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TAJUK: ENHANCEMENT OF AUTONOMOUS MAINTENANCE PROGRAMME TO ENHANCE EFFICIENCY OF INJECTION MOULDING MACHINE

SESI PENGAJIAN: **2023-2024 Semester 1**

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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MUHAMAD IKHWAN BIN ZAHURIN
B092010214

BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (BMIP) WITH HONOURS

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A THESIS SUBMITTED
IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (BMIP) WITH HONOURS

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

DECLARATION

I declare that this Choose an item. entitled "ESTABLISHMENT OF AUTONOMOUS MAINTENANCE PROGRAMME TO ENHANCE EFFICIENCY OF INJECTION MOULDING MACHINES" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Signature	:	
Supervisor Name	:	PROF. MADYA TS. DR. WAN HASRULNIZZAM BIN WAN MAHMOOD
Date	:	15/2/2024

DEDICATION

To my beloved family especially to my parents :

Mr. Zahurin Bin Mon and Mrs. Norhayati Binti Rashidi

To my respected supervisor :

Prof. Madya Ts. Dr. Wan Hasrulnizam Bin Wan Mahmood

To my supporttve friends in UteM :

Especially for my coursmate from BMIP and housemates

ABSTRACT

A versatile and often used instrument in machining and manufacturing is the injection moulding machine. It is necessary for precisely and efficiently cutting and shaping a range of workpieces. Although injection molding machines are commonly used in the industry for repetitive jobs, this study focuses on the machines in the FTKIP laboratory, where they are regularly used for injection procedures with various products and specifications. Neglecting maintenance will have an impact on both the machine's functionality and the user's safety. The goal of this study was to improve the functionality of the injection moulding machines by suggesting OPL and SOP for the machines' abnormality eradication. The main objective was to study and apply the best autonomous maintenance practices for abnormalities in lathe machine at FTKIP laboratory. Fuguai analysis was carry out to find abnormalities on the injection moulding machine. Any fuguai discovered during the machine inspection will be labeled with an F-tag, indicating that the region needs more care and attention. To get rid of the anomalies discovered in the machine, a number of One-Point Lessons (OPL) and Standard Operating Procedures (SOP) have been implemented. However, a lack of cleaning instruments in the laboratory makes it challenging to create some SOP.

ABSTRAK

Alat yang serba boleh dan sering digunakan dalam pemesinan dan pembuatan ialah mesin pengacuan suntikan. Ia adalah perlu untuk memotong dan membentuk pelbagai bahan kerja dengan tepat dan cekap. Walaupun mesin pengacuan suntikan biasanya digunakan dalam industri untuk kerja berulang, kajian ini memfokuskan kepada mesin di makmal FTKIP, di mana ia kerap digunakan untuk prosedur suntikan dengan pelbagai produk dan spesifikasi. Mengabaikan penyelenggaraan akan memberi kesan kepada kedua-dua kefungsian mesin dan keselamatan pengguna. Matlamat kajian ini adalah untuk menambah baik kefungsian mesin pengacuan suntikan dengan mencadangkan OPL dan SOP untuk pembasmian keabnormalan mesin. Objektif utama adalah untuk mengkaji dan menggunakan amalan penyelenggaraan autonomi terbaik untuk keabnormalan dalam mesin pelarik di makmal FTKIP. Analisis Fuguai dijalankan untuk mencari keabnormalan pada mesin pengacuan suntikan. Mana-mana fuguai yang ditemui semasa pemeriksaan mesin akan dilabelkan dengan tag F, menunjukkan bahawa rantau ini memerlukan lebih penjagaan dan perhatian. Untuk menyingkirkan anomali yang ditemui dalam mesin, beberapa Pelajaran Satu Titik (OPL) dan Prosedur Operasi Standard (SOP) telah dilaksanakan. Walau bagaimanapun, kekurangan alat pembersihan di makmal menjadikan ia mencabar untuk mencipta beberapa SOP.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

BMIP	-	Banchelor Mechanikal Industry Process
FTKIP	-	Fakulti Teknologi Kejuruteraan Industri Proses
AM	-	Autonomous Maintenance
IJM	-	Injection Moulding Machine
SOP	-	Standard Operation Procedure
OPL	-	One-Point Lesson
TPM	-	Total Productive Maintenance
UTeM	-	Universiti Teknikal Malaysia
F-tags	-	*Fuguai* tags

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Almost all industrial sectors use injection moulding technology for a wide range of goods. The automotive sector has some of the most advanced parts and some of the strictest quality standards. A plastic product can be created using injection moulding technology using an injection moulding machine, a mould, and specific technology that is specified in the mould by Nardin et.,al (2002).The main sequential step of the injection moulding process is the conversion of plastic pellets into a moulded object. A cyclic technique is used to create identical parts. First, a pellet or powder resin is melted, then the polymer melt is injected under high pressure into the hollow mould cavity.

By employing an injection moulding machine, polymeric components are frequently produced. In contrast to metal die casting, the injection moulding process requires polymer melts to have a high viscosity and cannot simply be poured into the mould. The polymer must instead be injected into the hollow cavity of the mould with a lot of force. For practical tasks in a manufacturing lab, understanding of the clamping, injection, cooling, and ejection processes is crucial (Siregar et.,al 2017).The material, which is typically sold as grains or powder, is plasticized in an injection unit before being injected under high pressure (500–1500 bar) into a clamped mould. Injection moulding's key benefit is that it is a very economical way of mass production. In general, additional processing steps are not required because it is possible to make ready parts with strict tolerances in one step, frequently entirely autonomously (Goodship 2017).

1.2 Problem Statement

In the faculty of mechanical and manufacturing engineering technology's (FTKIP) lab at Universiti Teknikal Malaysia Melaka (UTeM), injection moulding machines (IJM) are frequently used. The IJM machines are frequently employed in industry for repetitive routines, however in the FTKIP laboratory, the machines are used for various procedures with various parameters and materials. If maintenance is neglected, it will have an impact on the machine's functionality. For the safety of machine users as well as to restore the IJM machines to their peak performance, proper maintenance must be performed.

The problem at hand pertains to the implementation of autonomous maintenance in the context of student learning and practical application of injection moulding machines. While autonomous maintenance plays a vital role in ensuring the efficient operation and longevity of these machines, students often face several challenges in understanding and applying these techniques. Insufficient practical exposure and hands-on experience hinder their ability to grasp the significance of autonomous maintenance and its practical implementation. Additionally, the scarcity of educational resources, including manuals, guidelines, and training modules specifically designed for students, further exacerbates the problem.

The lack of structured integration of autonomous maintenance into the curriculum leaves a gap between theoretical knowledge and practical application. Moreover, limited research has been conducted to evaluate the impact of incorporating autonomous maintenance techniques in student learning, hindering the assessment of its benefits. Addressing these challenges is crucial to equip students with the necessary skills and knowledge to effectively maintain and operate injection moulding machines autonomously, ensuring their preparedness for real-world scenarios.

1.3 Research Objective

The main objectives of this study are:

a) To study autonomous maintenance practices for abnormalities in injection moulding machine shop.

b) To apply autonomous maintenance basic steps for selected injection moulding machine.

c) To recommend SOP and OPL for abnormalities elimination for the selected injection moulding machine.

1.4 Scope of Project

The creation of an automated maintenance programme for IJM machines in the FTKIP lab at UTeM is the major goal of this project. A laboratory assistant with knowledge of the IJM machines is supervising this study. The project's primary focus is the implementation of autonomous maintenance procedures. Between March 2023 and January 2024, the project will begin. The results of this project are based on laboratory job shops conducted for educational purposes only they are not intended for use in industry. As a result, the findings might not be applicable to different IJM machine types.

1.5 Importance of Project

The importance of the project :

a) Establishing a good machine maintenance schedule will allow for the early detection of abnormalities and the ability to avoid expensive repair costs.

b) To start creating a beneficial workplace that is safe and clean in order to reduce the likelihood of accidents.

c) To increase machine availability and prolong machine life.

d) To raise students awareness of the significance of equipment maintenance for academic objectives.

e) To better equip students with the knowledge of machine maintenance necessary for the industrial workplace of the future.

1.6 Outline of the Project

The project's origins, problem statement, and objectives were all introduced in Chapter 1, along with the project's importance and its defiance of the project's scope.

The literature review is the focus of Chapter 2. This chapter describes the literature study on the notion of maintenance, in particular, on autonomous maintenance and review on the injection moulding machines.

The research approach is presented in Chapter 3. The project's concept in depth as well as the technique for gathering data are presented in this chapter. With the use of flowcharts and gantt charts, the specifics of the project design flow are shown, and this chapter goes on to discuss data gathering techniques, analytical techniques, and *Fuguai* investigations.

The analysis and discussion of the findings are presented in Chapter 4. This chapter presents the data collected and makes the data visually appealing using tables, charts, and graphs. Through OPL and specific actions, the countermeasures for each discovered *fuguai* are shown and described.

By summarising the facts and solutions used throughout the project, Chapter 5 brings the project to a close. This chapter also includes future suggestions for enhancements.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Autonomous by words means independent or self -governing while maintenance is the preserving process of certain condition and functionality (Khan et al., 2020). From the review, automation is the capability of a machine to help reducing human work. Maintenance includes technical, administrative and supervision actions to restore the initial state of required function. More precisely, according to Müller et al., (2021) autonomous maintenance is a system which able to make independent decisions to achieve a fixed plan. Likewise, autonomous system is to address the abnormalities by sensing and interacting with the environment (Chen et al., 2019).

In research from Trout (2019), autonomous maintenance is defined as a maintenance strategy where machine operators continuously monitor their equipment, perform suitable adjustments and perform minor maintenance tasks on their machines. Autonomous maintenance is a self-governing preventative maintenance strategy to perform maintenance activity to eliminate abnormalities that affect the system. Similar definition is defined by Agustiady & Cudney (2018), autonomous maintenance involves maintaining equipment by operators while emphasising proactive and preventative maintenance. Autonomous maintenance is the first step in the implementation of Total Productive Maintenance (TPM).

In the study by Palomino-Valles et al., (2020), the development of autonomous maintenance is the key to success in TPM. Autonomous maintenance is the conducted among operators with the support of technicians to run easy and planned daily maintenance activities. The principle of autonomous maintenance is to maintain the equipment at its peak performance by proper management and to prevent the deterioration of equipment through a proper operation.

2.2 Concept of Autonomous Maintenance in TPM

According to Singh and Ahuja (2015), TPM establishes a system of productive maintenance relating the equipment involving all employees and promotes group division of autonomous activities. Autonomous maintenance is the first pillar in TPM and the aim is to maintain the machines in its initial condition. Figure 2.1 shows autonomous maintenance as the first pillar in TPM.

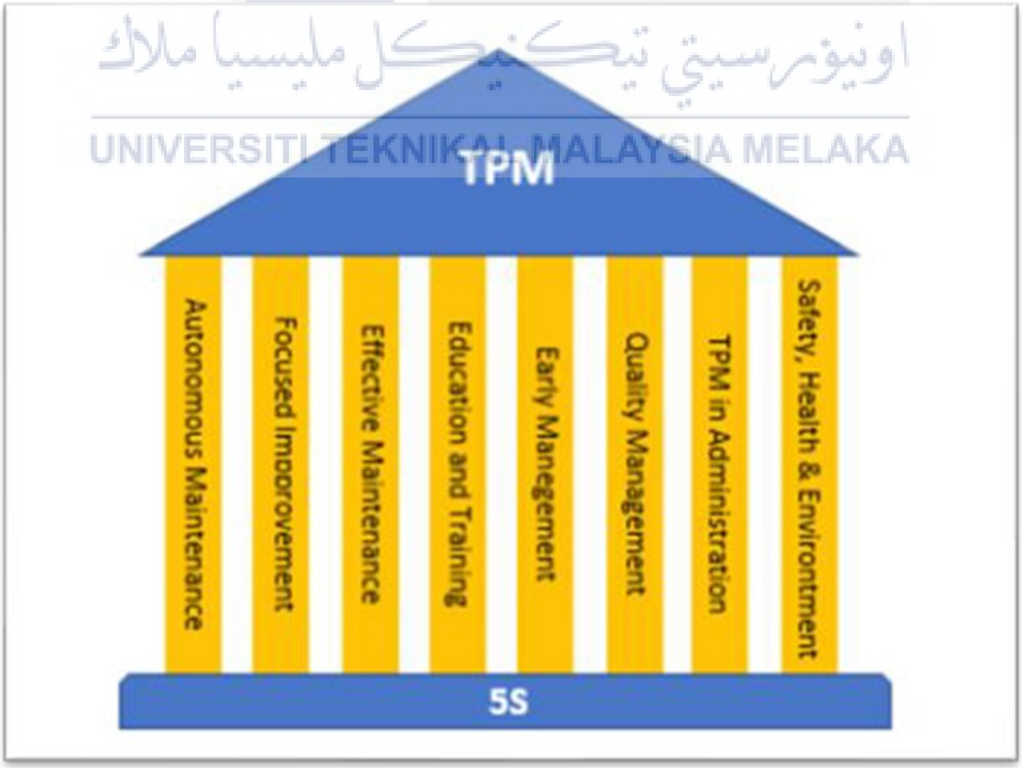


Figure 2.1 : TPM pillars (Iswidibyo et al., 2019)

In the study of J. Singh et al., (2018), Total Productive Maintenance is the combination of three words. Total, which means a look over at all activities related to maintenance. Productive relates to the outcome of the implementation of maintenance efficiency while maintenance is the reliable maintaining programme. Autonomous maintenance as the first pillar in TPM means maintaining one's equipment by oneself.

To make this concept a realistic, everyone is responsible for the machines and not only rely on technicians to fix the machine. It is rather a prevention concept on the machine before any malfunctioning happens. Machine operators spend long hours working with the machine and they are more familiar with the machines. Autonomous maintenance is an activity to be done by operators for the maintenance of base conditions of the machines for optimal operation. Operators with developed knowledge will be able to carry out small maintenance task, thus allowing the skilled maintenance personnel for more precise technical repairs and activities.

The same principle is extended in the research by Moscoso et al., (2019) stating that the implementation of TPM mains on preventative activities carried out by operators such as basic cleaning, lubrication, adjustment and verification. Furthermore by Okpala et al., (2018), autonomous maintenance as the first step in TPM implementation prevents unnecessary breakdown of equipment and improves the equipment efficiency so as to provide the operators a sense of ownership of the equipment. Implementation of autonomous maintenance requires the support from management and maintenance department as advisor when there is a need for specialized maintenance activity in finding the best solution for improvement (Pačaiová & Ižaríková, 2019).

2.3 The Steps in Implementation of Autonomous Maintenance

The idea of setting up autonomous maintenance in a step-by-step fashion was introduced by the Japan Institute of Plant Maintenance (JIPM) (Nakamura, 2016). The Japan Institute of Plant Maintenance (JIPM) introduces the deployment of autonomous maintenance in a seven-step programme where operators receive training in fundamental maintenance techniques (Shankul & Buke, 2019). The seven-step autonomous maintenance methodology teaches the operator how to care for the machines using fundamental maintenance techniques (Kumar et al., 2017). The major goal of applying steps in autonomous maintenance is to educate operators in the fundamentals of machine maintenance so they can spot issues with equipment early on.

The seven steps of autonomous maintenance implementation are divided into phases, allowing for a well-organized procedure that concentrates on the objectives of each step (Molenda, 2016). From the review of Ali (2019), The preparation of operators, initial cleanup measures, countermeasures, fixing preliminary autonomous maintenance standards, general inspection, standardisation, and autonomous management are the seven processes in autonomous maintenance. The description of each stage and its purpose by Duques Maciel Filho et al. (2019) adds support to the synopsis of the seven steps in autonomous maintenance. The conclusions drawn from these investigations are in line with JIPM's suggestion that autonomous maintenance involves seven processes. Figure 2.2 show there seven steps in autonomous maintenance.

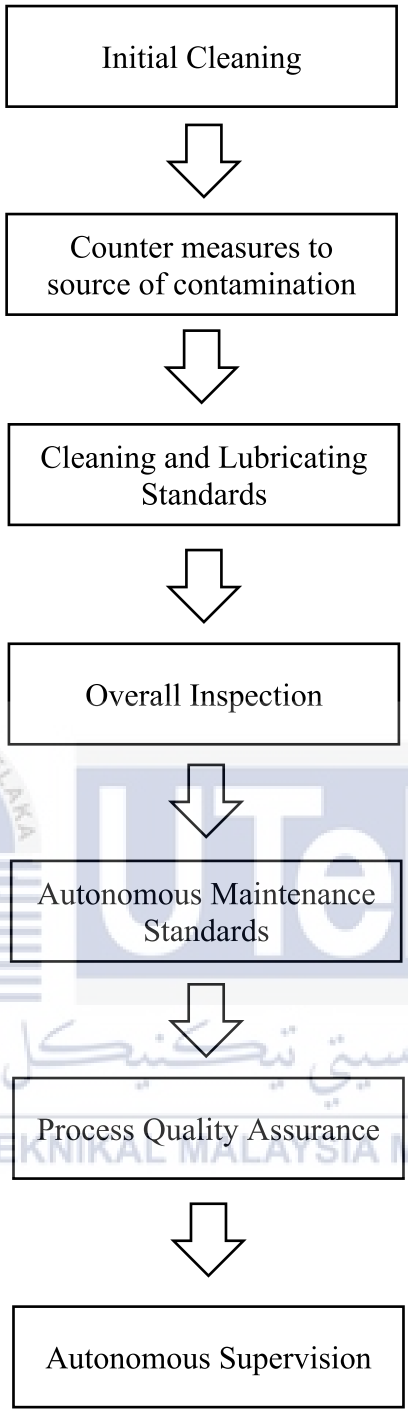


Figure 2.2 : Seven steps in Autonomous Maintenance

2.3.1 Step 1 : Initial Cleaning

The first thing that needs to be done is clean the machine and its surroundings. Initial cleaning enables the operator to thoroughly clean and spot wear and tear on the equipment while restoring them to their initial state for observation in order to spot and correct hidden flaws (Hemlata, 2018). For example, cleaning and replace the new lubricant, tightening loose bolts and nut, clean the dirt and so on.

- **Cleaning tools and equipment**

Rising energy consumption is currently seen as a trend in the development of the world economy. Researchers have focused increasingly on the exploitation process as resource demands have increased. Machine processing speed will increase as demand rises. Cleaning the wells becomes a necessary processing procedure as well as an inevitable challenge (Liu et al., 2022).

Figure 2.3 : Scraper cleaning tool

Tools for cleaning the floor include mops, vacuum cleaners, floor scrubbers and brooms. For various cleaning tasks, there are various types of cleaning brushes, including hard brushes and soft brushes. To remove rust and dirt, hard brushes like wire brushes are frequently employed. For gentle cleaning of dust and debris, soft brushes like jute brushes are typically used. A sample of a range of cleaning brushes is shown in Figure 2.4.

Figure 2.4 : Wire brushes

When cleaning after finishing the process and want to change the mould and also the material, the iron pipe is also one of the items required for the material change process. This is done after the excess material is completely removed from the injection unit. The pipe will pull the material that has come out and clean the area of the material.

Figure 2.5 : Example of iron pipe

A soft brush is used to remove plastic granules from the machine and it can also be used to remove dust from the machine. This tool is good because it can remove small dirt that is stuck in the narrow gap of the machine.

Figure 2.6 : Soft Brush

Soap and laundry brush are also included in the machine cleaning tool. This tool is used on parts of the machine that are not sensitive to water and can be removed from the machine.

Figure 2.7 : Soap and Laundry Brush

The category of cleaning tools including buckets and cleaning cloths are important tools that are needed. The use of this tool is to clean non-chemical dirty areas such as dust. It also requires repeated water changes so that it is cleaned properly and no dirt remains.

Figure 2.8 : Example of Small Bucket

Figure 2.9 : Example of Cleaning Rag

Isopropyl alcohol, also known as rubbing alcohol, is a colorless, flammable chemical compound with the molecular formula C3H8O. Isopropyl alcohol effectively dissolves and removes grease, oils and other residues from machine surfaces. It is solvent properties make it ideal for degreasing, ensuring a clean and smooth operation of machinery while preventing the buildup of contaminants that can impede performance or cause damage over time. The way to use this kind of material is with the help of a bottle spray tool because this liquid is not good if it comes into contact with human skin.

Figure 2.10 : Isopropyl Alcohol

Figure 2.11 : Bottle Spray

Allen key set is a set of tools with hexagonal wrenches for turning screws and bolts with corresponding hexagonal sockets. This tool function is to tightening or loosening screws and bolts with hexagonal sockets. Most machines use a hexagonal screw as a tool to assemble one part to another. Similarly, the mold on the injection molding machine, it uses a hexagonal screw because it has a larger screw size and the strength is different compared to other screws.

Figure 2.12 : Allen Key Set

Handglove is a protective covering for the hand, typically made of flexible material like rubber or latex. Provides a barrier between the hand and cleaning agents, preventing direct contact and enhancing safety during the cleaning of machines. Most of cleaning on machine must use glove to avoid injury or direct contact chemicals on the hands.

Figure 2.13 : Hand Glove

- Method sensing based inpection

Using your senses is the best way to spot irregularities during the cleaning procedure. An ordinary sense method called eyesight viewing can spot anomalies like oil leaks, broken parts, or scratches. The sense of smell is utilised to detect strange scents, such as unusual burning or gas smells. Continuously listening for strange noises like buzzing sounds or mechanical vibrations is done with the hearing sense.

2.3.2 Step 2 : Counter Measures to Sources of Contamination

In this step, personnel take corrective action, learn how machinery operates, and look for the contamination source. According to Kowalski et al. (2018), operators should identify and take action against pollution sources and difficult-to-reach regions. As it is crucial to maintain the machine or equipment to remain in top operational condition, the right procedures should be taken into consideration. The actions to be taken in this step are to prevent contamination, encourage orderliness, and encourage safe access. The approach to the source of contamination as depicted in Figure 2.5 can serve as an example of how this practise has improved.

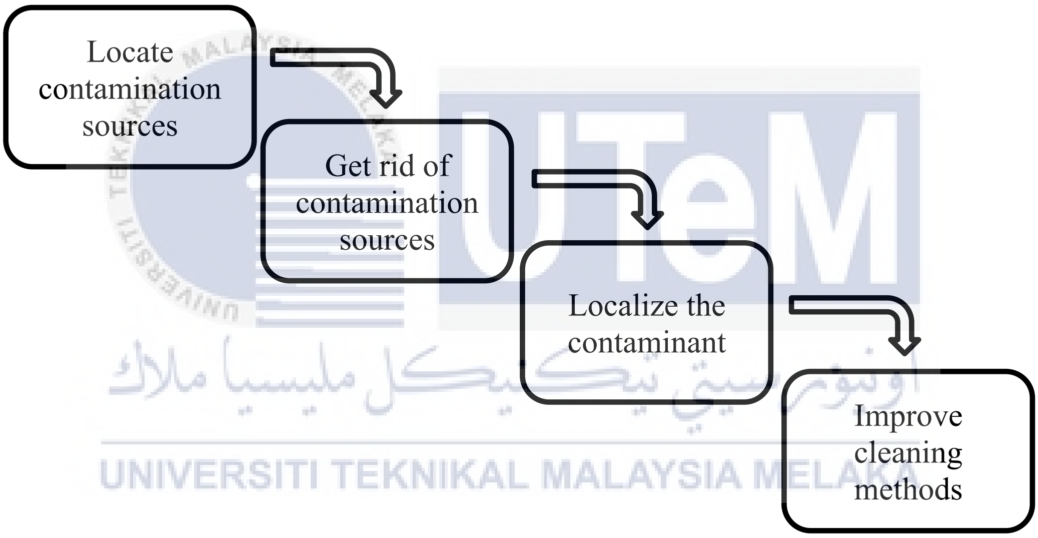


Figure 2.14 : Step approach in counter measures to source of contamination

2.3.3 Step 3 : Cleaning and Lubricating Standards

A thorough check is conducted to spot any damaged or poorly lubricated locations, especially those that are concealed or challenging to access. Standards for lubricating and cleaning operations were defined during the introduction of autonomous maintenance in the study by Lozada-Cepeda et al. (2021) in the Maintenance Plan based on TPM for Turbine Recovery Machinery. In this step, guidelines for cleaning, lubrication, and inspections are prepared to help operators follow the best practises for machine maintenance. The standards specify what needs to be cleaned, how to apply the technique, how often or when cleaning should be done, and other details that serve as operators' guidelines. Figure 2.6 illustrates the methodology used to generate the cleaning and lubrication criteria.

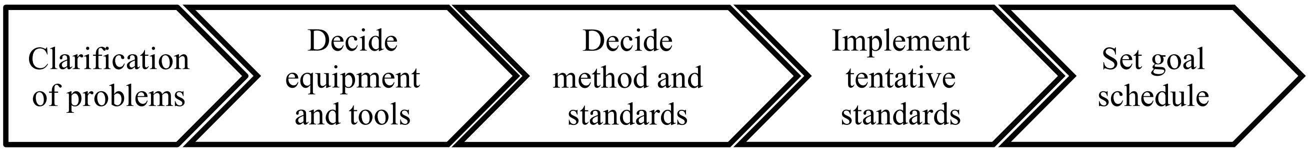


Figure 2.15 : Approach towards development of cleaning and lubricating standards

2.3.4 Step 4 : Overall Inspection

According to Ferreira and Leite (2016), operators already have the training and standards to follow in the practise of machine maintenance, hence the entire inspection is also known as a general inspection. This step involves evaluating the equipment and fixing any found problematic sections, putting the operators' newly acquired abilities into practise. For better standard and regular adjustment and increased output, inspection is necessary. To monitor and evaluate the effectiveness of the maintenance programme and upkeep, scheduling tools can be used.

2.3.5 Step 5 : Autonomous Maintenance Standards

Autonomous maintenance standards are established to complete tasks and practise on the equipment to ensure that the whole inspection is carried out properly (Sun, 2018). Further efforts must be made to make the required task simpler and error-free by constant maintenance in accordance with the standards. In this step, the use of visual controls is established. Visual control harmonises autonomous maintenance in preserving each piece of equipment's integrity. By ensuring that the machinery or equipment is in reliable functioning order, the standards are intended to create an organised shop floor.

2.3.6 Step 6 : Process Quality Assurance

To avoid producing defective products and letting them into downstream processes, a highly dependable process is achieved. In order to completely integrate autonomous supervision, this stage analyses the operators' knowledge of product quality, equipment, and techniques for continual improvement (Azizi, 2015).

2.3.7 Step 7 : Autonomous Supervision

Periodically, previous assessments of the standards and practises are reviewed. Failure reports are kept in order to provide information for next maintenance tasks and the development of better machinery. monitoring the standardised procedures to identify areas for enhancement and ensuring their smooth operation. Operator feedback is essential for ongoing improvement. This makes it possible to anticipate problems.

2.4 Important of Implementation of Autonomous Maintenance on Machine

The deployment of autonomous maintenance has been shown in a number of studies to increase productivity in general. According to Min et al., (2011), presented a case study on the creation of an implementation framework for autonomous maintenance based on four systematic stages: AM initial planning and setting up, training and motivating, the five-step execution, and audit. The case study shows that lowering machine breakdown rate through the use of autonomous maintenance led to a considerable improvement in production performance.

Periodically, previous assessments of the standards and practises are reviewed. Failure reports are kept in order to provide information for next maintenance tasks and the development of better machinery. Monitoring the standardised procedures to identify areas for enhancement and ensuring their smooth operation. Operator feedback is essential for ongoing improvement. This makes it possible to anticipate problems. Similarly, Blanco et al.'s (2020) research demonstrates how the adoption of 7 phases of autonomous maintenance significantly decreased waste and pollution from dirt, noise, heat, and stink in the ceramic tile production.

According to Guariente et al. (2017), the use of autonomous maintenance has allowed operators responsibility to autonomously conduct activities linked to cleaning, checking, and making sure the machines are in excellent condition to develop. While operators are taught on problem solutions in the workplace to reduce production losses and contribute to the development of productivity, autonomous maintenance has an impact on the maintenance times by reducing processing and order waiting times (Morales Méndez & Rodriguez, 2017). From a more in-depth perspective, Iswidibyo et al. (2019) noted that autonomous maintenance standardises and enhances the operator's fundamental machine maintenance abilities while also enabling early detection of irregularities on the machine prior to the occurrence of serious machine failure. Early machine abnormality detection can increase both the operator's and the working environment's overall safety.

2.5 Significance of Autonomous Maintenance on Machine

The relevance of autonomous maintenance on machines attracts deeper attention to effect towards machines, whereas earlier research on the application of autonomous maintenance is established in a larger field on overall effect. The study by Azizi (2015) proposed the idea of thoroughly examining the effectiveness of autonomous maintenance using data. The research demonstrates how autonomous maintenance successfully lowered fault rates by 8.49%. Time spent on machine breakdowns has greatly decreased. Machine performance and failure rate information are interrelated. As a result, improved production productivity performance is the outcome of improved machine performance.

According to research by Duques Maciel Filho et al., (2019), the improvement in operators' understanding of machines and autonomous maintenance techniques, the decrease in equipment downtime, and the rise in machine availability serve as evidence of the effects of autonomous maintenance. Operator skill levels are sufficient for basic maintenance, freeing up technical maintenance staff to handle more urgent problems.

Similar to this, Kwaso and Telukdarie (2018) demonstrate that the application of autonomous maintenance lowers downtime, increases machine availability, and lowers breakdown rates while instilling a sense of ownership in workers towards the machine. The use of autonomous maintenance has had a good impact on operating time, machine availability and efficiency, and it has also extended the life of the equipment (Aseem Acharya et al., 2019)

The results of these research suggested that implementing autonomous maintenance will benefit both personnel and equipment. Increased machine availability and a decrease in machine breakdown rates are frequently noted factors. Finding the optimal method for maintaining machine components and the maintenance schedule, however, has received much too little attention. The thorough process for implementing autonomous maintenance for a single machine in a job shop can be used as a guide for more extensive applications in the future. To produce an acceptable standard that can be used in a mass production line to avoid excessive costs, preventive measures should be identified starting from a single machine.

2.6 Injection Moulding Machine : In Review

This project focus on the autonomous maintenance program for Injection Moulding machines. According to Goodship (2017), injection moulding is one of the most commonly employed processes to produce plastic parts. It is a cyclic process of rapid mould filling followed by cooling and ejection. A variety of material both plastic and non-plastic can be use as feedstock. However the machine must be configured for the type of material used.

The material, which is generally available as grains or powder is plasticised in an injection unit and injected into a clamped mould under high pressure (500-1500 bar). The main advantage of injection moulding is it is a very economical method of mass production. Ready parts with tight tolerances can be produced in one step, often completely automatically and in general subsequent processing steps are not necessary. It is possible to integrate different functions into one part to avoid the formation of different components that would be more expensive.

Figure 2.16 : Diagram of ZHAFIR PLASTIC MACHINARY (IJM)

2.7 Injection Moulding Machine for Job Shop Operation (Process Based Layout)

During the injection moulding process, the mould and the plasticizing area are separate from each other. The temperature of the plasticizing area and the plasticizing cylinder is maintained at the same level as the processing temperature. The mould on the other hand is kept cold enough for demoulding of the injection moulded part (thermoplastics) or warm enough for crosslinking (thermosets). The plasticized material is injected into the clamped mould. In an IJM, the clamping unit which contains the mould and injection unit is integrated. Completely automated production is possible if the mould is installed with a vertical parting line, which enables the parts to fall down and out of the mould after demoulding. IJM more typically used for the processing of thermoplastics. There are two types of injection unit available. Piston injection unit and a screw piston injection unit (reprocating). The reprocating screw method is the most common. Only screw piston machines can be used for the processing of thermosets high. The injection sequence for both types of machine now follows (Goodship 2017).

According to Goodship (2004), the properties of an injection moulded part depend upon the working material and upon the processing conditions. In the production of a series of parts, a certain deviation in quality features such as weight, dimensional consistency and surface characteristics may always occur. The size of this deviation will vary from machine to machine and from material to material. Furthermore, external influences or negative factors have an effect on the quality of an injection moulded part. Examples of such negative factors may include changes in the viscosity of the melt, temperature changes in the mould, viscosity changes of the hydraulic fluid and changes in the characteristics of the plastic.

Flow Chart Process

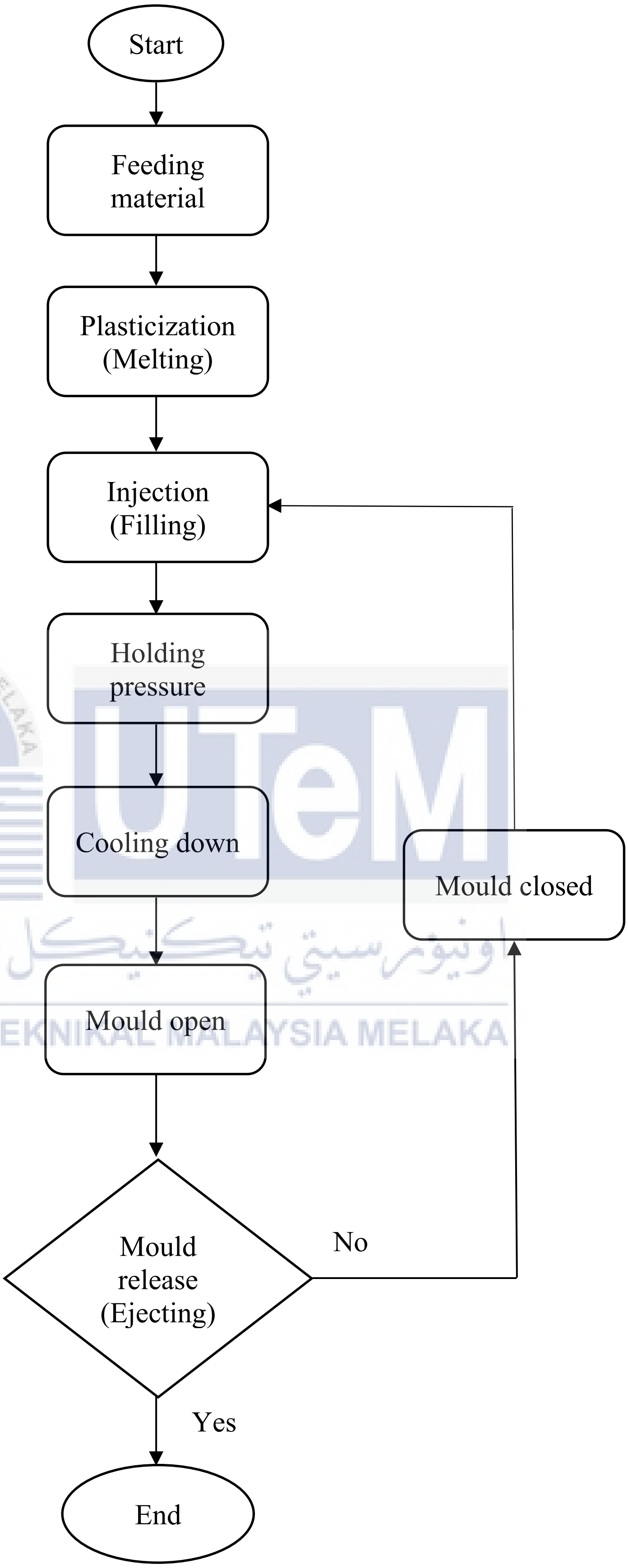


Figure 2.17 : Flow Chart Injection Moulding Machine Process

2.8 Safety Precautions for IJM Process

Since injection moulding is a high-pressure, high-speed process, it is clear that a great deal of force and heat are generated in the IMM. Thus, machine safety is a must to ensure operator safety. A machine without adequate safety guards is dangerous to the operator and other personal working in the area. There are standard requirements for processing equipment. Safety information and standards are available from various sources, including the equipment suppliers, National Safety Council, Society of Plastics Industry (SPI), American National Standards Institute (ANSI), Occupational Safety & Health Administration (OSHA), International Organization for Standardization (ISO) and European Machinery Safety Directive (EMD). For the past century equipment manufacturers and fabricating plants have increased their efforts to upgrade safety. Safety features are many and different for the different equipment in the lines. Safety interlocks ensure that equipment will not operate until certain precautions have been taken. Safety machine lockout procedures are set up for proper lockout of the machines operation as in electrical and mechanical circuits.

2.8.1 Training for Safe Operation

Before using the Injection Moulding machines, operators must receive enough training on topics such potential machine risks, control measures, operating procedures, emergency procedures, and safety precautions. To safeguard their own safety, operators must completely comprehend how to use personal protective equipment (PPE), such as safety goggles, hearing protection, and hand gloves.

2.8.2 Hazards

According to Dominick, Donald and Marlene (2012), hazards are objects that move, pinch, rotate, get hot, have electricity, or simply exist and have the potential to harm, injure, or cause loss. A few risks associated with injection moulding machines are plain to see (such the clamp shutting). Others (parts failing as a result of pollution) might not be evident or even foreseeable. Therefore, it becomes everyone involved with the machine's job to be aware of potential dangers. It is necessary to assess the danger and likelihood of occurrence of visible hazards. This evaluation starts with the creation of the earliest concepts and continues all the way through the life of the product.

Take an IMM's clamp motion as an illustration of this evaluation procedure. In a typical IMM, a mould is opened and closed with a lot of force. This action produces a risk that cannot be removed. Parts have traditionally been removed by human operators. There is a significant risk of serious damage as a result of this action and expected human mistake. We must investigate the second option for establishing safety, namely eliminating the human and his or her expected errors from the hazard, as we cannot remove this risk and yet have a technology that can be used. By introducing tools like conveyors or robots for part removal, this can be accomplished. A significant accident could also be avoided by using automatic part-loading equipment for setup or by placing operating equipment remotely and away from the danger zone.

When physical barriers are not an option, warning signs can be utilised to alert the operator that a hazard is there. A portion exit area is necessary because part removal is necessary. The only way to stop someone from reaching into this space might be to alert the operator about this danger. The machine design should only rely on warning indicators after all other options have been tried. One predicted human error is the operator's tendency to respond to circumstances before considering the repercussions. The machine's design reflects the level of safety that is intended, but incorrect assembly, deviations from crucial part tolerances, and loose belts can all compromise the system's integrity. To ensure this integrity, testing and inspection of the IMM must be carried out and documented.

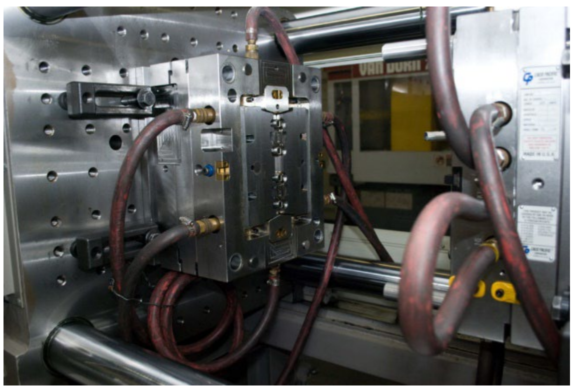
The machine user must also follow the manufacturer's analysis method. He or she has gained control of the device and is now in charge of ensuring its security. A checklist could be useful for ensuring safety. Additional risks may be created by auxiliary equipment, which is frequently added to increase production or safety. Examples of such risks include pinch spots, tripping hazards, and gadgets that have been haphazardly wired. Additional risks could be created by local staff members. Establishing and enforcing safety regulations for the moulding department is one strategy to protect against emerging risks.

2.8.3 Safety Precaution

The basics of injection moulding machine safety precautions are described as follow:

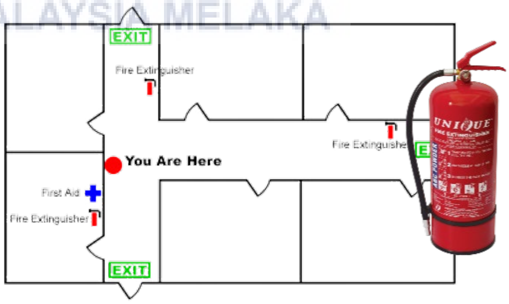
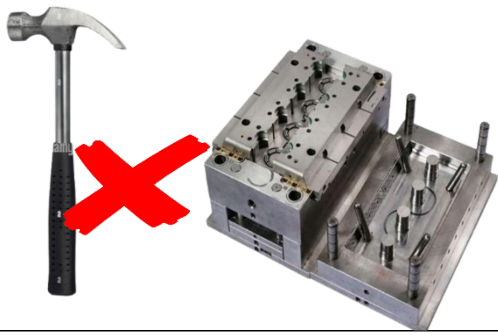
Table 2.1 : Basic Safety Precaution

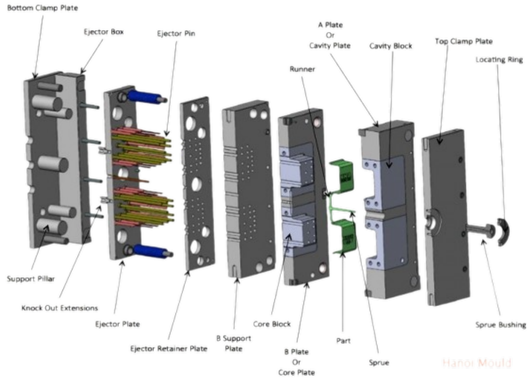
No.	Description	Picture
1	The machine and its platform are free of debris, past materials, oil, water and no vital safety equipment/devices are missing.	

2	All safety equipment (especially eye protection) is present, undamaged, and operative.	
3	Fire extinguishers, first aid kits, and personal protective equipment are present and readily available in needed quantities as per work staff numbers.	
4	The environment around the machine is clean and free of slipping hazards such as oil or water leaks on the ground.	
5	All tooling and equipment are in good condition (this will depend on maintenance-specific factors of your machine).	
6	All mould setup steps are followed as posted on the setup procedure before injection moulding.	

The basics of injection moulding operation safety precautions are described as follow:

Table 2.2 : Basic Operation Safety Precaution

No.	Description	Picture
1	PPE such as bump cap, safety shoes and respirators should always be worn during operation and proper lifting techniques should be learned.	
2	Before touch the machine, all operators must be adequately trained in machine operation, workspace management and proper lockout.	
3	Operators should never free climb on the machine, horseplay around the area or leave railed platforms when the machine still running.	
4	Every worker should know the location and route to fire extinguishers, fire exits and other emergency.	
5	No steel tools are to be used on the mould cores when cleaning/performing maintenance, opting instead for copper, aluminum, or bamboo tools that will not scratch the mould.	

<table>
<tr><td>6</td><td>The operator must always be alert to the components on the mould</td><td>

</td></tr>
<tr><td>7</td><td>It is strictly forbidden for operators to open the safety door at unauthorized times. The front gate should have mechanical, electrical, and hydraulic devices to prevent closing when the gate is open.</td><td>
</td></tr>
</table>

2.9 Standard OperationProcedure of IJM

2.9.1 Step 1 : Preparing the IJM

- Make sure the moulding machine is clear and clean from any plastic material, oil and water is clean around the area of machine.

2.9.2 Step 2 : Selecting and sceuring the part

- Choose the mould that need to use for production.
- Verify the type of material for mould to produce a part.

2.9.3 Step 3 : Setting the machine parameters

- Based on the specifications of the mould and the part need to produce, adjust the speed of clamping mould.
- Identify the size of mould and adjust the pressure of material need to inject inside the mould.

2.9.4 Step 4 : Starting the IJM

- Verify that all security measures are in place and active.
- Turn on the heating and pre-plasticizing the material.
- Wait for 5 min for pre-heat system and start the injection process.

2.9.5 Step 5 : Performing the machining opearation

- Make sure always ready when the mould return and the ejector pin push the part.
- Take the part carefully without any friction on any side of the part especially on cavity part side.
- Close safety door after pick up the part and trim the parting line on the part carefully.

2.9.6 Step 6 : Finishing the opearation

- After achieve the target quantity of part and finish the process, stop the machine and remove the excess material from injection unit.
- Spray anti-rust on cavity and core surface on mould and close the mould manually using machine computer.
- Close the safety door and switch off the machine step by step.

2.9.7 Step 7 : Post-opeartion tasks

- Cleaning the moulding machine of any excess material, water leakage and grease or oil on machine and work area.
- Check the work area for any trim material parts that fall during the trim process.

2.10 Maintenance Activities for IJM

Regular maintenance should be carried out to prevent unwelcome issues and downtime. Table 2.1 describes the Injection Moulding machine maintenance inspection item and measures.

Table 2.3 : IJM Maintenace and Inspection

<table>
<tr><th colspan="3">Maintenance and inspection</th></tr>
<tr><td colspan="2">Check Before Work</td><td>To avoid equipment failure and personal injury, the items must be checked before machine operation.</td></tr>
<tr><td colspan="2">Daily Check</td><td>Check items of machine daily operation, focusing on voice, vibration, temperature, pressure and speed.</td></tr>
<tr><td rowspan="3">Regular Check</td><td>Monthly Check</td><td rowspan="3">Appoint maintenance men to carry out regular checks on consecutive days at the weekend or at the end of the month or in holidays.
Moreover, regular check like half year check and yearly check shall be prepared with spare parts in advance.</td></tr>
<tr><td>Half year check</td></tr>
<tr><td>Yearly check</td></tr>
</table>

Table 2.4 : Clamping unit maintenance

Type of Maintenance	Description
Clamping Unit Maintenance	Please carry through machine operation with a suitable smallest clamping force according to the requirement, not only energy saving but also lifespan extending.
	Do not use inferior mould. As the fixed plan and movable platen have high precision of mould installation surface, the machine's toggle or clamping unit will be damaged, which is the reason of flash or equipment damaged. Mould parallelism shall not exceed 0.2mm/m.
	Please do not keep guiding rod extended in a long time (more than 10 minutes) in high pressure mould clamping state after mould installed. Otherwise, it will lead to toggle bush oil shortage and mould cannot be opened.
	Regularly and automatically fill lubricant grease for the bushes of toggles and guiding rods. But if the storage decrease or grease line broken, the system will raise an alarm of feeding failure. In this case, the malfunction must be relieved and maintained, otherwise, the machine will be damaged due to lubricant grease shortage.
	Need to periodically tighten the clamping ball screw nut, thereby clamping ball screw run smoothly and maintain clamping accuracy, prevent loosening caused by screw and bearing the risk of injury. Machinery required to carry out such clamping screw nut tightened to maintain the control panel screen will appear, please carefully follow the steps.

Table 2.5 : Injection unit maintenance

Type of Maintenance	Description
Injection Unit Maintenance	Rotate screw in a low speed (slower than $40 min^{-1}$ {rpm}) before materials are being fed to the barrel. After confirming molten resins flow out from the nozzle, we shall raise screw charge speed. If there are no resins but the screw rotates very fast, the screw and collar seats will be gripped.
	Please change decomposable resins PVC and POM into PE and PP for completely clean, which can prevent long time heating when machine is not on operation.
	After machine operation, please carefully clean about the screw and barrel. The main purpose is to protect screw tip and to prevent gas produced by decomposition when machine runs again.
	During dismantle nozzle, screw tip and collar seat, the heating above 400°C shall be avoided. Otherwise, the intensity of the parts will be lowered down and some parts will be damaged. Do not use parts that are overheated by high temperature.
	During barrel head installation, please adjust bolt tightness torque suitably. Abnormal tightness will lead to the inner diameters of the screw and barrel distortion and collar seat damaged.
	Make sure the threads greased with hot lubricant grease during installing the screw and barrel as well as nozzle. No greasing will bring difficulties for take-down as thread part will be oxidized.
	Screw, barrel and screw tip will be damaged if the resins are mixed with something metallic. So it is very necessary to hold material storage area as clean as possible.

Table 2.6 : Electrical unit maintenance

Type of Maintenance	Item	Description
Electrical Unit Maintenance	Circuit insulation and grounding	The machine uses power amplifier in the electrical circuits. So, It is forbidden to carry out insulation test by insulation tester because it will damaged semiconductor component
	Basic points	• Power supply shall be kept within the rated scope. • Maintenance in electrical cabinet shall be carried out by special maintenance men who have received machine operation training and acquired basic electrical knowledge. • Turn off the main power supply before checking about electrical cabinets, motors and heaters. • Please do set operation of controller in empty-handed mode, setting value as well as confirming switch. Indiscreet operation will cause failure.
	Heat elimination	Install electrical fans around electrical cabinets for heat elimination. If the positions of fans located are blocked, the heat of control unit won't be completely eliminated, which will cause temperature rising in the electrical cabinets and affect equipment lifespan. If goods need to be placed beside air intake and outlet, it is required that the goods shall be laid always from the machine side for more than 20cm so as to ensure enough ventilation space.
	Cooling fan and dustproof filter net clean	Install dustproof filtering net at the air intake and it needs to be cleaned regularly (half a year) or else will be blocked. If the filter meshes have been blocked, it will lead temperature rising in the electrical cabinet and finally affect equipments lifespan. Please sweep dust on cooling fan as well as filter net.

Type of Maintenance	Item	Description
Electrical Unit Maintenance	No plug electrical connectors with power	Turn off the main power supply before pulling out plugs lest unexpected accidents happen. Especially in barrel heating circuit as the strong current flows by no pull out electric plugs power.
	Motor maintenance	The machine adopts 3-phase full closed synchronous servo motors. According to the different running states, the general lifespan of lubricant grease for bearings is 20000 hours. After 20000 hours, the grease needs to be changed as it cannot ensure precision and will create abnormal noise. At this moment, please turn to Service Department of machine for solutions.
	Maintenance of barrel heater	• Heaters installed on the barrel are insulated by insulators for heating up the barrel. After machine operation, the heaters are shut off and the temperature of the barrel will drop to the indoor temperature. As per different seasons, the surface of heaters will be dewed, decreasing the insulating property. • The heaters on the barrel are with band shapes. If they are not fixed tightly or attached tightly on the barrel, which will lead to partial superficial temperature rise up. Before machine delivery or change for a new heater please screw down the fixed bolts on the heater.
	Check loose bolt	• Please check if heater terminals and thermocouple terminals are loose or not. • Please check if encoder plugs and three-phase power supply line plugs of servo motors are loose or not.
	Operational switch	• Operating buttons, keyboard and LCD screen shall be avoiding being excessive loaded, heated, watered and oiled, and shall be operated by clean hands. • If the surfaces of buttons and LCD screen have been stained, please use mild agent to clean.

Table 2.7 : IJM check before operation

Type on Maintenance	Inspection item	Inspection methods and measures
Check before operation	Safety door (operational side, non-operational side)	• Visual check Open and close check
	Safety cover	Visual check of clamping unit, injection unit and machine seat.
	Cooling water valve	Water valve is open or not
	Bolts for mould installation	Use spanner to check if bolts are loose or not
	Mould	Check mould open/close of it is ok or not
	Controller	Is the setting temperature suitable for applied resin
	The setting place of the controller	• If the setting are ok or not • Do alarm exists • Do switch conditions have any problem
	Barrel safety cover	Check if it loose or not
	The cooling water loop of servo motor	• Is the water pipe connection of water-cool servo motor right • Is the setting of valve right. • Is the connection of pipe on the cooling water manifold right. • Does the infall of the cooling water manifold has brass filter

Table 2.8 : IJM daily checklist

Type of Maintenance	Inspection item	Inspection methods and measures
Daily Checklist	Servo motor	• Stop for temporary check • Screw down bolts • Temperature gauge check, if the temperature extreme high, stop for temporary check. Make sure ventilation around equipments • Stop for temporary check
	Synchronous belt	Stop for temporary check

Daily Checklist	Ball screw	Stop for temporary check
	Barrel seat	Check fastening clasps for the hose
	Water valve manifold	Check fastening clasps for the hose
	Nozzle center [Mould change]	Adjust nozzle center
	Mould mounting bolts [mould change]	Adjust nozzle center

Table 2.9 : IJM monthly checklist

Type of Maintenance	Inspection item	Inspection method and measures
Monthly Checklist	• Power voltage • Grounding	Check if voltage is within ± 10V in other equipment movements and set rated voltage.
	• Clamping unit • Glide place of injection unit	If the lubricant don't have grease, apply it.
	Cooling water circuit	Confirm water valve movements and check water supply.
	Water filter	If the water filter dirt, clean it or change the filter.

Table 2.10 : IJM half year checklist

Type of maintenance	Item inspection	Inspection method and measures
Half Year Checklist	Synchronous belt	Check and adjust the belt.
	Distribution box	• Tighten fixed screw on connecting point. • Clean the dust and resin powder in the cabinet. • Clean the oil and water invade.
	Guiding rail of clamping unit	Adjust the guiding rail if it is fluctuant of transversal excursion.
	Guiding rod	Feed lubricant grease if the sliding point was stuck or noisy
	Link pin	Screw down if the bolts is fix with the link pin
	Barrel flange	Screw down if the bolt is fixed for connecting screw and barrel
	Nozzle	Screw down if the nozzle loose.

Table 2.11 : IJM yearly checklist

Type of maintenance	Item inspection	Inspection method and measure
Yearly Checklist	Machine body	Adjust levelness of machine body.
	Binding parts of the whole machine	Tighten when the bolt loose
	Mould platen	Adjust if the levelness not achieve the target.
	Wire connection inside and outside of the machine	Repair and change if wire have abrasion and damaged.
	Nozzle contact force	Adjust if have deflection.
	Control battery change	Change battery if the voltage falls down.
	Manual lubricate	Put grease manual if the state abusive.

2.11 Types of Abnormalities

After the discussion on the possible breakdown problems IJM machines may encounter, moving on how to discover more in the types of abnormalities that will cause the machine breakdown. There are six types of abnormalities under autonomous maintenance pillar in Total Productive Maintenance (TPM) and they are namely unnecessary item, incomplete assemble, tool on machine, dirty, no grease and waste material on machine.

Unfinished installation is an abnormal thing that can lead to machine damage and material defects. Some abnormalities can also be detected through unusual sounds, strong vibrations and strange smells. Figure 2.9 shows an example of an unfinished installation on an injection molding machine.

Figure 2.18 : Tube incompleted assemble

Dirt on the machine is also one of the abnormal things that need to be taken care of. The condition of the machine will get worse when small dirt is not cleaned and over time it will become a big dirt. This will make the cleaning process difficult if the dirt is already attached to the machine.

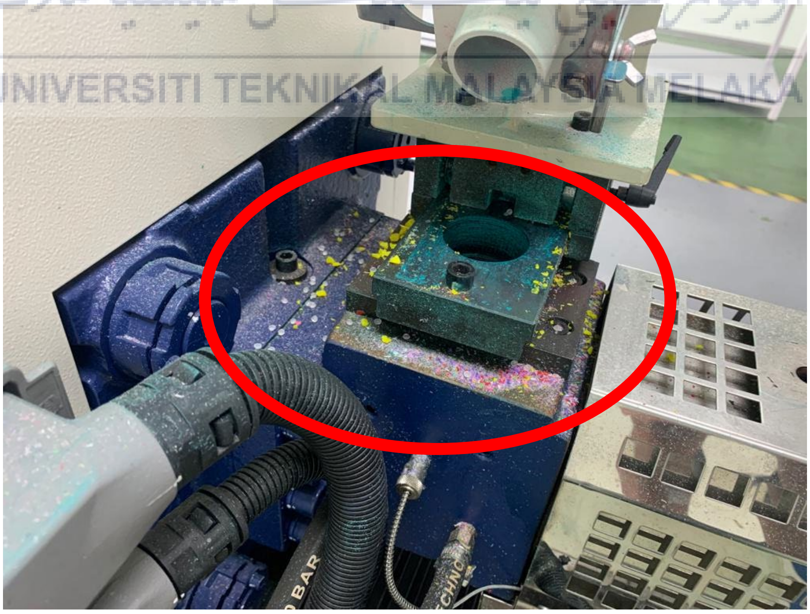


Figure 2.19 : Example of dirt

The next abnormal thing on the injection molding machine is no grease. This is a very serious abnormal issue because the injection molding machine will close and open the mold every time it wants to complete a process cycle. The absence of lubricant will cause the material to scratch and can also damage the material. In Figure 2.11 this is an example of a material with no grease on it.

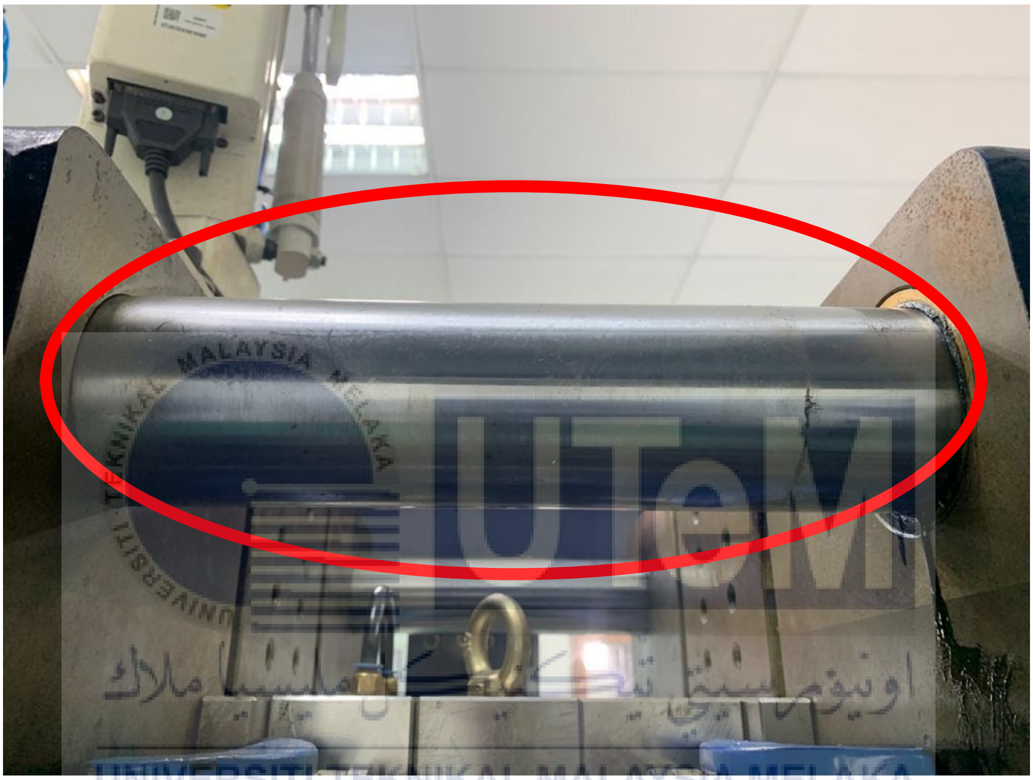


Figure 2.20 : Example material no lubricant

The next abnormality is the material waste in the wrong place which is one of the reasons the machine is full of garbage and disorganized. Similarly, unnecessary items that should not be on the machine when the injection molding process is being carried out. The act of placing an item on the machine slows down the process that needs to be done in that area. Figure 2.12 below shows one example of unnecessary items on the machine.

Figure 2.21 : Example of unnecessary item

2.12 *Fuguai* (Abnormalities) and *Fuguai*-tag

The huge eyes are represented by the *fuguai* tag. Red tag and blue tag are the two different colours of *fuguai*-tags. blue tags were used for simple *fuguai* that didn't require a high level of technical understanding, whereas red tags were used for *fuguai* that did. *Fuguai*-tags are utilised to collect data. The objects listed on the *fuguai* tag are described as follows (Hasrulnizzam and Ilyana, 2008). In the context of autonomous maintenance, the term "*Fuguai*" refers to deviations or irregularities from the typical operating parameters of a machine or piece of equipment. These abnormalities can take the form of failures, flaws, defects, or any other atypical occurrences that limit the machine's performance or yield substandard outcomes. As part of autonomous maintenance, *fuguai* are abnormalities found on a machine as it is being cleaned for the first time (Suryawanshi & Buktar, 2015).

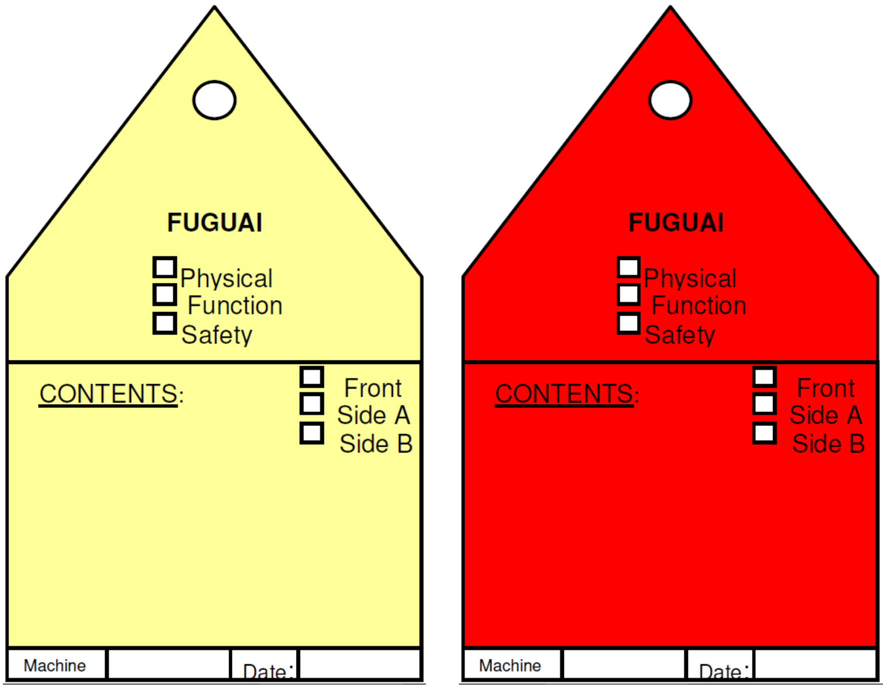


Figure 2.22 : Example of *Fuguai*-tags

The yellow tag indicates that non-technical operators may resolve the machine's abnormaly, whereas the red tag indicates that a technical mechanic is needed. The mechanics and operators needed to address the abnormalities are indicated by the yellow tag. The *fuguai*-tags detail the specifics, including the date, the kind of abnormalities, and the issues.

2.13 Effects on Machine Without Proper Maintenance

Equipment maintenance must be done correctly because neglecting to do so could have detrimental repercussions on the equipment. As operation efficiency declines and component functional breakdowns are more likely to occur, one effect is an increase in equipment operation costs by Zhang et al., (2016). According to Kiran et al., (2016), similar studies show that when maintenance methods are not properly followed, the performance of the machineries would have an impact on the production of a process plant.

Lack of maintenance has negative effects such as resulting in faults in work equipment, reducing the technical lifespan of equipment, and creating a hazardous working environment (Buica et al., 2019). The study also shows that maintenance activities have an effect on worker health and safety because failing to carry out preventative maintenance can result in damage and disruption as well as more serious workplace accidents and illnesses.

Reviewing the value of autonomous maintenance at an injection moulding workstation is crucial since little issues that could eventually cause a machine to fail are frequently disregarded. When issues go neglected, hidden factors like oil, dust, or debris that have accumulated in processing regions can cause significant losses.

2.14 Major Losses in Autonomous Maintenance

To prevent losses, autonomous maintenance is being implemented under TPM to enable faster detection of problems discovered on the equipment. The abnormalities or *fuguai* discovered on the system will directly impact its performance and operation and may result in the six significant losses (Aseem Acharya et al., 2019). The review by Sutoni et al., (2019), highlights six significant losses under TPM that impair machine effectiveness and interrupt the manufacturing process as a result of poor machine maintenance. The six major losses under TPM, according to Erry Rimawan et al. (2018), are divided into three main categories depending on the type of loss. These categories include equipment failure, set-up and adjustment losses under the downtime losses category, equipment failure, idling and minor stoppages, reduced speed, and finally, process defects and reduced yield under the defect losses category.

2.15 Summary

In summary, the research has proven that establishing autonomous maintenance can enable the system to function at its best. The idea and strategy for adopting autonomous maintenance are covered throughout the chapter. The results for machines with failed autonomous maintenance demonstrate the significance and importance of using the technology. Autonomous maintenance extends the life of machines while enabling a constant, dependable, and economical operation. Discussions on the injection moulding method, equipment, safety measures, and maintenance schedule are ongoing. Further discussion includes *fuguai* (abnormalities), *fuguai*-tags, and losses brought on by poor up keep.

CHAPTER 3

METHODOLOGY

3.1 Design of the Project

The achievement of the goal and the desired project outcome depend on a well-defined project plan. To make sure the project's outline is in the right direction for reaching the milestones, the design of the project should adhere to a few rules. This project's plan is organised into a few stages. Throughout this project, each stage's planning and application are covered in detail.

The process of problem identification is the project's first phase. The project's goals are then described in order to visualise how it will address the difficulties it has identified. The project's scope is then determined to make sure that the facilities, equipment, and personnel required for it are available. In order to learn more about the subject and have a clearer perspective, data collecting is done in the project design's next stage. Primary data and secondary data are the two categories into which data can be divided.

Through case studies and bibliographic research, data were gathered and analysed using both quantitative and qualitative methods. In this study, both varieties of data collection techniques are used. There are four approaches for gathering primary data: observation, interview, *fuguai* research, and concentrated group discussion. The methods used to obtain secondary data include *fuguai*-tags, manual machine operation, analytical approaches, and online resources.

On the autonomous maintenance, *fuguai* detection, and injection moulding machines, further data collecting and information gathering is carried out. An ideal autonomous maintenance programme is then created for the laboratory's injection moulding equipment using the combined data from the various sources and comparisons with earlier studies. To build the most appropriate autonomous maintenance programme for EDM machines, additional analysis and revision of the combined data are performed for justification. This project's design flow is depicted in Figure 3.1.

This project uses a Gantt chart as a project management tool. A Gantt chart is an effective tool for showing the project's tasks and timetable. In the gantt chart for this project, each task is represented by a bar, and the length of the bar denotes the task's duration. The task timeline for planned and actual planning for the entire project is shown on the gantt chart. In Figure 3.2, the gantt chart for this project is shown.

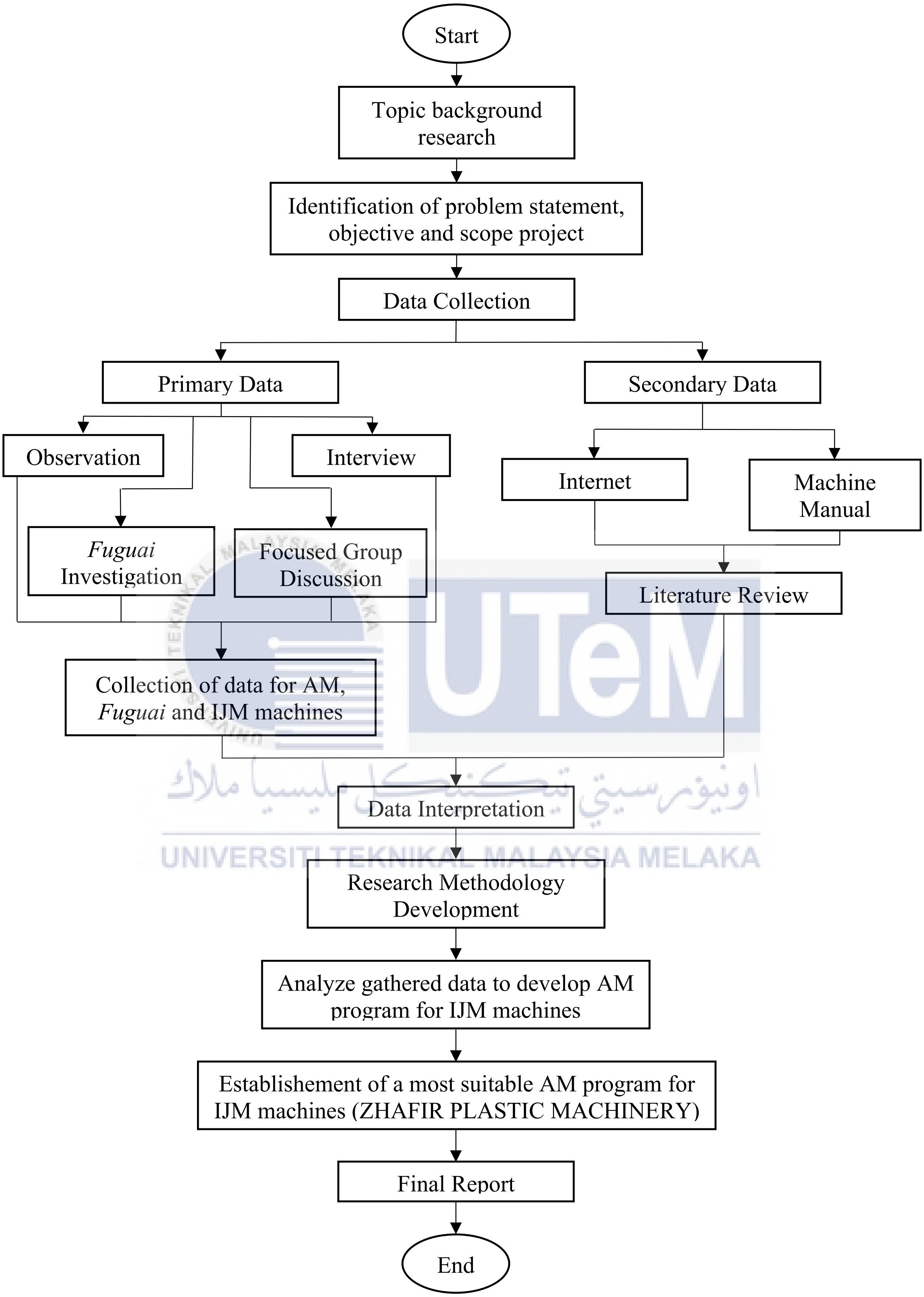


Figure 3.1 : Flow chart for design of the project

Table 3.1 : 5 Steps for Implementatating Autonomous Maintenance in Laboratory

Steps	Description
Step 0 Preparation	Collect the supplies, machinery, and data required for autonomous maintenance tasks in the lab. Make sure that the relevant information, lubricants, inspection checklists, and cleaning supplies are all easily available. Any equipment or supplies that require replenishment or replacement should be marked with an F-Tag.
Step 1 Initial machine cleaning and inspection	Thoroughly clean the lab's furnishings and surroundings to get rid of any dirt, dust, or debris. This procedure contributes to keeping the lab environment hygienic and secure. In this stage, we utilise F-Tag to designate the regions or pieces of equipment that need repair and apply 7 sorts of fuguai to identify the type of fuguai that is involved.
Step 2 Counter measures to source of contamination	Regularly check the apparatus for leaks, frayed connections, and signs of excessive lubrication. To prevent contamination and potential faults, fix these issues as soon as you can.
Step 3 Cleaning and lubricating standards	For cleaning, inspection, and maintenance chores, create and document standard operating procedures (SOPs). These SOP give detailed guidance on how to keep maintenance efforts consistent and productive.
Step 4 Overall inspection	Conduct ocular checks using an OPL or specific equipment to find issues. Any observations should be noted and given to the lab assistant for further action.
Step 5 Autonomous maintenance standards	Encourage students to recognise abnormalities and respond to them as quickly as feasible. This action promotes participation in preventive maintenance. Effective inspection methods, proper equipment use, and the ability to spot and report anomalies should all be taught to students.

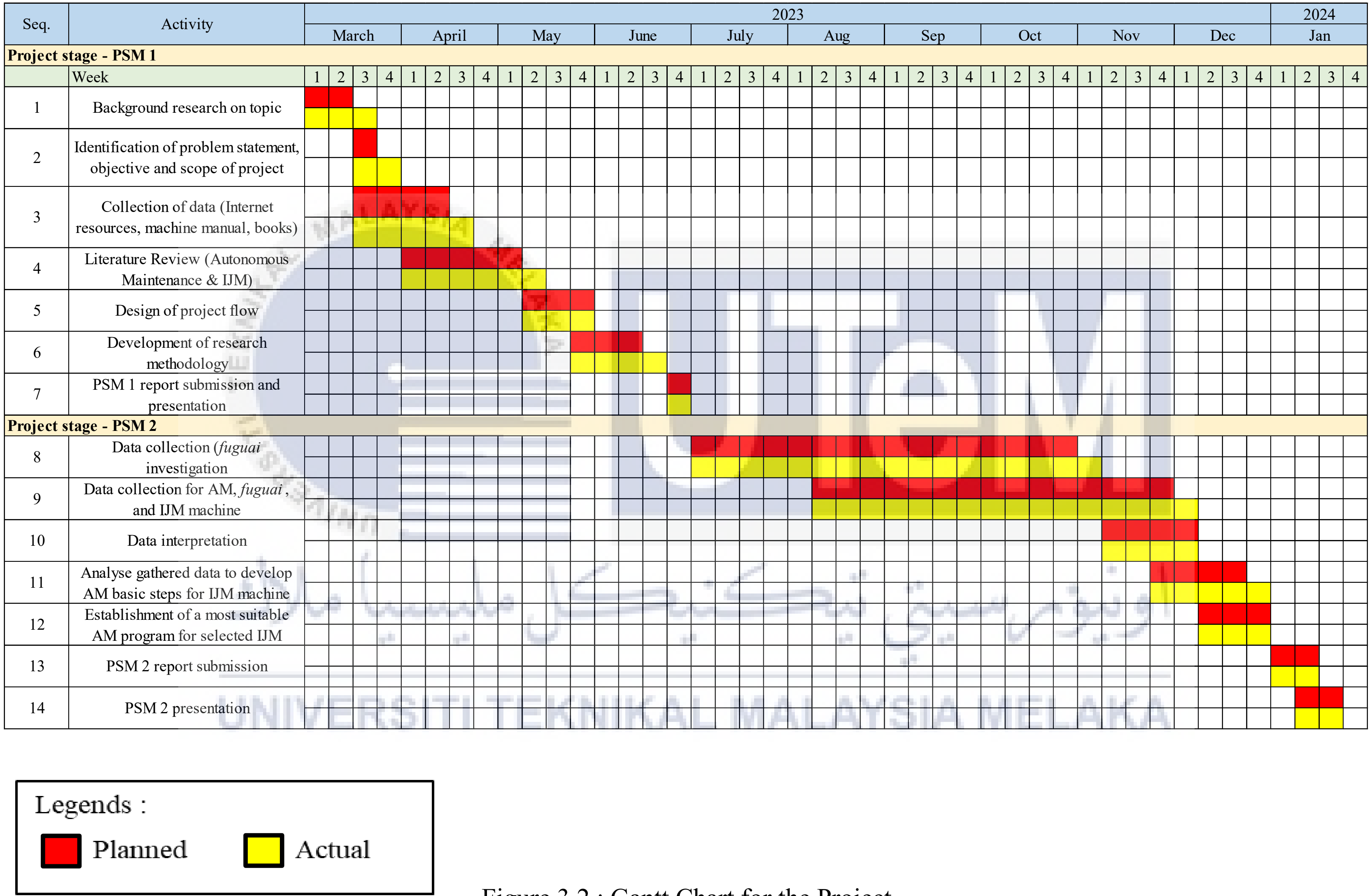


Figure 3.2 : Gantt Chart for the Project

3.2 Data Collection

This thesis presents a new and integrated analytical approach to estimate TL of MV distribution network. The essence of the approach used in this project is centered on the concept of EFM and RF. The selected approach is based on quantitative type, which aims to develop analytical model to calculate and analyze the TL on MV distribution network component (i.e. MV feeders and transformers). The method (design) is experimental, which utilizes empirical modelling and statistical approach. Subsequently, Figure 3.1 shows the research design of this thesis.

3.2.1 Primary Data

Primary data is unprocessed information that has been gathered from a reliable source and directly relates to the research problem. The main methods of data collecting for this project were focused group discussions, interviews, observations, and *fuguai* investigations.

3.2.1.1 Observation

Observation is a basic skill in daily life. Through the process of recording data or information from what we hear and see, observation enables us to analyse that data. In this study, data and information on IJM machines (ZHAFIR) in the FTKIP laboratory are gathered using the observation approach. Information and data about the machine's status, maintenance procedures, and instruments utilised in those procedures are all documented.

3.2.1.2 Interview

Asking and responding to questions about the specifics of the topic are required during the interview process. In this study, the laboratory assistant (ZHAFIR), who is in responsible of running the IJM machines, is interviewed. information on the routine maintenance, specifics on the equipment, and issues operators run across during the IJM process.

3.2.1.3 *Fuguai* Investigation

The identification of abnormalities discovered on IJM equipment is known as a *fuguai* investigation. Three categories physical, function, and safety represent different sections of the abnormalities found in the examination. The machine parts that need maintenance have *fuguai*-tags attached to them.

3.2.1.4 Focused Group Discussion

With the assistance of an advisor, a focused group discussion is held inside a small group to replicate discussion about the material. As there are three students working on projects with a similar title discussing autonomous maintenance programmes for various machines focus group discussions are used in this project to gather data. Members of the organisation undertake idea exchanges and information sharing among themselves.

3.2.2 Secondary Data

Secondary data are those that have been collected based on information from earlier studies. The available information is compiled and examined as a review for the chosen subject. Secondary data are gathered from a variety of sources, including academic journals, books, periodicals, and online databases.

3.2.2.1 Internet Resources

Because so much information can now be found online, using internet resources is one of the main ways to collect data. Online resources are used to compile e-books, research journals, articles, conference papers, and other relevant data. Major internet databases including Google Scholar, Mendeley, Science Direct, and Emerald are used to identify research journal findings. Various websites are used to find additional information on IJM machines and autonomous maintenance.

3.2.2.2 Machine Operation Manual

A better knowledge of IJM machines (ZHAFIR PLASTIC MACHINE) is achieved by the collecting of data from the machine operation manual. The machine operator manual gives general information about the IJM machines as well as specifications, problems to be solved, and particular information. The specifics and information are helpful for establishing a benchmark for the creation of an autonomous maintenance programme.

3.2.2.3 Analytical Techniques

a. Column Chart

The category of data is represented by a rectangle in a column chart, commonly known as a vertical bar chart, and the values being plotted are displayed as the height of the rectangle. Column charts are frequently employed to compare values between categories. A column chart is used to visualise the relationship between *fuguai* frequency and *fuguai* category as well as between *fuguai* frequency and the distribution of *Fuguai*-tags. The column chart prototype model is displayed in Figure 3.3.

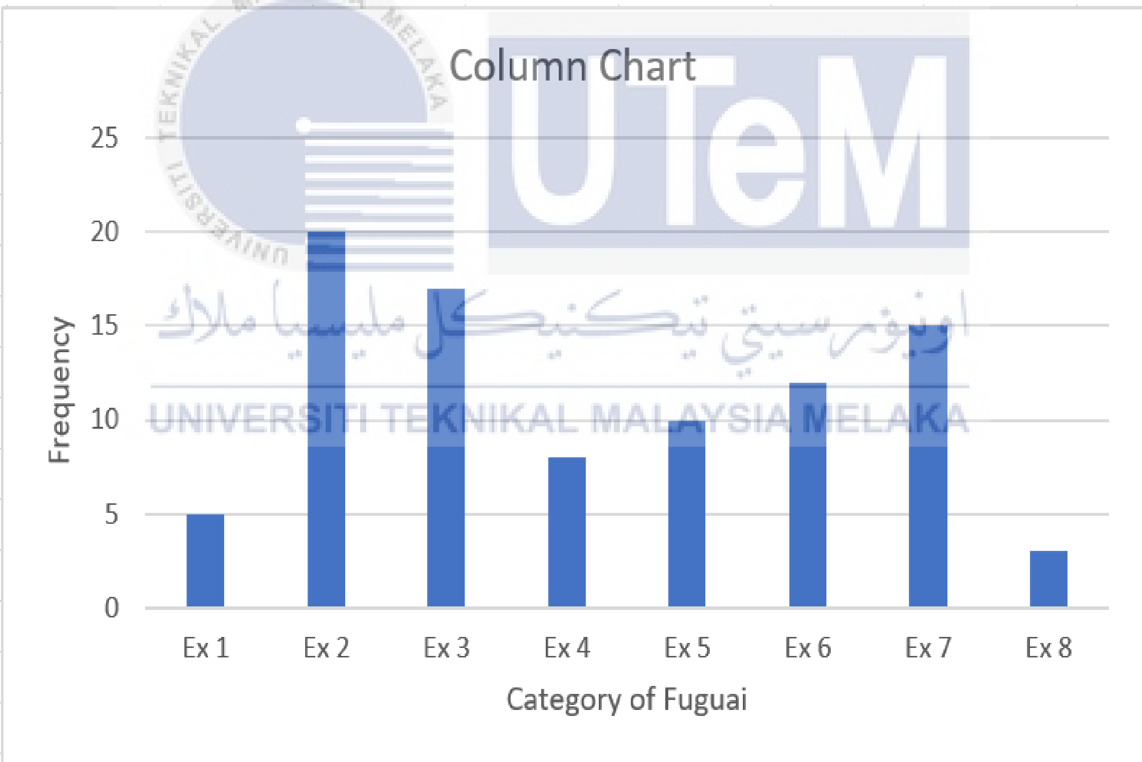


Figure 3.3 : Column Chart Prototype Model

b. Pareto Chart

The longest bars are on the left of a Pareto chart, and the shortest ones are on the right. The bars' lengths correspond to frequency. The graph demonstrates which factors are more significant. The Pareto chart is used to examine the data's frequency and problems, focusing on the key problems. In this project, a pareto chart is utilised to show the types and geographic distribution of *fuguai* as well as their frequency of occurrence. The pareto chart prototype model is displayed in Figure 3.4

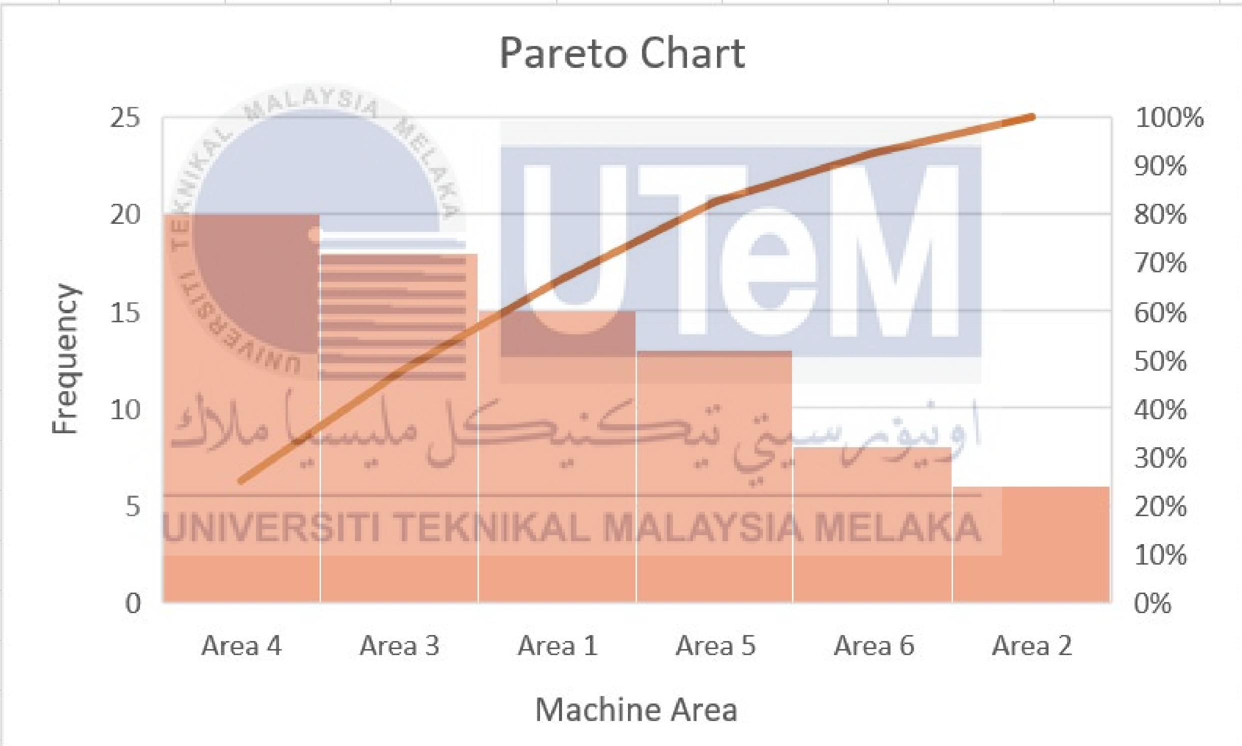


Figure 3.4 : Pareto Chart Prototype Model

c. **Pie Chart**

The breakdown of data into categories for each segment is represented by a pie chart. While the divided segments show the data proportion, the entire circle represents all of the data. Pie charts are used in this project to categorise and analyse the various *fuguai* types. Figure 3.5 shows the prototype model for pie chart.

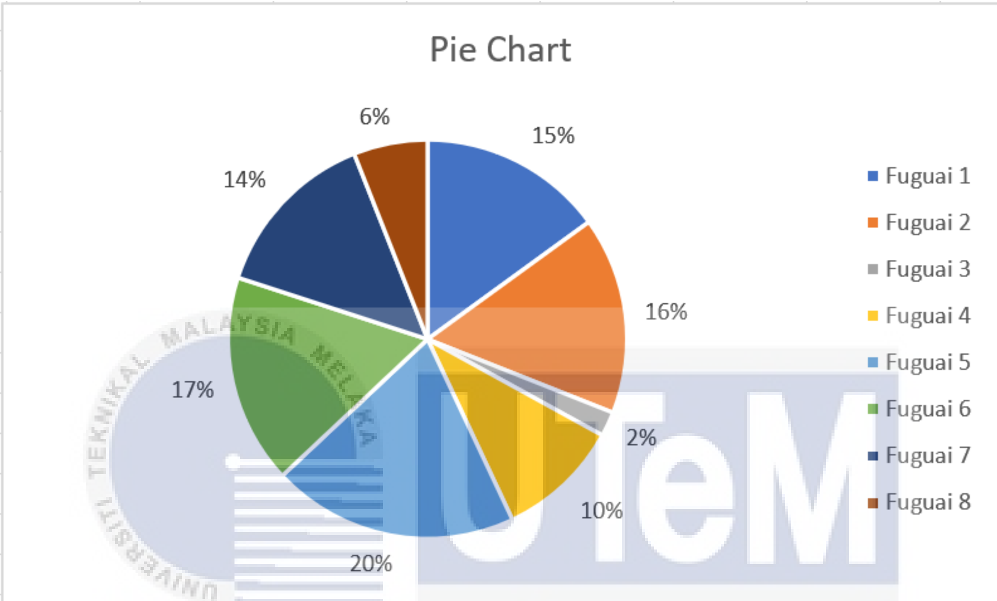


Figure 3.5 : Pie Chart Protoype Model

d. **One Point Lesson (OPL)**

A One-Point Lesson (OPL) is a quick instructional document that focuses on succinctly and clearly outlining a certain concept or ability. It describes how a task ought to be finished. An OPL is a concise document made up of simple text, symbols, and graphics. Making instructions for tasks simple to learn and understand is the core goal of OPL. In this project, OPL is utilised to provide students with an easily understandable paper that is visually beautiful. The one point lesson template sample utilised in this project is shown in Table 3.1.

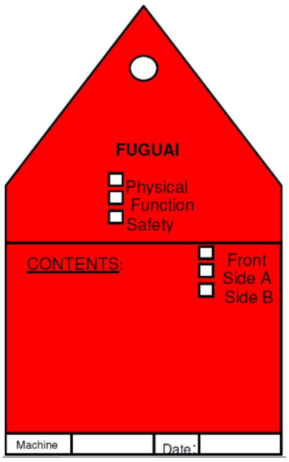
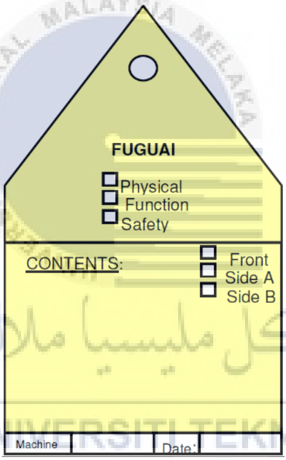
Table 3.2 : One Point Lesson template

One Point Lesson		
Part:		Ref No:
		Date:
Classification:		
Physical	Function	Safety
BEFORE		AFTER

3.2.2.4 *Fuguai* Tags

Fuguai-tags (also known as *Fuguai*-tags) are used to mark the locations of abnormalities discovered during the initial cleaning step of a machine. *Fuguai*-tags come in a variety of colours to help identify the various levels of irregularities so that the appropriate course of action can be taken. There are two distinct colour *Fuguai*-tags with distinct indication purposes. *Fuguai*-tags come in two colours: red and blue. The information about f -tags is provided in Table 3.2.

Table 3.3 : *Fuguai*-tags colour and function description

***Fuguai*-tags**	**Descriptions**
 Figure 3.6 : Red *Fuguai*-tag	The colour red conveys the idea of danger. A technical mechanic with extensive expertise of maintenance is required to address the abnormality indicated by the red f-tag in order to resolve the issue. As anomalous incidents may occur during the procedure, maintenance staff with greater technical expertise are required to handle the maintenance.
 Figure 3.7 : Yellow *Fuguai*-tag	The abnormalities detected might be corrected by operators or anybody with the right instructions and guidance, according to the yellow colour f-tag. The task mentioned on the yellow *fuguai*-tag could be completed by someone with only the most basic training or maintenance knowledge. The issues indicated by the yellow *fuguai*-tag don't require advanced maintenance expertise because they can be resolved with simple maintenance techniques like cleaning or repositioning the component.

Fuguai-tags in different colours enable operators or anyone else who sees the tag to handle the issue right away with a clear picture of the problem's specifics, including the problem's category, location, and discovery date. The *fuguai*-tag elements are as listed in Table 3.3.

Table 3.4 : *Fuguai*-tags elements with descriptions

Elements	Descriptions
Fuguai Category	On the *fuguai*-tag, there are three categories of *fuguai*, each of which represents a different function. a. Physical means when a machine has dust or an oil stain, the abnormalities can be seen with the naked eye. b. Function means the discovered abnormalities may cause the machine to malfunction. c. Safety means the abnormalities could create hazardous situations for the operators.
Machine	Indication of a specific type of machine.
Date	In order to ensure that the issue is not overlooked, the date the tag was issued is recorded.
Contents	a thorough description of the issue, including details like the problem's location or potential solutions.

3.3 Summary

This chapter has discussed the project's design flow and offered a research approach for gathering and analyzing data. A flowchart is used to present the project's design, while a Gantt chart is used to show its timeframe. This chapter describes the procedures for gathering primary and secondary data. Primary data come from interviews, concentrated group discussions, observations, and *Fuguai* investigations. Internet sources, machine operation manuals, analytical methods, and *fuguai*-tags are examples of secondary data. Column charts, pareto charts, pie charts, and one-point lessons are examples of analytical approaches. Prototype models and example templates are used to illustrate each analytical technique in detail. The *fuguai*-tags used for this project are shown, along with more explanations of their details. The flow of further findings and the analysis of results in this project are both dependent on the design of the research approach.

CHAPTER 4

ANALYSIS AND DISCUSSIONS

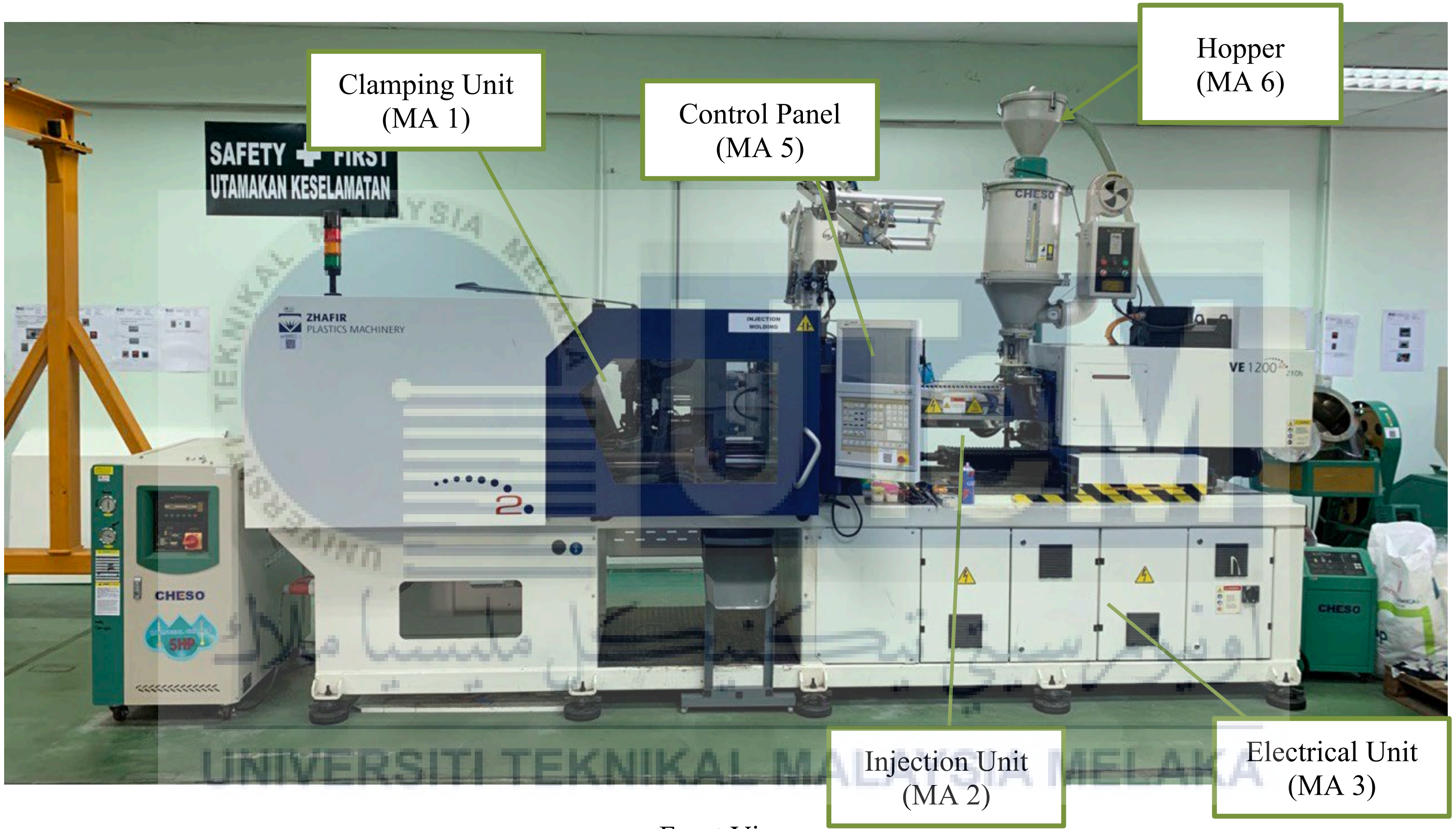
4.1 *Fuguai* Analysis

The irregularities on the machines are called *fuguai*. The data collection techniques covered in the preceding chapter are used to the analysis of the *fuguai* data. The acquired fuguai are summarized and categorized using *fuguai* analysis. By connecting the gathered data, *fuguai* analysis facilitates the identification and discovery of patterns in the data.

Prior to beginning the initial cleaning procedure, the machine's condition is being examined and monitored. *Fuguai* that were found at various locations throughout the machine during the first cleaning procedure can be divided into many kinds. The purpose of the fuguai research is to gather fuguai data on the machine through the use of chart analysis and F-tagging.

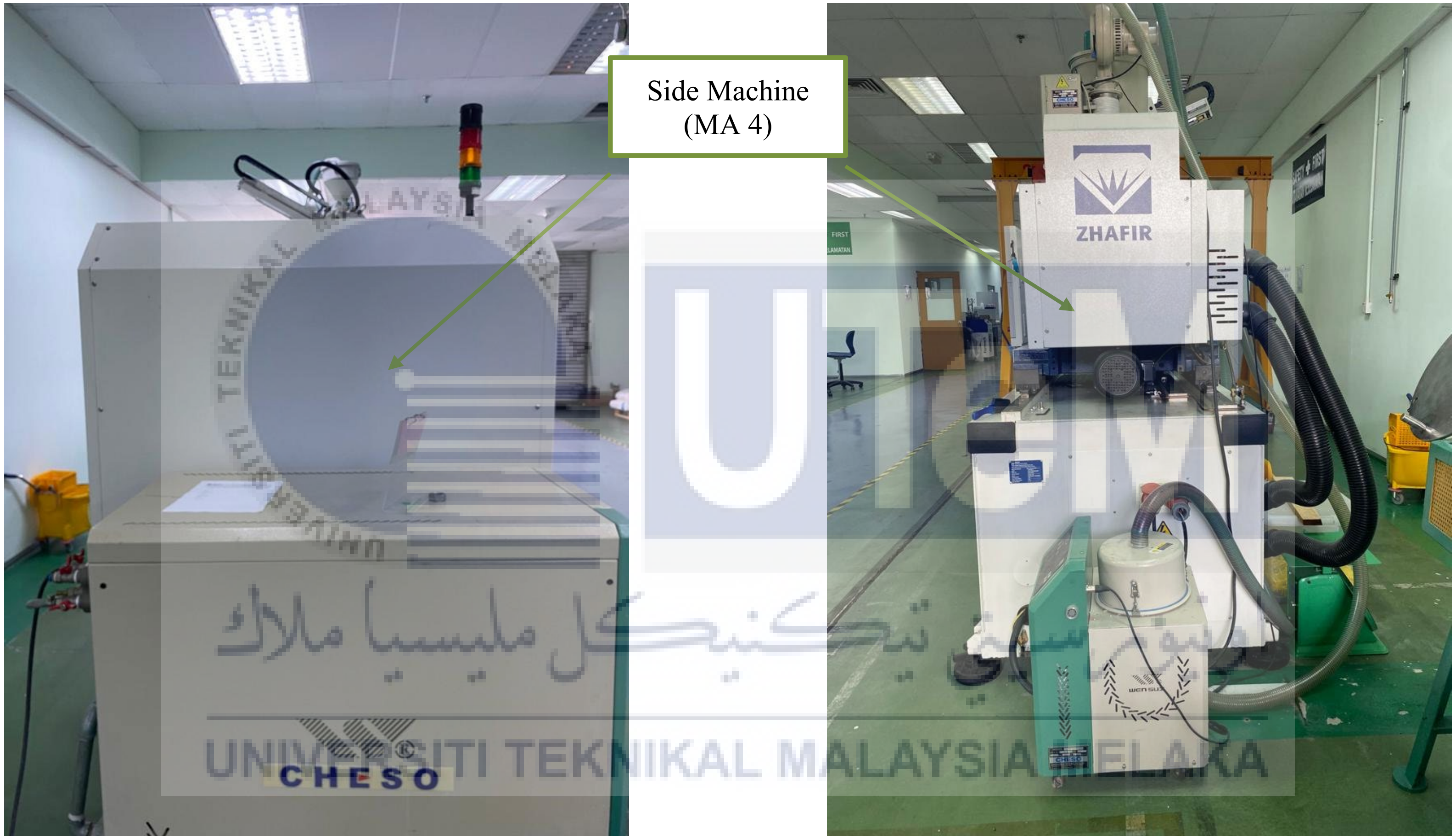
4.1.1 Machine Area

The IJM Machine are divided into smaller sections for easier identification of *fuguai* around the machine. The IJM machine are dvided into 7 main areas which are clamping unit (MA 1), injection unit (MA 2), electrical unit (MA 3), side machine body (MA 4), control panel (MA 5), hopper (MA 6) and machine body back (MA 7). The machine area are illustrated as shown in Figure 4.4 below.



Front View

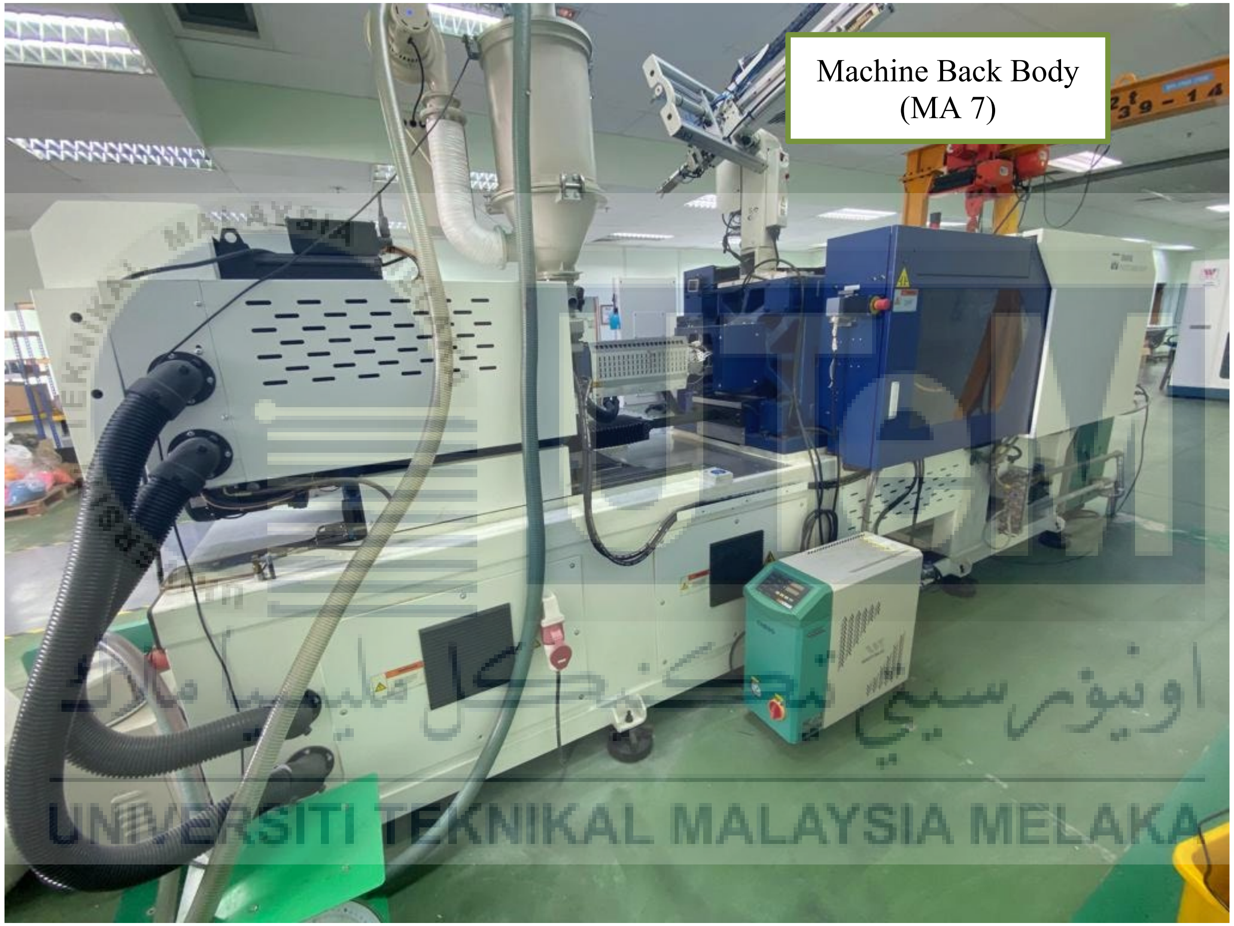
Figure 4.1 : Injection Moulding Machine area layout



Left View

Right View

Continue Figure 4.1 Injection Moulding Machine area layout



Back View

Cont Figure 4.1 Injection Moulding Machine area layout

4.1.2 Types of *fuguai*

Eight major categories can be used to classify the identified *fuguai* surrounding the IJM machines: dust (F1), dirt (F2), leftover objects (F3), unorganized items (F4), rusted parts (F5), broken parts (F7), missing components (F6), and loosen components (F8). Table 4.4 lists the recognized *fuguai* types for each *fuguai* category.

Table 4.1 : List of *fuguai* identified

Ref	*Fuguai* types	*Fuguai* identified on machine	Description
F1	Dust	Cover top machine	Dust full on top machine and can give dented to product
		Top clamping unit	Dust full and thick on top area and dangerous for clamping unit when machine run
F2	Dirt	Cover clamping unit	Dirt are full on the cover area
		Safety door	Dirt cover on safety glass door
		Back clamping unit	Area are near with water chiller and give dirty on the area
		Back cover below mould	Area are covered by dirt
		Rubber Carpet	Carpet full covered of dirt
F3	Leftover items	Dirty worktable	Too many items leftovers on the worktable area
		Injection area	Recycle plastic left on the injection area
		Surface hopper	Plastic granules are fall from hopper when machine run
F4	Disorganized items	Cover injection unit	Cover is placed under the machine
F5	Missing components	Missing screw	Screw on cover area are missing and need to find a new one

4.2 Identification of *fuguai* on machine areas

The identification process for *fuguai* involves labeling each one that is discovered with a distinct colour and a thorough description on the f-tag. Different *fuguai* are identified on different place on the injection moulding machine. Different *fuguai* also need to complete also with different tool.

There are type of *fuguai* on Injection Moulding Machine have been identified that is dirty worktable, plastic injection area, cover injection unit, dirty surface hopper, dirty cover clamping unit, dirty safety door, dirty back clamping unit and cover below mold. There are 2 *fuguai* is tagged by red f-tag which are plastic injection area and cover injection unit. Injection Moulding Machine have the common *fuguai* which are dirty surface on machine and have same steps in *fuguai* elimination. These *fuguai* are tagged in blue f-tag as they can resolved by operators. This machine use water chiller on mold to absorb heat from molten plastic and allowing for faster and more uniform cooling. If the water leaking, this can make the machine dirty because the area being covered by grease.

Plastic injection area really need to do *fuguai* because this can give bad when the machine start to inject the plastic. This happen when the machine need to stop, change mold or change material. The remain plastic need to remove to make sure there are no plastic inside the heaters.

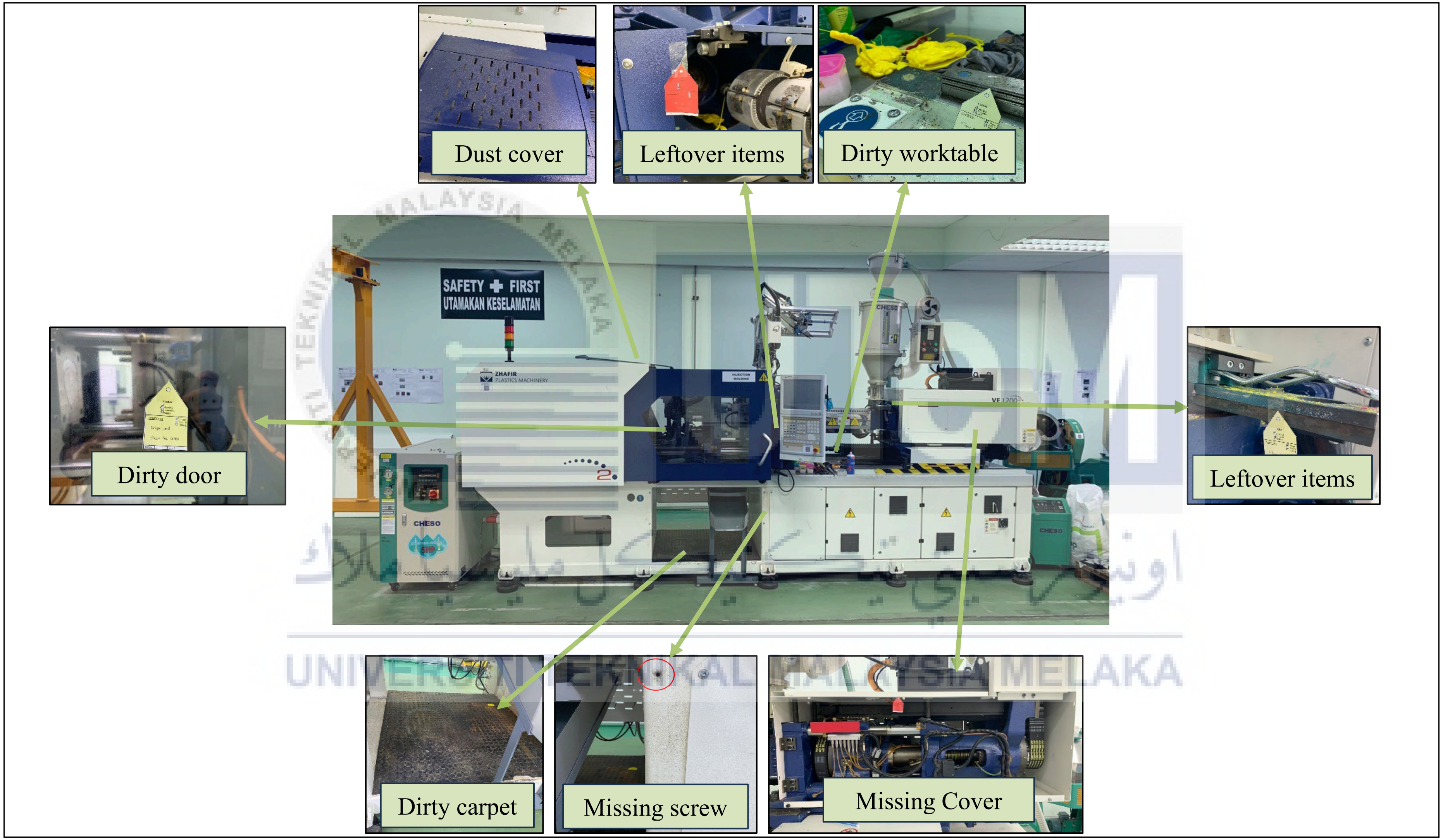


Figure 4.2 IJM Machine Front Area

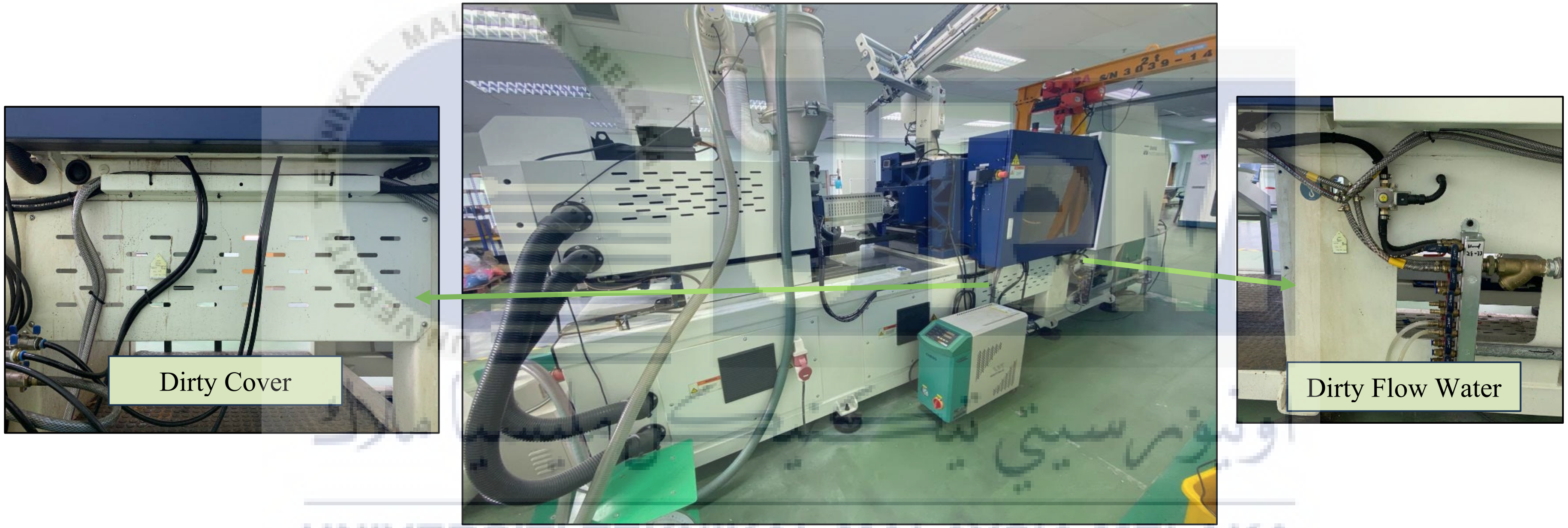


Figure 4.3 IJM Machine Back Area

4.3 Data analysis of *fuguai*

The goal of data visualisation is to uncover important features and patterns in a data collection in advance of statistical analysis and decision-making. It is a graphical representation of important characteristics and patterns in a data set that is often used with big data sets (Krok, 2021). Graphs and charts are used as statistical tools to examine the raw data of *fuguai* that are recorded through the *fuguai* tagging process. The analysis of the *fuguai* located around the machine is done according to the machine area, distribution of f-tags, *fuguai* category, and *fuguai* types. The statistical graphs pie chart, pareto chart, and column chart chosen for this analysis show the interrelatedness of the data. Based on the information provided, decisions are taken about how to resolve the *fuguai*.

4.3.1 Analysis of *fuguai* types

Table 4.2 shows the *fuguai* types identified on each machine.

Table 4.2 : Data collected for *fuguai* types Injection Moulding Machine

***Fuguai* types**	**Front**	**Top**	**Side**	**Back**	**Total**
F1	0	3	1	2	6
F2	3	1	2	3	11
F3	3	1	3	2	9
F4	3	1	0	0	4
F5	2	0	0	0	2

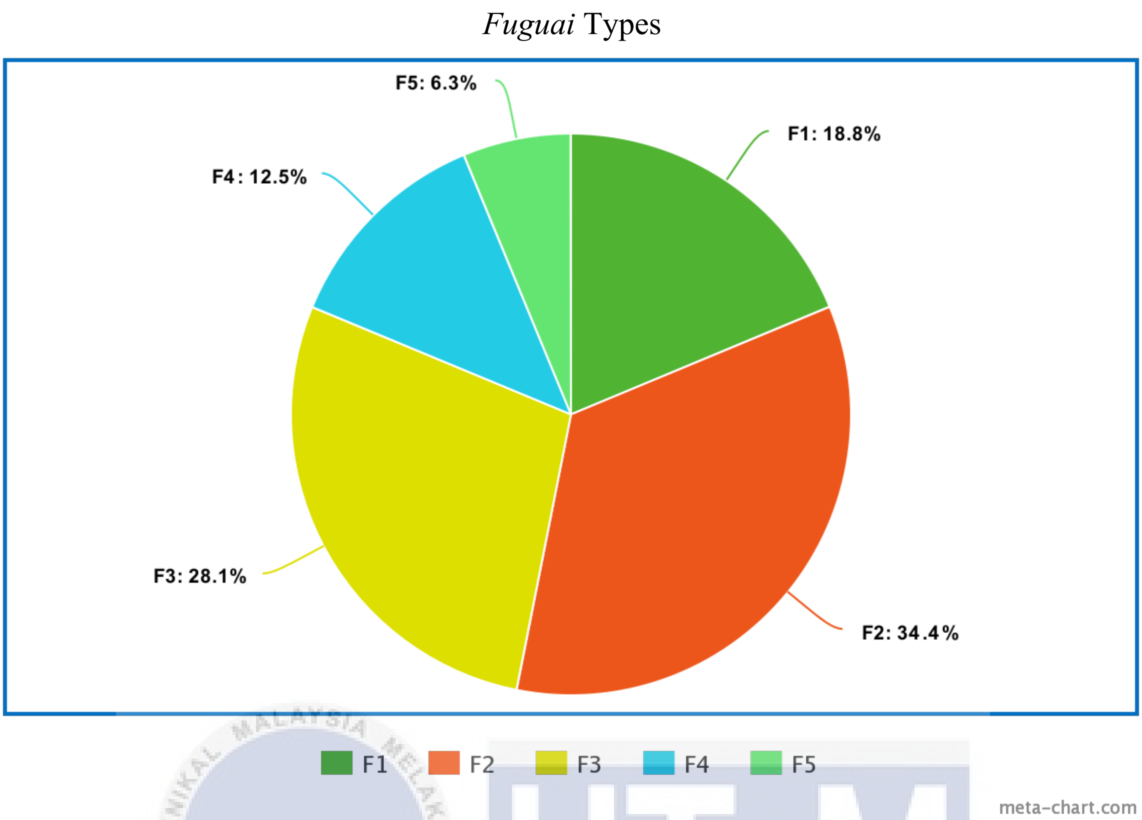


Figure 4.4 Pie chart for *fuguai* types

The *fuguai* types are analyzed by using pie chart as shown in Figure 4… to show the highest *fuguai* occurrence among the machines. From the pie chart analysis, dirty (F2) contributed the highest percentage of 34.4% among all 5 types of *fuguai*. A lot of dirt as a result of leaking water mixed with grease. Leftover items (F3) are the second highest percentage of 28.1% and the third is dust (F1) with percentage 18.8%. The lowest percentage *fuguai* is missing components (F5) with 6.3% because of the machine can work very well due to sufficient components.

4.3.2 Analysis of F-tags distribution

Table 4.3 shows the *fuguai* types identified according to the distribution of f-tags

Table 4.3 Analysis based on F-tags colour

***Fuguai* types**	**F-tags colour**	
	Yellow	**Red**
F1	6	0
F2	6	2
F3	5	2
F4	0	4
F5	0	2

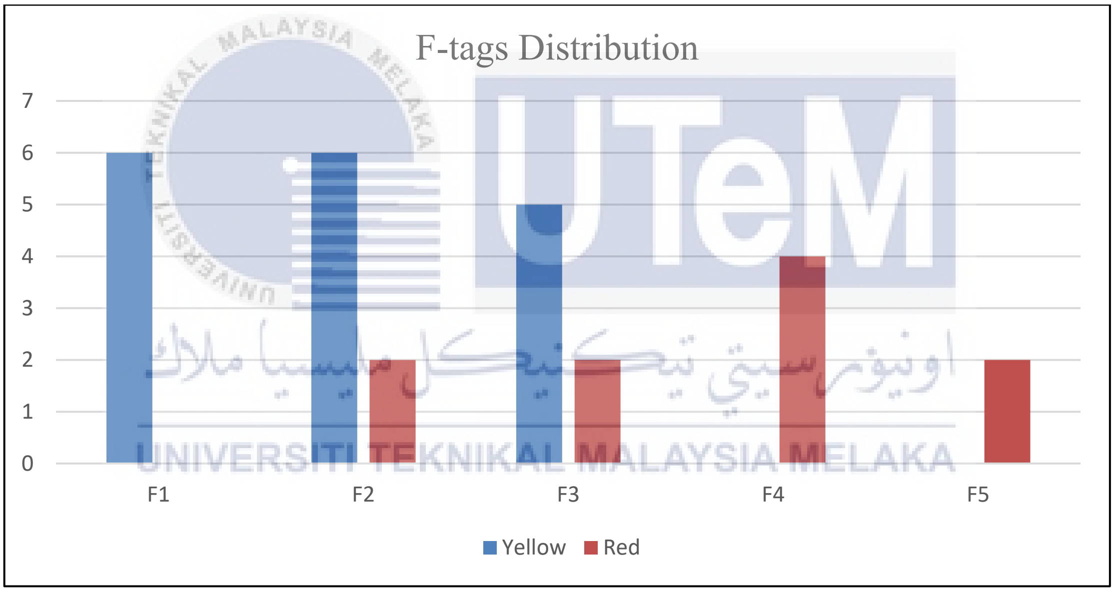


Figure 4.5 Column chart for F-tags distribution

Figure 4... shows the distribution of tellow and red f-tags on the types of *fuguai* found. There are 2 types of *fuguai* that reach the highest yellow f-tags which is dust (F1) and dirt (F2). On the other hand, the highest red f-tags are disorganized items (F4) and there are 3 red f-tags share the same value which is dirt (F2), leftover items (F3) and missing components (F5) with value 2 f-tags.

4.3.3 Analysis of machine area

Table 4.4 shows the *fuguai* data collected around the IJM machine area

Table 4.4 Data collected of *fuguai* on machine area

Machine Areas	Front	Top	Side	Back	Total
MA 1	0	2	1	2	5
MA 2	2	1	1	1	5
MA 3	2	1	2	1	6
MA 4	0	1	1	0	2
MA 5	1	0	0	0	1
MA 6	1	0	0	0	1
MA 7	0	0	0	7	7

Table 4.5 shows the cumulative frequency of occurence of *fuguai* around the machine area

Table 4.5 Cumulative frequency of *fuguai* collected on machine area

Machine Area	Frequency	Cumulative Frequency	Cumulative Percentage (%)
MA 1	5	5	18.52
MA 2	5	10	37.04
MA 3	6	16	59.26
MA 4	2	18	66.67
MA 5	1	19	70.37
MA 6	1	20	74.07
MA 7	7	27	100

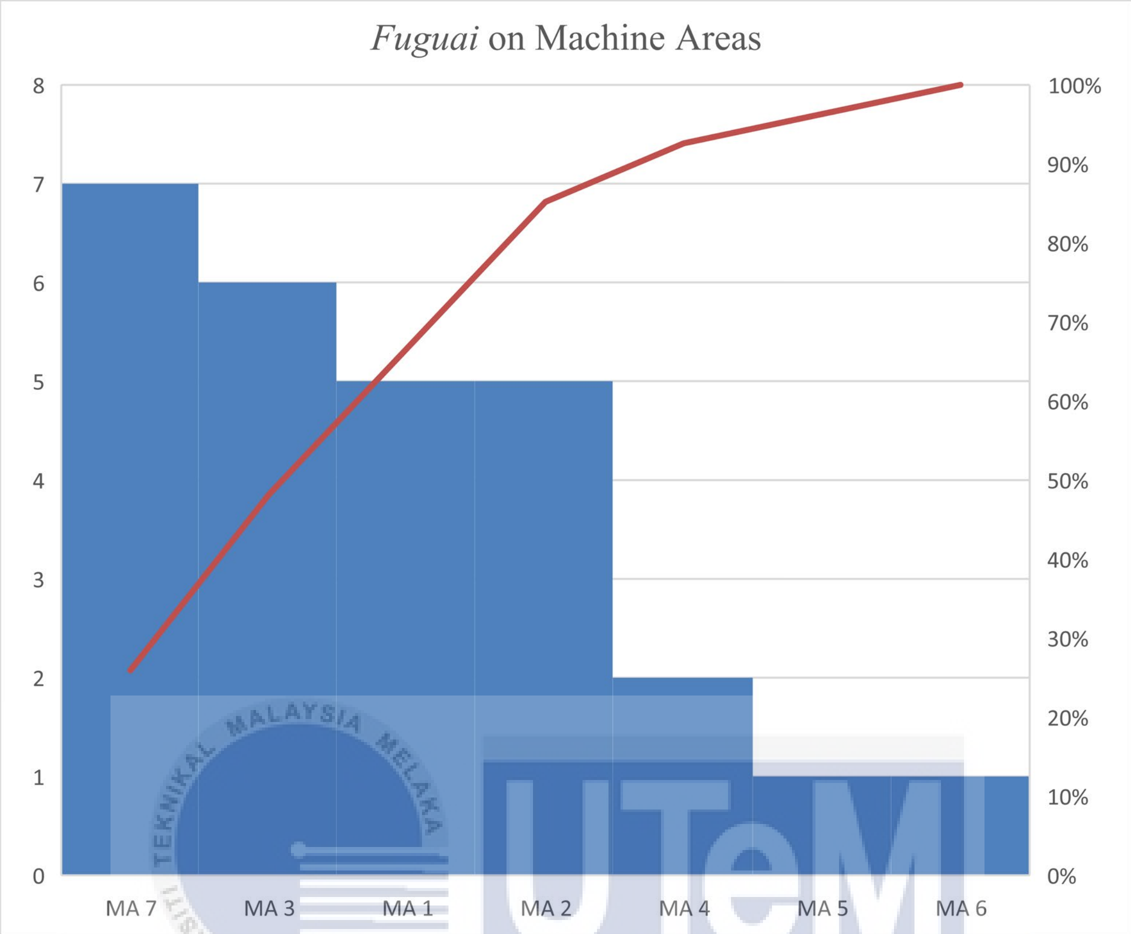


Figure 4.6 Pareto chart for *fuguai* identified on machine areas

Pareto chart in Figure 4.6 is constructed to analyze the most frequent occurrence of *fuguai* at the machine area. The most critical part of *fuguai* occurrence on the machine is determined through pareto chart. From the pareto chart, the most critical *fuguai* occurrence area is around the machine back body (MA7) with a frequency of 7 followed by electrical unit (MA3) with a frequency of 6. The machine clamping unit (MA1) and injection unit (MA2) shared the same frequency with the value of 5. After that, side machine (MA4) followed with the frequency 2 and lastly 2 machine area shared the same frequency is control panel (MA5) and hopper (MA6).

4.3.4 Analysis of *fuguai* category

Table 4.6 shows the *fuguai* data collected around the IJM machine area according to *fuguai* category.

Table 4.6 Data collected for *fuguai* category on machine area

Machine Area	*Fuguai* Category		
	Safety	Physical	Function
FRONT	1	5	0
TOP	0	4	1
SIDE	0	5	0
BACK	3	7	1

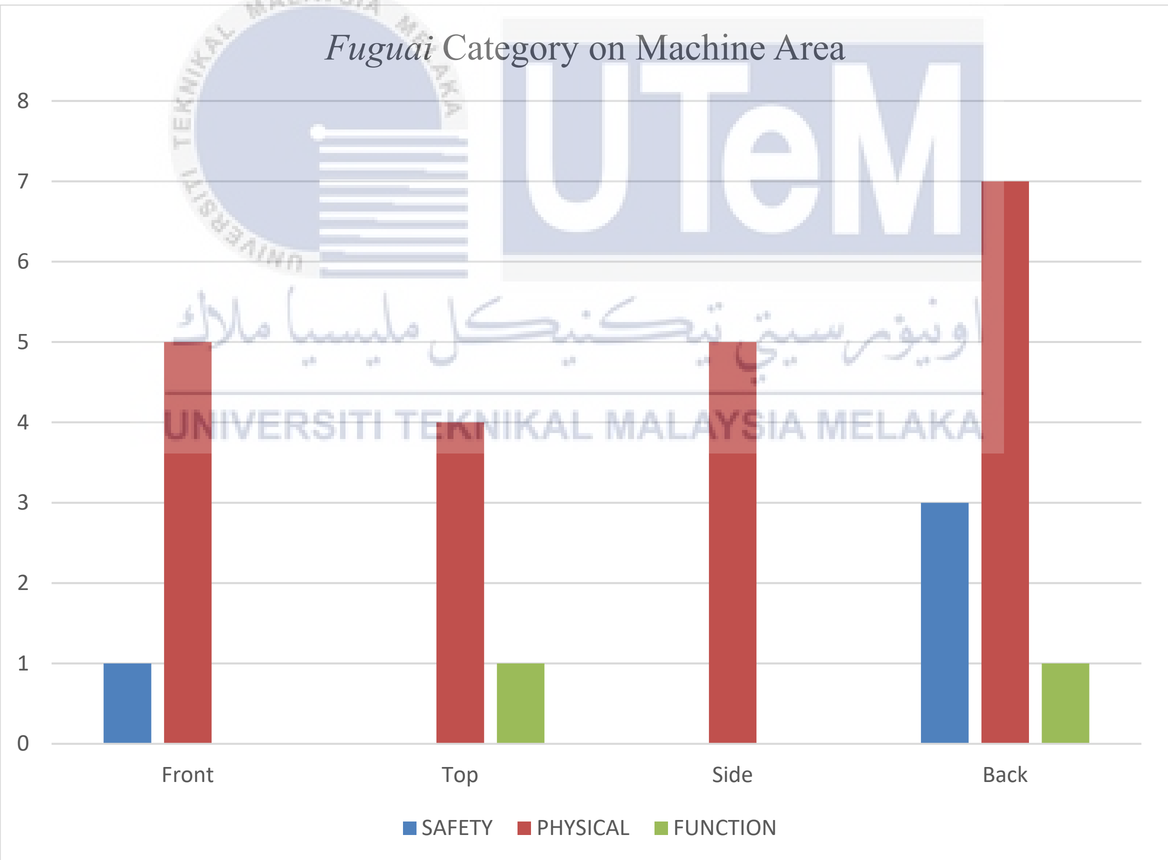


Figure 4.7 Column chart of *fuguai* category on machine area

Column chart in Figure 4.7 presents the three fuguai category frequency against the machine area of occurrence. From the chart, the physical *fuguai* occurred the most at the machine back body (MA7) with a frequency of 7. Highest for safety and function *fuguai* not reach the second high physical *fuguai* with value 4 which is clamping unit (MA1) and electrical unit (MA3). The third function *fuguai* side machine (MA4) reach same value with highest safety *fuguai* and safety machine area shared the same 2 value which is injection unit (MA2) and electrical unit (MA3). The lastly 4 same value with 2 physical and 2 function *fuguai* wich is control panel (MA5) and hopper (MA6) for physical and clamping unit (MA1) and electrical unit (MA2) for function with 1 only value.

4.4 Standard Operation Procedure for *Fuguai* elimination

A one point lesson (OPL) corrects a problem or improves a working method at a machine or in a process. To communicate the assignment to their collagues and team, operators or team leaders can draft an OPL. OPL is used to explain the *fuguai* elimination because it is clear-cut, fundamental and succinct and because each OPL is followed by illustration of a countermeasure for *fuguai* elimination.

There are three categories for *fuguai* which is safety, function and physical. The OPL specifies the kind and classification of *fuguai*. To help the machine operator comprehend the machine's standard condition, each OPL displays the machine's condition both before and after the initial cleaning procedure based on each *fuguai* that has been found. Even though *fuguai* are classified similarly, each *fuguai* requires a different technique to be tackled.

Figure 4.8 shows the OPL for dirty worktable. The IJM machine's cutting technique leaves the worktable unclean because no regular cleaning procedure is used thereafter. The IJM machine is used frequently, but neither operators or users do routine maintenance on it after usage, which leaves debris on the worktable. The steps in *fuguai* elimination for dirty worktable is as describe in Table 4.7.

***Fuguai* : Dirty Worktable**	
Classification : Physical	
Before	After
	
Worktable covered with plastic waste and dirty cloth	Clean and wipe the leftovers surrounding the worktable

Figure 4.8 OPL for Dirty Worktable

Table 4.7 Steps in *fuguai* elimination (Dirty Worktable)

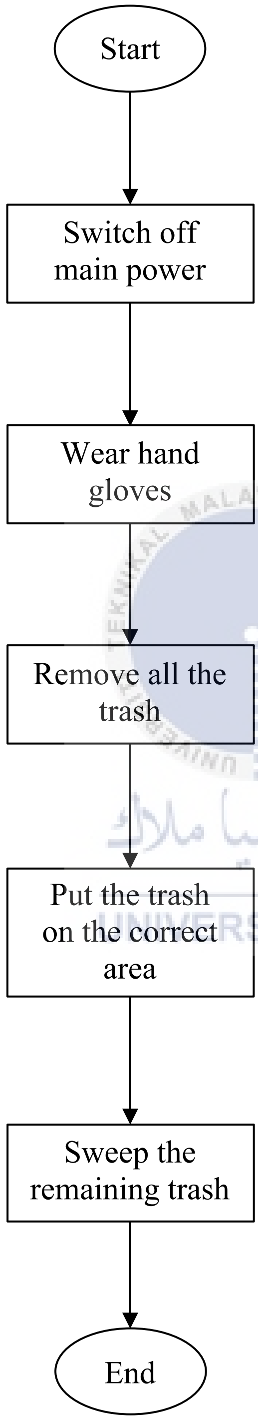
Cleaning process flow	**Description**	**Images**
	1. Make sure the main switch is switched off before cleaning process to ensure safety.	 IJM Machine main switch
	2. Wear hand gloves to protect the hands during cleaning process.	 Hand gloves
	3. Bring and put plastic granules label container and spray anti-rust on the correct place	 Material plastic granules container and spray anti-rust
	4. Collect all the plastic waste and dirty cloth and put on the recycle bin.	 Recycle plastic and dirty cloth
	5. Use brush and sweep the area to remove plastic granules. Take broom and sweep the remain on the floor	 Sweep plastic granules
	6. Throw the plastic granules to the trash can.	 Throw it in trash

Figure 4.9 shows the OPL for injection area. The plastic that was left was due to several factors such as wanting to change to a new mold or wanting to stop the machine. when the machine wants to be stopped, the plastic that is still inside the injection unit needs to be removed at the end so that it does not harden inside and this will damage the machine.

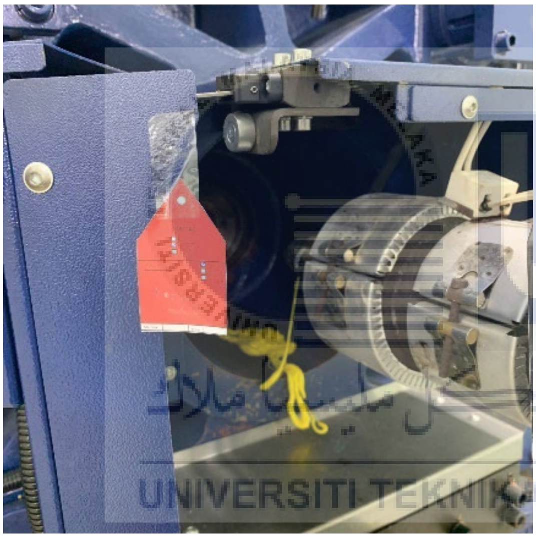
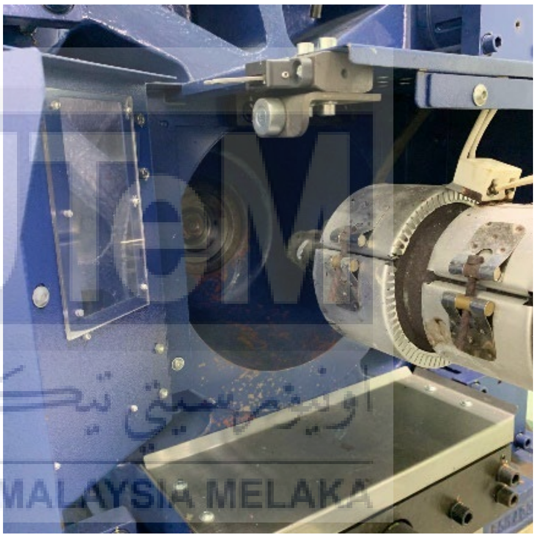
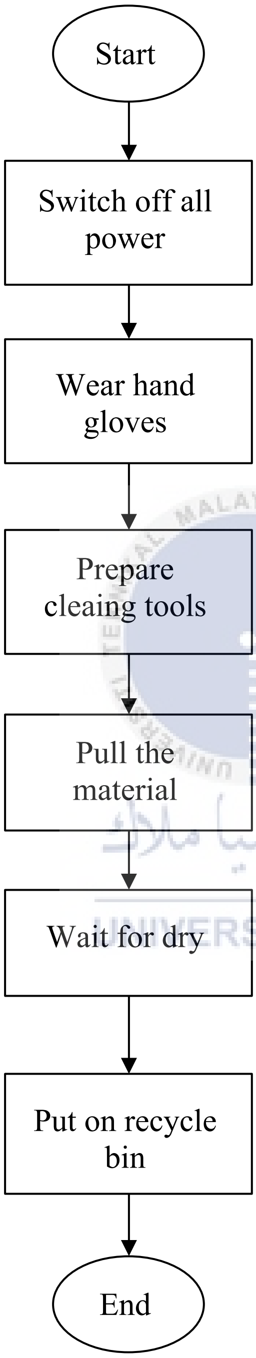
***Fuguai* : Plastic Injection Area**	
Classification : Function	
Before	After
	
Excess plastic is left in the injection area	Pull the plastic until there is no plastic left

Figure 4.9 OPL for Plastic Injection Area

Table 4.8 Steps in *fuguai* elimination (Plastic Injection Area)

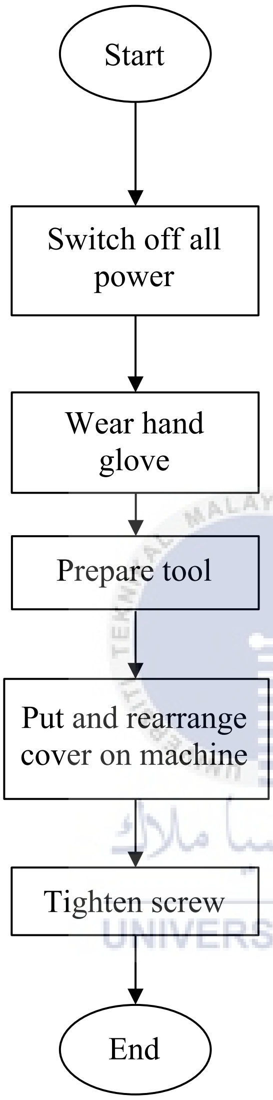
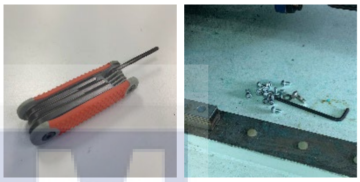
Cleaning Process Flow	**Description**	**Images**
	1. Make sure the main switch is switched off before cleaning process to ensure safety.	 IJM Machine main switch
	2. Wear hand gloves to protect the hands during cleaning process.	 Hand gloves
	3. Prepare iron pipe with long around 400mm.	 Iron pipe
	4. Pull the material that have been removed from injection nozzle.	 Pull material
	5. Wait for the plastic totally dry and solid.	 Drying material
	6. Take the plastic and put it on recycle bin	 Put on recycle bin

The next OPL is the cover injection unit found in figure 4.10 below. This cover is open as a result of the previous maintenance workers not closing it again after the maintenance work is carried out. This *fuguai* is categorized as safety because the exposed internal system can be life-threatening to anyone nearby.

***Fuguai* : Cover Injection Unit**	
Classification : Safety	
Before	**After**
	
The injection unit cover is not closed	Cover with the injection unit cover neatly and install the screws neatly

Figure 4.10 OPL for Cover Injection Unit

Table 4.9 Steps in *fuguai* elimination (Cover Injection Unit)

Cleaning Process Flow	Description	Images
	1. Make sure the main switch is switched off before cleaning process to ensure safety.	 IJM Machine main switch
	2. Wear hand gloves to protect the hands during cleaning process.	 Hand gloves
	3. Prepare assemble tools.	 Allenkey set and countersunk screw
	4. Pick up the cover and rearrange it untill the cover perfectly can be screw.	 Rearrange cover
	5. Tighten up screw correctly.	 Screw area

The OPL in the figure below is a *fuguai* labeled as a surface hopper. This *fuguai* is labeled with a yellow tag because the labor required does not involve high security and is easy for anyone to solve based on the reference steps of *fuguai* elimination. This waste occurs due to the fall of plastic granules when the machine is running.

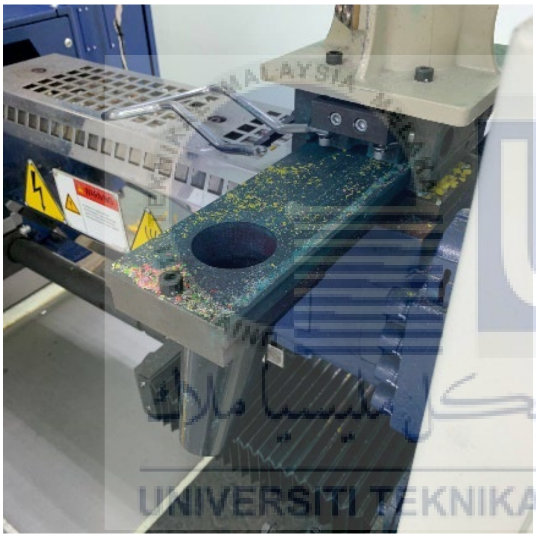
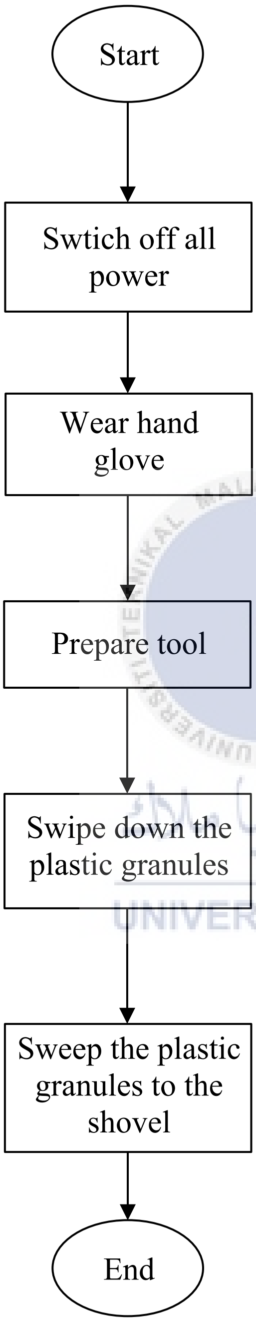
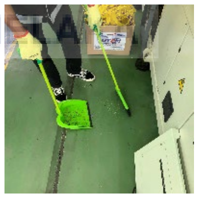
***Fuguai* : Surface Hopper**	
Classification : Physical	
Before	After
	
Stand hopper covered with plastic granules	Clean and wipe the plastic granules on the surface area

Figure 4.11 OPL for Surface Hopper

Table 4.10 Steps in *fuguai* elimination (Surface Hopper)

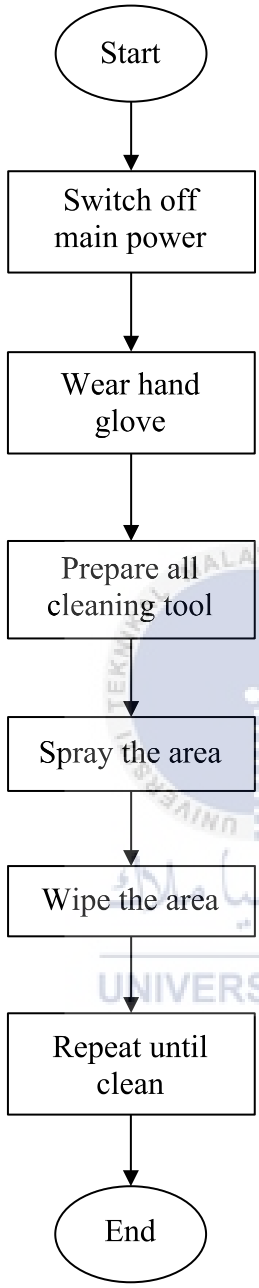
Cleaning Process Flow	**Description**	**Images**
	1. Make sure the main switch is switched off before cleaning process to ensure safety.	 IJM Machine main switch
	2. Wear hand gloves to protect the hands during cleaning process.	 Hand gloves
	3. Prepare brush tool to clear the plastic granules.	 Brush
	4. Clear the plastic granules use brush from the area to the floor.	 Swipe plastic granules
	5. Use broom and sweep the remain plastic granules to the shovel	 Sweep plastic granules
	6. Remove plastic granules to the trash	 Remove from shovel

Injection molding procedures and ambient conditions can lead to dirt buildup on the side clamping unit. During the molding process, dust, airborne particles, and leftover plastic fragments from the manufacturing environment may land on the clamping unit's surfaces. Unmaintained equipment, poor ventilation, and unclean work environments can all lead to the accumulation of dirt on the side clamping unit. This buildup could make it more difficult for the device to operate smoothly, which could affect how well the molded products turn out. In order to prevent dirt-related problems and guarantee the efficient operation of the injection molding equipment, regular cleaning and maintenance procedures are essential.

***Fuguai* : Cover Clamping Unit**	
Classification : Physical	
Before	After
	
Cover clamping unit covered by dirty oil	Clean and wipe the cover with no oil surrounding the area

Figure 4.12 OPL for Cover Clamping Unit

Table 4.11 Steps in *fuguai* elimination (Cover Clamping Unit)

Cleaning Process	Description	Images
	1. Make sure the main switch is switched off before cleaning process to ensure safety.	 IJM Machine main switch
	2. Wear hand gloves to protect the hands during cleaning process.	 Hand gloves
	3. Prepare the cleaning item such as isopropyl alcohol, spray and scraps of cloth	   Cleaning item
	4. Use spray bottle and spray the isopropyl alcohol on the dirty area	 Spray area
	5. Wipe the dirty area after spray isopropyl alcohol	 Wipe area

Back cover below the mold in an injection molding machine serves as a protective housing, enclosing components like the clamping unit and ensuring the safe and efficient operation of the machinery. Dirt happen on the figure 4.13 because of the cover is very near with water heater. Cover will dirt when the water tube leaking and fall to the cover.

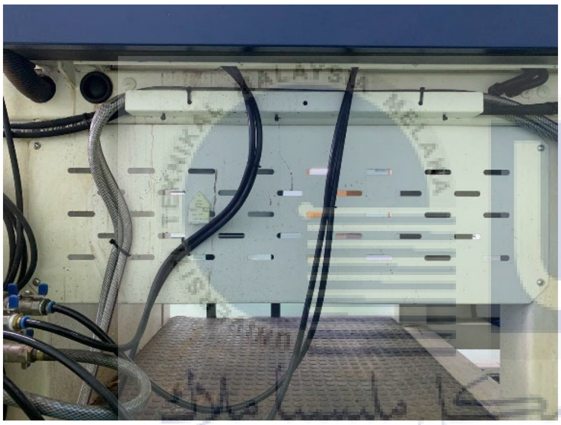
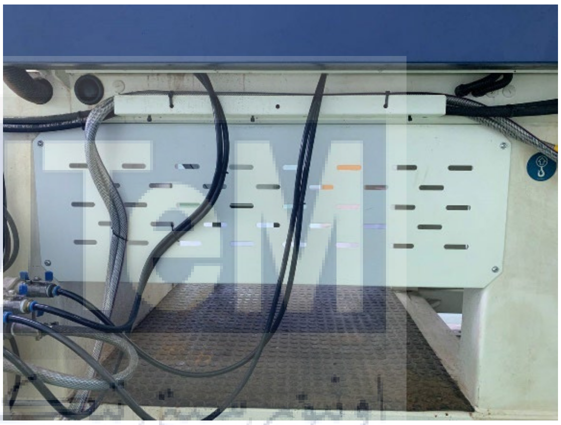
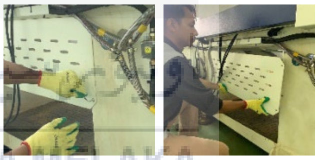
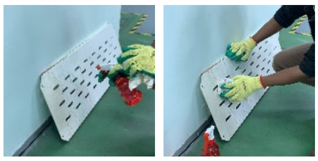
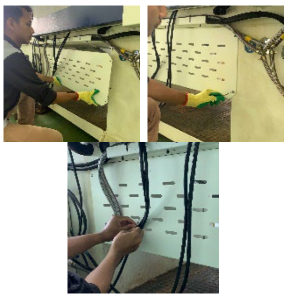
***Fuguai* : Back Cover Below Mould**	
Classification : Physical	
Before	After
	
The cover full off dirty and must be cleaned properly	Open and clean each part of the cover and reassemble it correctly

Figure 4.13 OPL for Back Cover Below Mould

Table 4.12 Steps in *fuguai* elimination (Back Cover Below Mould)

Cleaning Process	Description	Images
Start → Switch off main power → Wear hand glove → Prepare cleaning tool → Cut cable tight → Unscrew and bring out the cover → Clean the cover → Put cover back and install the screw → Put the cable tight → End	1. Make sure the main switch is switched off before cleaning process to ensure safety.	 IJM machine main switch
	2. Wear hand gloves to protect the hands during cleaning process.	 Hand gloves
	3. Prepare tool and cleaning items for cleaning the cover	 Cleaning tool
	4. Cute the cable tight that link the cover to water tube	 Cut cable tight
	5. unscrew all the screw area and pull out the cover and put on the wide area	 Open screw and pull out the cover
	6. clean the cover with isopropyl, wipe and repeat again on the dirty area	 Spray and swipe
	7. Put the cover on the location, reinstall all of the screw and put a new cable tight back on the correct place.	 Put cover, tighten screw and cable tight

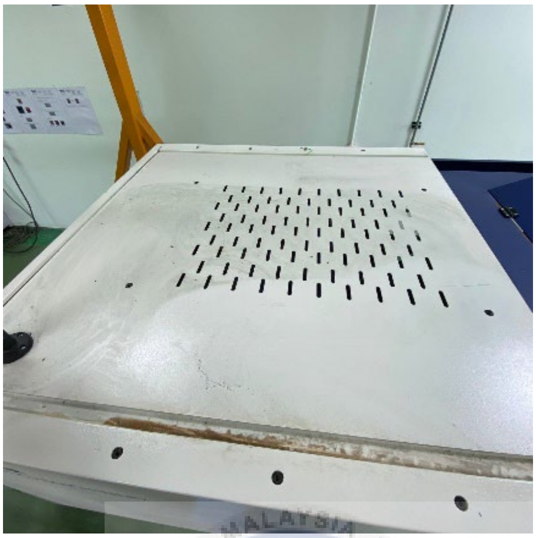
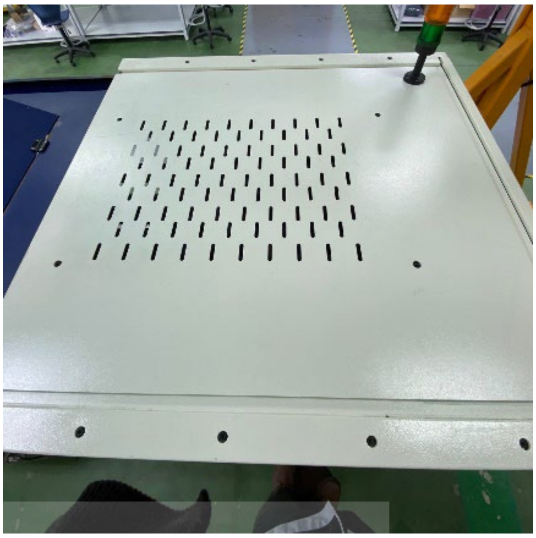
***Fuguai* : Top Clamping Unit**	
Classification : Physical	
Before	After
	
Cover top machine are cover by dust	Wipe it several times to remove thick dust

Figure 4.14 OPL for Top Clamping Unit

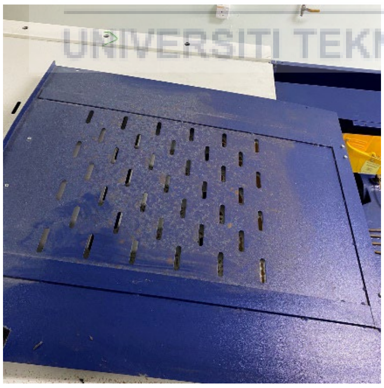
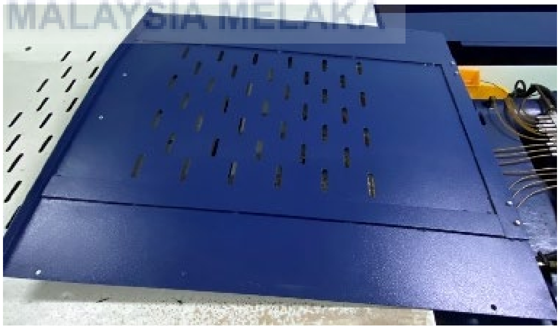
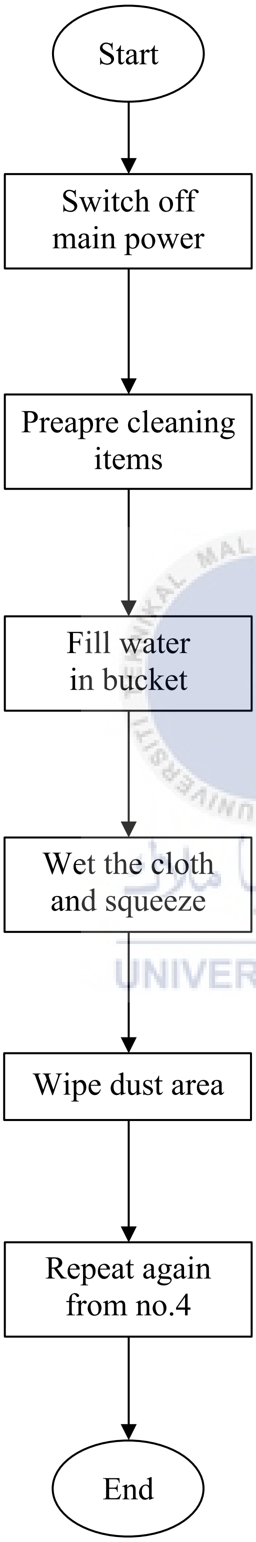
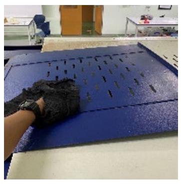
***Fuguai* : Cover Top Mould**	
Classification : Physical	
Before	After
	
Cover top machine are cover by dust	Wipe it several times to remove thick dust

Figure 4.15 OPL for Cover Top Mould

Table 4.13 Steps in *fuguai* elimination (Cover Top Mould)

<table>
<tr><th>Cleaning Process</th><th>Description</th><th>Images</th></tr>
<tr><td rowspan="7">
</td><td>1. Make sure the main switch is switched off before cleaning process to ensure safety.</td><td>
IJM machine main switch</td></tr>
<tr><td>2. Prepare cleaning item</td><td>
Cleaning item</td></tr>
<tr><td>3. Fill the water inside the bucket as much to clean the dirt area</td><td>
Fill water</td></tr>
<tr><td>4. Wet the cloth and squeeze it until dry</td><td>
Wet the cloth</td></tr>
<tr><td>5. Wipe the dust area slowly in one direction only</td><td>
Wipe area</td></tr>
<tr><td>6. Repeat again process no.4 to clean the cloth</td><td>
Wet the cloth</td></tr>
<tr><td>7. Wipe the cover until it clear from dust.</td><td>
Wipe again</td></tr>
</table>

Missing screw as in figure 4.16 below is a fuguai that is classified as safety because the loss of this screw occurs on the part of the barrier. There are 2 screws missing and need to be replaced with new ones. Replacement should also be in accordance with other screw specifications, especially in terms of size and also the material of the screw.

Fuguai **: Missing Screw**	
Classification : Safety	
Before	After
	
Screw on machine is missing	Find and put it back on the right place with strictly

Figure 4.16 OPL for Missing Screw

Table 4.14 Steps in *fuguai* elimination (Missing Screw)

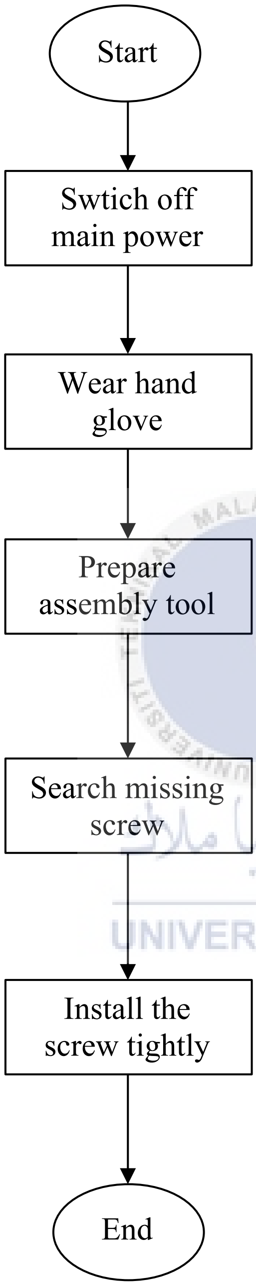
<table>
<tr><th>Cleaning Process</th><th>Description</th><th>Images</th></tr>
<tr><td rowspan="5">
</td><td>1. Make sure the main switch is switched off before cleaning process to ensure safety.</td><td>
IJM machine main switch</td></tr>
<tr><td>2. Wear hand gloves to protect the hands during cleaning process.</td><td>
Hand gloves</td></tr>
<tr><td>3. Prepare tool for assembly</td><td>
Assembly tool</td></tr>
<tr><td>4. Find screw with correct size for the hole threads</td><td>
Screw</td></tr>
<tr><td>5. Install the screw tightly using correct size of allenkey</td><td>
Install screw</td></tr>
</table>

Figure 4.17 below shows fuguai rubber carpet which is classified as physical fuguai. This dirt on the rubber carpet is due to the change of mold and also the spillage of the water line that leaked and got on the machine grease. A lot of dirt as a result of not being cleaned after the dirt happened.

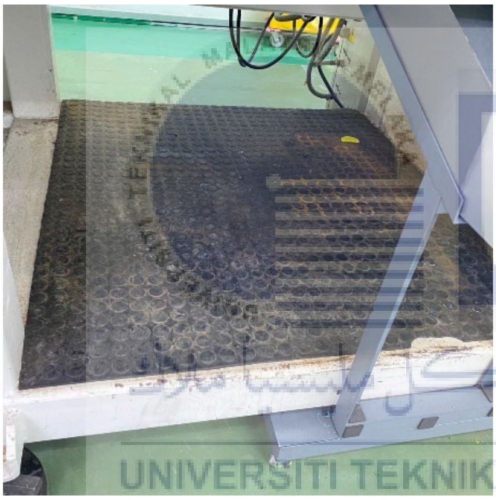
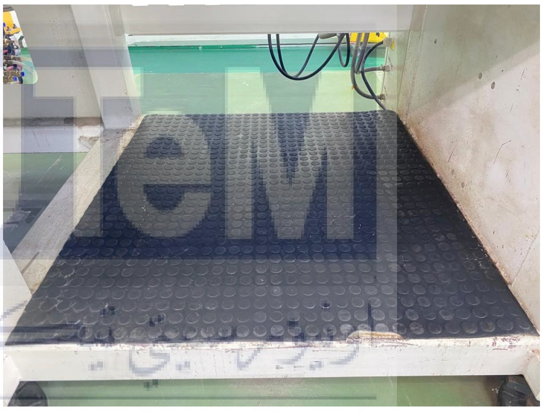
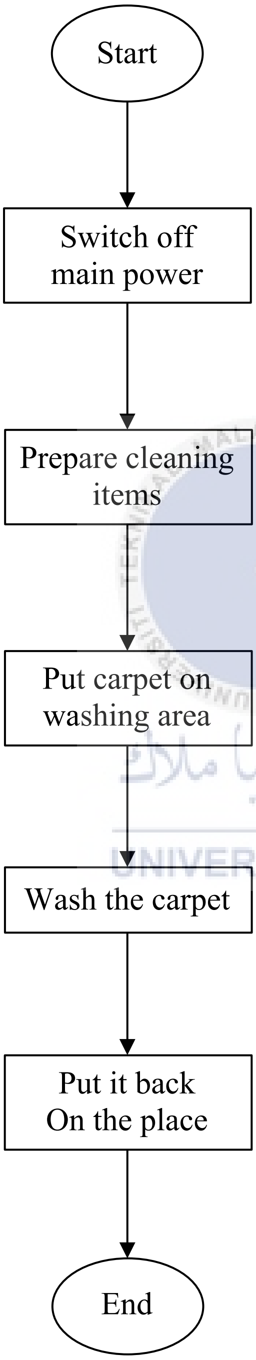
***Fuguai* : Rubber Carpet**	
Classification : Physical	
Before	After
	
Rubber studded mat carpet dirty	Brush several times to remove the dirt and clean

Figure 4.17 OPL for Rubber Carpet

Table 4.15 Steps in *fuguai* for elimination (Rubber Carpet)

Cleaning Process	Description	Images
	1. Make sure the main switch is switched off before cleaning process to ensure safety.	 IJM machine main switch
	2. Prepare cleaning tool which is brush and soap	 Cleaning items
	3. Pull out the carpet and put it on the washing area	 Pull out carpet
	4. Run the water first to make the carpet wet	 Run the water
	5. Put soap and brush the carpet on every area, repeat it until clean	 Put soap and brush
	6. Run the water back to clean the soap	 Run the water
	7. Put back the carpet on the right place	 Return the carpet

4.5 Summary

Autonomous maintenance serves as a valuable maintenance augmentation during the early stages of process optimization. While the laboratory setting may not demand the extensive data collection seen in industrial settings, implementing autonomous maintenance has significantly reduced fuguai on Injection Molding (IJM) machines. The improvement is evident, with cleaner and defect-free equipment, contributing to the overarching goal of minimizing malfunctions, failures, waste, and accidents.

One Point Lesson (OPL) stands out as an effective countermeasure for identified fuguai. This tool fosters transparency and knowledge transfer, ensuring that both new and seasoned operators can achieve consistent results. OPL establishes standard guidelines for handling fuguai, creating a shared understanding among all users, facilitating efficient responses to anomalies.

Beyond measurable outcomes like reduced fuguai, autonomous maintenance has intangible benefits. Operators gain a deeper understanding of machine maintenance, enhancing their technical capabilities and autonomy. Improved communication between operators and maintenance technicians fosters a collaborative approach to problem-solving. Furthermore, involving shop floor workers in maintenance tasks leverages their proximity to machinery, enabling swift breakdown resolution. Overall, the implementation of autonomous maintenance not only improves machine performance but also cultivates a culture of shared responsibility and continuous improvement among operators and maintenance personnel.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the implementation of autonomous maintenance has yielded remarkable improvements in addressing *fuguai* on Injection Molding (IJM) machines, marking a transformative journey towards enhanced operational efficiency and machine reliability. While the reduction in *fuguai* numbers may not match the extensive figures observed in high-workload industrial settings, the significance of the positive impact is unmistakable. The tangible outcomes are reflected in the visibly improved condition of the IJM machines, characterized by heightened cleanliness and a notable decrease in defects.

A key component of this success lies in the strategic application of One Point Lesson (OPL) as a countermeasure for identified *fuguai*. OPL serves as a catalyst for transparency and knowledge sharing among operators, facilitating a consistent attainment of optimal results across varying experience levels. The establishment of standardized guidelines through OPL fosters a cohesive and uniform approach to handling *fuguai*, creating a shared understanding among all users involved in the machine operations.

In addition to quantifiable *fuguai* reductions, autonomous maintenance has bestowed operators with a deeper understanding of machine maintenance, elevating technical capabilities and autonomy. Improved collaborative dynamics between operators and maintenance technicians have enhanced communication and problem-solving. The expanded responsibilities assigned to operators in equipment maintenance underscore the comprehensive success of autonomous maintenance.

In essence, the journey towards minimizing malfunctions, failures, waste, and accidents has seen commendable progress through the adoption of autonomous maintenance practices. The study conclusively affirms the effectiveness of this approach in not only optimizing machine functionality but also in nurturing a culture of continuous improvement and shared responsibility among the personnel involved in the operation and maintenance of the equipment.

As the *fuguai* reduction journey continues, it is essential to acknowledge the ongoing evolution in operator roles and the depth of understanding regarding machine maintenance. The success of autonomous maintenance is not confined to numerical reductions; it extends to the empowerment of operators, the establishment of robust communication channels, and the cultivation of a proactive mindset towards equipment care. This comprehensive approach ensures sustained progress and resilience against potential future challenges, reinforcing the significance of autonomous maintenance as a pivotal strategy in modern manufacturing practices.

5.2 Recommendations

In the student lab, where autonomous maintenance is crucial for optimal equipment functionality, it is essential to address identified issues hindering the efficiency of maintenance practices. By proactively tackling challenges hindering autonomous maintenance, the lab can ensure uninterrupted operation and longevity of equipment. This focus on issue resolution not only enhances immediate efficiency but also fosters a culture of responsibility among students. It transforms the student lab into a dynamic learning environment, equipping students with practical skills that extend beyond the educational setting, preparing them for real-world applications in diverse industries.

In the research that has been done, there are several issues that have been identified among them which is lack of a comprehensive inventory poses a significant challenge, as the absence of detailed records on cleaning tools and resources hampers the effectiveness of routine maintenance tasks. Additionally, insufficient training is evident, with students lacking proficiency in machine maintenance and One Point Lessons (OPL), underscoring a crucial need for hands-on skill development. Furthermore, the absence of a designated maintenance team contributes to limited accountability, leading to challenges in ownership and responsibility for routine checks and cleaning activities.

The presence of an issue also requires a solution and that should be done to prevent the issue. The solution is To address the inventory issue, it is imperative to create a comprehensive and detailed list of cleaning tools and resources needed for routine maintenance tasks. This approach ensures completeness and readiness, allowing for a more systematic and efficient maintenance process. Simultaneously, integrating practical training sessions into the curriculum is recommended, providing students with valuable hands-on experience in machine maintenance techniques and the execution of One Point Lessons (OPL). Moreover, establishing a dedicated student maintenance team with assigned responsibilities for routine checks and cleaning tasks is crucial. This initiative fosters a sense of ownership and accountability, addressing the identified challenges and contributing to a more proactive and effective maintenance culture within the student lab.

Applying autonomous maintenance in the industry. Implementing autonomous maintenance in the industry is highly recommended to optimize machine performance and minimize downtime. This proactive approach empowers operators to take ownership of routine maintenance tasks, fostering a culture of responsibility and accountability. By adopting autonomous maintenance, industries can enhance equipment reliability, reduce the likelihood of unexpected breakdowns, and ultimately improve overall operational efficiency. This also can improve the steps of autonomous maintenance from 5 steps that used on student lab to 7 steps and use it on industry which is process quality assurance and continuous improvement. Additionally, recommend integrating other maintenance strategies such as preventive maintenance, involving regular systematic checks, and predictive maintenance, utilizing data to predict and prevent equipment failures. This combined approach ensures a proactive, holistic, and effective maintenance strategy for optimizing machinery performance and minimizing downtime in industrial settings.

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