objectives

The objectives of the study is to develop a Process Failure Modes and Effects Analysis (PFMEA) for the centrifugal pump at Loji Air Bertam, Syarikat Air Melaka Berhad (SAMB) by:

(a) Analysing the common problems and issues related to the centrifugal water pump.

(b) Developing a Process Failure Modes and Effects Analysis (PFMEA).

(c) Implementing the PFMEA developed at Loji Air Bertam.

1.5 Scopes of the Study

The scopes of study are as follows:

(a) Analysing the common problems and issues related to the centrifugal water pump at Loji Air Bertam, Syarikat Air Melaka Berhad (SAMB) based on mainly the engineering team's expertise and previous maintenance records, whether from Loji Air Bertam or through information exchange with other water treatment plants. It does not include other pumps of similar functions.

(b) Developing a Process Failure Modes and Effects Analysis (PFMEA) for the centrifugal water pump at Loji Air Bertam. Syarikat Air Melaka Berhad (SAMB), up to the determination of the Risk Priority Number (RPN). Recommendations and implementations for improvements will not be covered in the project.

(c) Implementation the PFMEA developed through the development of a Standard Operating Procedure (SOP) to ensure that the practice can be continued throughout the organisation upon the completion of this project. Detailed work instructions will be prepared for every step, and existing internal documents that are related may be modified as needed. Seminars on FMEA will also be conducted with all related personnel at SAMB.

1.6 Rationale of Study

The rational of study are as follows:

(a) Known and/or potential failures of the centrifugal water pump at Loji Air Bertam, Syarikat Air Melaka Berhad (SAMB) can be defined, identified, and subsequently prioritised based on the frequency, effects and, severity of failures. This enables the engineering team to tackle the issues in the order of the highest to lowest risk.

(b) Identifies the "controls" of the centrifugal water pump, and their respective effectiveness in detecting and/or predicting the occurrence of failures in the process.

(c) Reduction of the rate of centrifugal water pump failures and/or effects of failure, and consequently the reduction of manufacturing wastes by loss of efficiency due to machine breakdowns.

(d) Ultimately leading to the improvement of service quality provided by Loji Air Bertam, increasing the reputation of the company.

(e) Facilitates interdepartmental discussions and decision-making on issues related to the centrifugal water pumping process. The FMEA also serves as a documentation of risks and actions for future reference in similar processes.

1.7 Thesis Organisation

The organisation of the thesis is as follows:

(a) Chapter 1 begins with the introduction of the study background and company background to provide an insight to the current situation of the centrifugal water pump at Loji Air Bertam, SAMB. From the problem statement, study objectives were defined within a set scope of study. The rational of the study is then stated. Finally, the thesis organisation and a short summary are provided as an overview of the study.

(b) Chapter 2 comprises of literature reviews about the introduction, types, and benefits of FMEA. This is followed by justifications on the integration of FMEAs, and finally the applications of FMEAs in various industries.

(c) Chapter 3 consists of the methodology, which describes the entire sequence of the study in detail. This includes a flow chart used to provide a clear overview of the process, and detailed explanations on all methods involved during the study.

(d) Chapter 4 discusses the results of the project, which includes both the development and implementation phases. It also provides explanations to various decisions made throughout the course of this study.

(e) Chapter 5 concludes the entire study, then recommends improvements that can be made to improve the project.

CHAPTER 2
LITERATURE REVIEW

The purpose of this chapter is to give the reader an overview and background information on Failure Modes and Effects Analysis (FMEA), as well as provide a review of relevant FMEA research and literature.

Areas that are referenced and discussed in this chapter include an introduction of the FMEA, various types of FMEA developed for different purposes, the advantages and rational for integrating FMEA into the manufacturing system, and examples of applications of the FMEA in the industry.

2.1 Failure Mode and Effects Analysis (FMEA)

In the manufacturing industry, the quality and reliability of the manufactured product, also known as the functional performance of the final product, are critical to the reputation of the company. Consequently, the quality system that is incorporated to ensure good product quality must be efficient and comprehensive. (Teng & Ho, 1996)

A failure mode and effect analysis (FMEA) is most widely defined as "an engineering technique used to define, identify, and eliminate known and/or potential failures, problems, errors, and so on from the system, design, process, and/or service before they reach the customer," (Omdahl, 1988; ASQC, 1983). It is also defined as "a systematic method of identifying and preventing product and process problems before they occur, focusing on preventing defects, enhancing safety, and increasing customer satisfaction (McDermott, Mikulak & Beauregard, 2009). In short, the FMEA is a reliability tool used to ensure and improve quality standards.

The application of FMEA dates back to the 1950's, where the technology was first used in the aerospace industry to design and develop flight control systems (Dhillon, 1992). It was then adopted by the National Aeronautics and Space Administration (NASA) of the United States of America (USA) for documentation and self-examination purposes in the Apollo Moon-Landing Project. In the late 1960's to early 1970's, the FMEA methodology was already widely adopted in the military's Research and Development (R&D) field (Pang, 2018). By 1976, the USA Department of Defence finally developed and included the FMEA as part of the military standard document MIL-P-1629 (1949), revised in 1980 as MIL-STD-1629A.

According to de Aguiar, Salomon & Mello (2015), a manual titled "Design and Process FMEA" was published in 1988 by the Ford Motor Company, detailing the product development and manufacturing process fault-checking methodology. Soon after, the quality assurance system was adopted and adapted by various organisations in the automotive industry up and down the supply chain. By 1994, the use of FMEA in the industry was so widespread that a set of standardised quality guidelines is required to harmonise the supply chains. This prompted USA automobile makers General Motors Corporation, Chrysler Corporation, and Ford Motor Company to develop the QS-9000 standard, which later served as the base for the ISO/TS 16949 standard.

Although the FMEA technique used to reduce failures and affect continuous quality improvement is very powerful, organisations will not be able to benefit if it is incorrectly applied (Devadasan, Muthu, Samson & Sankaran, 2003). In essence, the FMEA is a risk assessment tool that systematically presents to the manufacturing organisation the impacts of process failure on customers. Every single action to minimise risk or guide improvement activities must be carefully analysed. In other words, the FMEA is a "live" documentation system that requires the engineering team to review and update whenever changes occur, whether in the manufacturing procedures or quality issues (Aguiar, Salomon & Mello, 2015; Duckworth & Moore, 2010)

The "risk assessment" as mentioned in most FMEA functions are based on three scoring criteria – the *severity* of the failure mode, the *occurrence* or frequency that the problem takes place, and the chances of *detection* when the failure happens.

Aguiar, Souza & Salomon (2010) defines each of the scoring criteria as such:

(a) Severity, S

Severity is scored using the range of 1 to 10, where Score 1 is the least serious and Score 10 is the most serious. Three different methods can be used to judge the "seriousness" of the failure:

- the degree of customer dissatisfaction,
- the customer's perception of the failure with its respective effect, or
- the importance of necessity.

(b) Occurrence, O

Before the Occurrence score can be given, a potential cause must be determined. Based on the historical data of each failure mode, the Occurrence score between 1 to 10 can then be estimated. As with the Severity score, there are multiple ways to compare the frequency of failures:

- the Mean Time Between Failures (MTBF),
- the probability or ratio of failures, or
- statistical means such as the Process Capability Index (Cpk).

(c) Detection, D

Detection is admittedly the most diversely categorised criterion of the three. Some argued for it to be the possibility of identifying the modes of failure before the next step of operation, while others base the score on the customer. The scales proposed by FMEA researchers include:

- the assessment of different combinations of controls,
- the probability of a defect reaching the customer,
- the frequency or ratio of detection,
- the probability of detection through the use of controls, and
- the probability of detection through maintenance.

Naked eye visible			Switchboard or indirectly controllable			Visible after an inspection		Periodic inspection		Score
Yes	Partial	No	Direct	Indirect	No	Yes	No	Yes	No	
X										1
		X	X							
	X			X		X				2
		X		X		X		X		3
		X		X		X			X	4
	X			X			X	X		5
		X		X			X	X		
	X			X			X		X	6
		X			X		X		X	
		X			X	X		X		7
		X			X	X			X	8
		X			X		X	X		9
		X			X		X		X	10

Figure 2.1.1: Detection ratings based on control combination (Aguiar *et al.*, 2010).

2.2 Types of FMEA

The purpose of a Failure Modes and Effects Analysis (FMEA) is to compile a list of all possible methods a product or service can fail, where "fail" means that the product or service does not perform exactly as the manufacturer originally intended (McDermott, Mikulak & Beauregard, 2009; Dyadem, 2004). This means not only the design and blueprints of the product has to be analyzed, but also the production methods, or even the manufacturing system itself.

Based on the information obtained from Stamatis (2003), there are three main types of FMEA, as well as two lesser-known varieties:

(a) Design or Product FMEA

A design FMEA, also known as a product FMEA, is a systematic method of finding possible errors of a product during the designing stage. Through early identification of potential or known failure modes, and consequently, providing follow-up or corrective actions before the scheduling of the first production run, it allows for changes to be made with little to no penalty to the production cost and company reputation.