Faculty of Manufacturing Engineering

AUTOMATED VISION SYSTEM TO IMPROVE INSPECTION LEAD TIME FOR MOLDED COMPONENTS BASED ON NEURAL NETWORK

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AUTOMATED VISION SYSTEM TO IMPROVE INSPECTION LEAD TIME FOR MOLDED COMPONENTS BASED ON NEURAL NETWORK

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in fulfillment of the requirements for the degree of Master of Science
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2023

DECLARATION

I declare that this thesis entitled "AUTOMATED VISION SYSTEM TO IMPROVE INSPECTION LEAD TIME FOR MOLDED COMPONENTS BASED ON NEURAL NETWORK" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Master of Manufacturing Engineering in Manufacturing System Engineering

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DEDICATION

To my beloved mother and father

ABSTRACT

This research studies on the improvement on the traditional visual inspection method where in this thesis the manual visual inspection system will be improved to an automated visual inspection system with the aid of neural-network.This is to avoid molding defects to escape to customers and reduce the production lead time.This is because the manual visual inspection is prone to human errors.Therefore, there is a need of intellingent visual inspection method which reduces the reject escapee and also improves on the lead time.The objective of this thesis is to detect the critical defects that could be inspected using automated visual inspection. Moreover, this developed system should be able to detect defect on the molded package. In addition to that, the performance of this developed system is evaluated based on the reduction on the lead time and the effectiveness of the defect detection.Thus, the neural network method is used for defect detection and also to automated the system which aids in improving the lead time.The developed system achieves the objectives by reducing escapee by eliminating outgoing quality assurance detection which means 0 customer complain on molding defects. This also proves that the developed system have 0 escape rate to customers.This system also reduces the lead time from 57 minuted to 32 minutes which means 43.86% reduction on lead time.Moreover, the cost saving for 5 years for the developed system is RM 157500.00.Therefore, as a conclusion the developed system achieves the objectives set by able to identify critical defects which it is able to detect the defects for molded package which improves the visual system effectiveness and also reduces the lead time.

ABSTRAK

Tesis ini mengkaji tentang penambahbaikan kaedah pemeriksaan visual tradisional di mana dalam tesis ini sistem pemeriksaan visual manual akan ditambah baik kepada sistem pemeriksaan visual automatik dengan bantuan Neural-Network. Ini adalah untuk mengelakkan kecacatan acuan untuk terlepas kepada pelanggan dan mengurangkan masa pengeluaran.Ini kerana pemeriksaan visual manual terdedah kepada kesilapan manusia.Oleh itu, terdapat keperluan kaedah pemeriksaan visual pintar yang mengurangkan reject dan juga menambah baik pada masa pengeluaran.Objektif tesis ini adalah untuk mengesan kecacatan kritikal yang boleh diperiksa menggunakan pemeriksaan visual automatik. Selain itu, sistem yang dibangunkan ini seharusnya dapat mengesan kecacatan pada permukaan komponen . Di samping itu, prestasi sistem yang dibangunkan ini dinilai berdasarkan pengurangan masa pemgeluaran dan keberkesanan pengesanan kecacatan. Oleh itu, kaedah rangkaian saraf digunakan untuk pengesanan kecacatan dan juga untuk mengautomasikan sistem yang membantu dalam penambahbaikan. masa pengeluaran.Sistem yang dibangunkan mencapai objektif dengan mengurangkan pelarian dengan menghapuskan pengesanan OQA yang bermaksud 0 pelanggan mengadu tentang kecacatan pda permukaan komponen. Ini juga membuktikan bahawa sistem yang dibangunkan mempunyai 0 kadar terlepas kepada pelanggan. Sistem ini juga mengurangkan masa pengeluaran daripada 57 minit kepada 32 minit yang bermaksud pengurangan 43.86% pada masa pendahuluan. Selain itu, penjimatan kos selama 5 tahun untuk sistem yang dibangunkan ialah RM 157500.00.Oleh itu, sebagai kesimpulan sistem yang dibangunkan mencapai objektif yang ditetapkan dengan dapat mengenal pasti kecacatan kritikal yang mana ia dapat mengesan kecacatan untuk pakej acuan yang meningkatkan keberkesanan sistem visual dan juga mengurangkan masa pengeluaran.

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TABLE OF CONTENTS

	PAGE
DECLARATION	
DEDICATION	
ABSTRACT	**i**
ABSTRAK	**ii**
ACKNOWLEDGEMENTS	**iii**
TABLE OF CONTENTS	**iv**
LIST OF TABLES	**vi**
LIST OF FIGURES	**vii**
LIST OF APPENDICES	**ix**
CHAPTER	
1.INTRODUCTION	**1**
1.1 Background	1
1.2 Problem Statement	3
1.3 Project Objectives	3
1.4 Project Scope	4
1.5 Significance of Project	5
2.LITERATURE REVIEW	**6**
2.1 Introduction	6
2.2 Molding processes and types of molding defects	7
2.2.1 Injection molding	8
2.2.2 Transfer Molding	9
2.2.3 Compression molding	10
2.2.4 Types of defects able to sort out using vision	11
2.2.5 Mold Voids	14
2.2.6 Mold Bleed	15
2.2.7 Incomplete Fill	16
2.3 Visual Inspection Method	17
2.3.1 Manual Visual Inspection	18
2.3.2 Human- machine interface method	19
2.3.3 Fully Automated Visual Inspection	20
2.4 Image Processing Method	21
2.4.1 Automated Optical Measurement	22
2.4.2 Neural-Network Visual Inspection Method	23
2.5 Summary	24
3.METHODOLOGY	**29**
3.1 Introduction	29
3.2 Automotive parts Process Flow	30
3.3 Master Project Management Flow Chart	34
3.4 Vision System and Image Processing	37
3.5 Type of hardware for vision system	40
3.6 Image processing based on neural network method	43
3.7 Neural Network Mathematical model	45
3.8 Software for vision system	48

4.RESULT AND DISCUSSSION **50**
4.1 Chapter Overview 50
4.2.1 Assembly of the vision system 50
4.2.2 Assembly of the hardware 52
4.2.3 Programming sequence 54
4.3 Image Detection Adjustment 55
4.4 Analyzing Defect Detectability 58
4.5 Duration for the Operating Process 60
4.6 Time Consumption 62
4.7 Cost Saving 64
4.8 System Performance 67

5.CONCLUSION **68**
5.1 Conclusion 68
5.2 Recommendation for Future Work 70

APPENDIX A **71**

REFERENCES **72**

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Defects that can be detected by vision system	11
2.2	Defects unable to be detected by vision system	13
2.3	Mold Void defect versus molding type	24
2.4	Mold bleed defect versus molding type	25
2.5	Incomplete fill defect versus molding type	26
2.6	Image processing method versus criteria set	27
3.1	Vision system and image processing comparison	37
3.2	Comparison between Video Module and Arduino	40
4.1	Vision height and units detection result	56
4.2	Defect trial run and results compilation	59
4.3	The change of PPS and RPM obtained with the stability of the motor	60
4.4	RPM and time taken to complete a lot (mins)	61
4.5	Time consumption comparison	62
4.6	5-year cost comparison	64
4.7	Units per hour comparison	65

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Object detection using neural network	4
2.1	Injection molding process	8
2.2	Transfer molding process	9
2.3	Compression molding process	10
2.4	Mold void	14
2.5	Mold bleed defect	15
2.6	Incomplete fill defect	16
2.7	Manual Visual Inspection method	18
2.8	Human-machine visual inspection method	19
2.9	Fully automated visual inspection system	20
2.10	Automated Optical Measurement method	22
2.11	Neural-network visual inspection method	23
3.1	Automotive parts process flow	30
3.2	EOL process machineries and parts	32
3.3	Outer mold (Detailed process map)	33
3.4	Master Project management flow chart	34
3.5	Validation of reject process	36
3.6	YSH vision system camera	38
3.7	Keyence vision system camera	39
3.8	Video Module (976-PCIE-GIE74)	41
3.9	Arduino microcontroller	42
3.10	Layers comprised in neural network method	43
3.11	The Neural network image analysis system	44

3.12	Neural Network functional model	45
3.13	Interval activity of the neuron	46
3.14	Piecewise Linear function	46
3.15	Sigmoid Function	46
3.16	Artificial Neural Network function	47
3.17	Flow chart of the coding sequence	48
4.1	Assembly of the vision system	50
4.2	Vision system assembly	51
4.3	Vision system working mechanism	52
4.4	Hardware setup	53
4.5	Programming sequence Initialization	54
4.6	Image processing	54
4.7	Initial image detection	55
4.8	Vision system adjustment	57
4.9	Image detection after fine tuning on the focus	57
4.10	Mold void detection	58
4.11	Mold bleed detection	58
4.12	Incomplete fill detection	59
4.13	Comparison between conventional and automated vision system	63
4.14	Cost comparison between conventional and automated vision system	64
4.15	UPH comparison between conventional and automated visual inspection system	66
4.16	OQA detection trend (Monthly)	67

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	List of formulas and calculations	71

CHAPTER 1

INTRODUCTION

1.1 Background

In this globalization era, most parts are manufactured in large scales especially in automotive industry. During the production of the automotive parts, multiples defects may arise. These defects may appear on the inside or the surface of the parts. Some defects are visible, and some are not visible with naked eyes (Kmec et al., 2022). As we know, the automotive parts play a vital role in an automobile thus, the quality of the parts are the top priority. There are certain standards are to be complied in order to achieve the automotive standard such as ISO 9001 and IATF 16949 (Vykydal et al., 2022) .This standard demand a quality production line and better-quality finished parts. Moreover, in the current automotive industry, the customers demand for an automated system. This is because the industry is revolving towards Industrial Revolution 4.0 (Khan et al., 2022). The industry is currently focusing on automation. The knowledge regarding automation is being widely spread in all industry especially in semiconductor field (Kim et al., 2022).The spread in automation are then being adapted into various semiconductor processes. This will ensure that the parts produced are following all the quality standards set (Boeschoten et al., 2022). This also will gain the trust that customers have in the manufacturer as the parts supplied are as per the quality standards set (Ying et al., 2022)

To maintain the quality of the parts, each part will undergo Visual inspection. This inspection is to remove the defected parts from shipping to the customer. This will act as a gate to prevent escapee (Rožanec et al., 2022). This visual inspection process could not be skipped, especially in after molding process as molding process do produce some defects (Simaafrookhteh et al., 2020). Thus, this visual inspection process plays a vital role after molding process. This process is a tedious process as this requires more manpower and time-consuming process. The manual visual inspection process also

creates a risk of escapee of the defect products to the customer. Thus, this process can also be upgraded by automation whereby using vision system to detect the rejects. This is because humans have some limitations and by using machine, we can guarantee the quality of the inspection (Allaoua et al., 2023).

As automation is a part of industry 4.0 where it focusses on 100% machine and inline system which prevents from human interface. Therefore, automating visual inspection process brings more advantage especially to the semiconductor field and automotive production line. This vision inspection system can be integrated with neural network which is commonly known as artificial intelligence. This will enable a stable detection rate as per human intelligence. This neural network method is also adaptive as per the changes it incurred and also beneficial to the vision system in order to detect the defect modes (Muksin et al., 2023a).

Furthermore, as the automation have benefits there are also some items to be considered to upgrade the manual system to automation. Firstly, in terms of costs every improvement requires initial investment. Visual inspection method can cost from few thousands USD and up to millions. This is because the vision systems have some deep learning features which it could mimic as the humans without error. Thus, causing it to have a higher initial investment (Deepa et al., 2023). Second item to be considered is the time taken to train the vison system. This is because the method the codes are written varies according to the experts where some uses their self-coding algorithms and where the functions are created based on their customer requirements. Moreover, some have pre-trained models where requires less time to teach the vision system (Shao et al., 2022). Thus, these items are to be considered as well in this project.

Finally, in this project we will study on the automated vision inspection system for automotive parts components based on neural network. This project will show the usage of Neural Network which also means Artificial Intelligence (AI) with the vison system to detect defects.

1.2 Problem Statement

i. The current visual inspection system proposed is not suitable for molded components.
ii. The current visual inspection method is done by manual inspection process.
iii. The manual inspection system consumes higher lead time and increases the production cost.

1.3 Project Objectives

The main goal of this project is to automate the visual inspection process by using vision system. Therefore, the objectives are as follow:

i. To identify critical defects that could be inspected using automated visual inspection.
ii. To develop intelligent defect detection system for molded automotive components.
iii. To evaluate the performance of the developed system in terms of effectiveness of the detection and improve lead time for visual inspection process.

1.4 Project Scope

i. To study on the molding parts defects detection using Vision system.
ii. To study the implementation of neural network method to study on the molding defect with a higher degree of accuracy and precision.
iii. To create an early detection of molding defects or pre alert before producing defects.
iv. To ensure molding quality is always met and cost-efficient visual inspection.

The project scope covers of upgrading the current visual inspection from manual to using vision system. Moreover, the scope also covers the implementation of Neural Network into the vision system for a better accuracy and precise result. Other than that, this visual system also acts as an early detection before manufacturing massive detective parts. Finally, the project scope also covers on the quality aspect where to ensure that the molding quality are always met without compromising from the management aspect which is cost efficient.

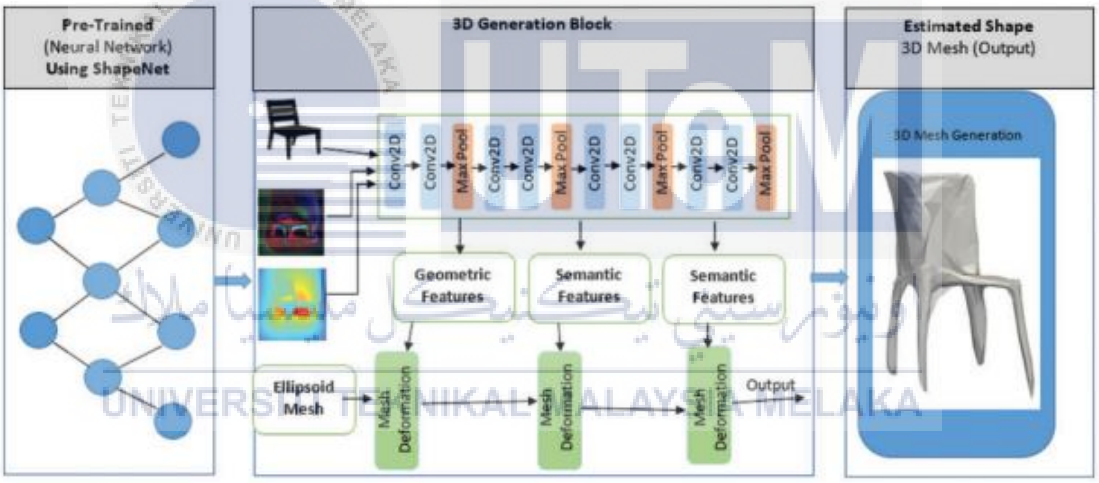

Figure 1.1: Object detection using neural network (Allaoua et al., 2023)

Figure 1.1 shows the object detection using the neural network method. This shows that the similar method is applicable for molding defect detection using a pre trained neural network.

1.5 Significance of Project

As we know, currently Malaysia is focusing on automation especially in the semiconductor industry. This is because the industry is moving towards automation and moving towards the well-developed country. Moreover, the industries are currently focusing on IR 4.0 where automation plays a vital role (Cheah et al., 2022).

As the country and industry focusses on automation and IR 4.0, the customer's demand on the quality of parts delivered increases. This creates the need for engineers to improve the production line by developing automated inspection systems to ensure the parts produced are high in quality. This obviously brings a lot of benefits to the industry as it keeps us updated towards the technology and systems.

The significance of this study is to replace the current visual inspection system (manual visual inspection) by using automated vision system integrated with Neural Network to detect the defects produced in molding process. This is because most semiconductor parts undergo molding process and thus focusing on this process will be a key and can be looked across to other processes. This evolution in technology is important in semiconductor industry especially in automotive production line as a steppingstone to a fully automated production and IR 4.0.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Visual inspection is a very crucial process in molding process. This process is to be done after molding process to check the molded parts quality. This process should not be skipped as it acts as a gate to the parts to ensure no escapee of reject parts to the customer's side. In automotive parts, the quality acts as the number one priority as the requirement is set as such due to the usage of the parts are on some crucial system of an automobile (Iftikhar et al., 2022). Since process is crucial and could not be skipped, the need of automation in this process is important to bring improvement and gain trust from customer. This is because humans may produce error and there are subjected to limitations while machine do not. Machines works as per programmed to do so (Li et al., 2023).

Thus, a literature study is done to understand the topic further and examines the objectives of this study. This study will show the advantages and challenges in implementing automated vision inspection system for automotive components based on Neural Network. This review also will study on the type of molding process, crucial molding defects, visual inspection method and image processing method to enable precise and accurate detection of molding defects.

2.2 Molding Processes and Types of Molding Defects

As discussed, this project is mainly on the molding defect detection method. This process is chosen because molding is an essential process in producing automotive parts. Molding process shapes the package shape as per the customer's requirements. Moreover, molding acts as an encapsulation which protects the internal components of the part. Molding process's purpose varies depending on its field and usage where some acts as an encapsulation, some acts as a decoration and some act as a form fit function (Edward et al., 2022).

Moreover, there are many types of molding process which suits for the preference of the manufacturer. There are mainly four types of molding process such as injection molding, transfer molding, and compression molding. The type of molding varies as per stated on the function and the field it is used (Philippa et al., 2018) .

Every process has its own advantages and disadvantages and so with every molding processes. Molding processes do generate defect which is known as molding defects. These defects can be categorized into crucial defects and non- crucial defects. Crucial defect are the defects which will lead to the product field failures. These are important to be resolved or to be eliminated before shipping the lots to customers as these are the limitations of the process (Tan et al., 2018).

There are many molding defects in general that is produced by the process. However, there are certain important defects that play a vital role in affecting the product's performances. Thus, these defects are eliminated by performing maintenance on the machines (Agrawal at al., 2023) and so on but some defects can only be reduced but not eliminated.

The reject that could not be eliminated are mold voids, mold bleed and incomplete mold. These defects are mainly due to the parameters set (Didilis et al., 2022) and the material itself. Most molding processes could not avoid from these defects, and we will learn more on the defects on the upcoming sub chapters. However, it could not be used as an excuse to allow theses defective parts to be shipped to the customers. Thus, a screening is required to remove these defects.

2.2.1 Injection molding

Injection molding is a process of encapsulation or providing shape for some parts of the automobile. This process is done by injecting molten compound into the cavity to provide the outline of the parts (Praveena et al., 2023). The process begins by heating the compound and injecting it to the mold cavity where it takes the shape of the cavity and cool down (Bellantone et al., 2022).

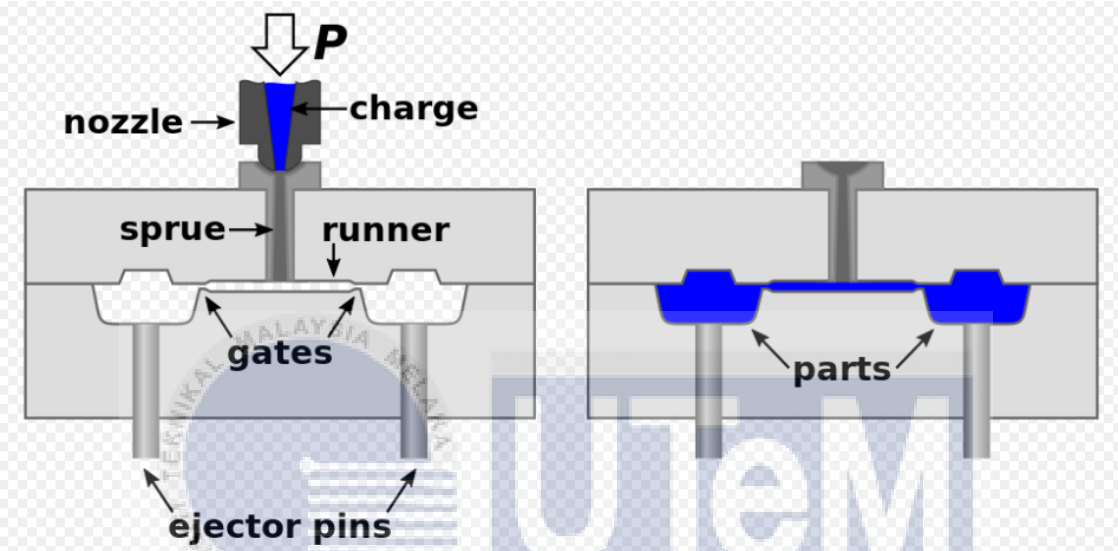

Figure 2.1: Injection molding process(Ariel et al., 2018)

Figure 2.1 shows the process of the process of injection molding where the pellets or molten compound is injected into the cavity and fill up the cavity where the final shape of the product. This method has many advantages where the parts is precise and lower lead time where the process may take up as fast as 10 seconds. However, there are disadvantages where there are high initial cost and, this may cause the non-consistent process where the injection speed is controlled manually (Saad et al., 2022) and it requires rework process to remove the sprue and runner which requires additional manpower and process (Weiland et al., 2021).

2.2.2 Transfer Molding

Transfer molding is used mostly in semiconductor process where it is a different process compared to a traditional molding process. Transfer molding is the combination of injection and compression molding process (Shrivastava et al., 2018). In transfer molding, the compound is heated which is also known as pre heat process in a chamber called pellet pot. The heated compound is then transferred using a plunger (Drobny et al., 2018). The plunger forces the heated compound (molten state) into the mold cavity. The molten compound is transferred and clamped at the same time to enable it to get the desired shape (Cantor et al., 2020)

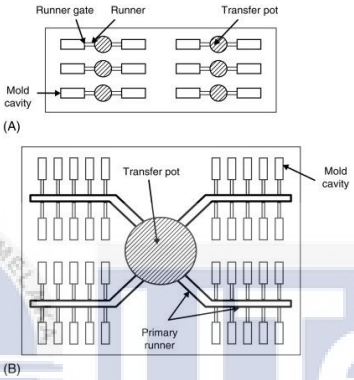

Figure 2.2: Transfer molding process (Fang et al., 2019)

Figure 2.2 shows the transfer molding process where in this figure we can see two types of transfer molding system where there is multiple transfer pot which is in part A where the compound is transferred individually in each row. This is a recommended process for semiconductor industry. In part B its shows that the compound is transferred from one pot into multiple rows and this system are used for low quantity frames and not recommended for matrix frames.

Transfer molding have more advantage compared to disadvantages where the transfer molding provides better product consistency. This is important in semiconductor industry as consistency is a key aspect in producing automotive parts. Moreover, transfer molding also provides a shorter curing time where it is around 45 seconds to 90 seconds, and this is relatively low. Transfer molding also produces less flashes where flashes removal process can be eliminated (Crawford et al., 2020). This process is all done automatically which is important to move towards zero defect process. However, there are also slight disadvantages which is high initial set up and it requires skill workers to understand the machine.

2.2.3 Compression Molding

Compression molding is a molding method in which the compound is preheated prior to mold the parts. In some other words compression molding is also known as conventional plate molding. This process begins by pre heat the mold compound and then the compound is transferred into the mold plate and the heat and pressure are in maintained state (Elshabini et al., 2017). The maintaining pressure and heat is a very vital process as this is crucial to hold the package shape. This is done manually using hydraulic press. This hydraulic cylinder plays an important role in getting the desired shape of the parts. These parts are usually compressed 5ºC – 10 ºC above the glass transition (Ghadi et al., 2017).

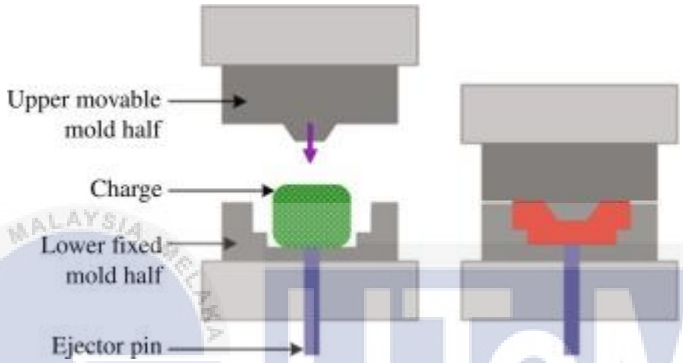

Figure 2.3: Compression molding process (Edebali, 2021)

Figure 2.3 shows that the compound (charge) is in the pot and the upper mold cavity forces it and takes the shape of the cavity and thus the shape of the part are taken. The compression molding is widely used even though it could produce products in larger scale, but the curing time may take up to 1 hour to 2 hours (Sharma et al., 2022).

There are some disadvantages in the compression molding method which is it is done manually where it requires manpower to unload the molded frames and it provides poor product consistency which is highly crucial in automotive parts caused by the molding process. However, these defects are not acceptable in customers' side especially automotive customers. Thus, quality need to be enhanced (Agrawal et al, 2023) and the customers trust are gained by not shipping out these defects to them. In this part the defects will be explained on the causes of the defects.