CYCLE TIME IMPROVEMENT OF COMBINED PUNCHING AND DRILLING MACHINE

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed .... (Rajeeha Binti Rohizam)

Date .... (24/7/2022)

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references.

Bibliography/references are appended.

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LIST OF ABBREVIATIONS

CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CNC	Computer Numerically Controlled
GFRP	Glass fibre reinforced polymer
TSP	Travelling Salesman Problem
USM	Universiti Sains Malaysia

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Appendix A Troubleshoot of The Machine

ABSTRAK

Masa kitaran ialah masa untuk menyelesaikan pembuatan unit produk. Dalam industri, masa kitaran rendah lebih disukai. Masa kitaran melibatkan masa persediaan dan masa operasi. Untuk mesin hibrid, di mana dua atau lebih proses digabungkan pada satu mesin menyebabkan pelanjutan jumlah masa kitaran kerana semua proses memiliki persediaan dan masa operasinya. Projek ini bertujuan untuk mengurangkan masa kitaran mesin hibrid. Ini boleh dilakukan dengan mengkaji keadaan semasa dan prestasi mesin. Berdasarkan kajian masa, beberapa penambahbaikan telah dibuat pada mesin untuk mengurangkan masa kitaran. Penambahbaikan yang telah dilakukan adalah dengan menambah rod baru pada lekapan berputar, menukar pemegang plat kepada meja boleh laras, menukar pembahagi dan membaiki acuan untuk menebuk dan menggerudi. Akibatnya, masa yang diperlukan untuk penyediaan telah dikurangkan sebanyak 19.2% dan masa kitaran sudah dianggap boleh diterima kerana ia adalah 42.04 saat yang berada dalam julat untuk masa kitaran yang digunakan dalam industri. Masih ada ruang untuk penambahbaikan dilakukan pada masa hadapan termasuk menambah sensor atau sistem penglihatan yang boleh mengesan lubang untuk menjajarkan pin. Ini boleh membantu mengurangkan masa untuk menjajarkan pin. Menggabungkan motor dalam lekapan berputar juga boleh membantu mengurangkan masa.

ABSTRACT

Cycle time is time to complete manufacturing a unit of a product. In industry, low cycle time is preferred. Cycle time involves setup time and operational time. For hybrid machines, where two or more processes combined on a single machine cause extension of the total cycle time as each processes own their setup and operational time. This project aims to reduce the cycle time of the hybrid machine. This can be done by studying the current conditions and performance of the machine. Based on the time study, a few bottlenecks were identified, and improvements had been made on the machine parts to reduce the cycle time. The improvement is by adding a new rod to the rotary fixture, changing the plate holder to an adjustable table, changing the divider and repairing the dies for both punching and drilling. As a result, time required for set up was cut down by 19.2% and the cycle time is already considered acceptable as it is 42.04 seconds to which is in the range for the cycle time used in the industry. There are still room for improvements to be done in the future including adding a sensor or vision system that can detect hole for the aligning the pin. This can help to reduce the time for aligning the pin. By incorporating a motor in the rotary fixture also can help to reduce the time.

CHAPTER 1

INTRODUCTION

1.1 Overview

Due to the global market, the demand for products is also increasing, which leads to reducing the cost of manufacturing, cycle time, setup time, and better quality. Cycle time is important as it will affect the cost of the product. Reduction of cycle time will benefit the company, as productivity also increases and profit (Suganthini Rekha et al., 2016). Punching and drilling computer numerically controlled (CNC) machine also known as the hybrid machine is commonly used in the sheet metal manufacturing process. It combines the punching and drilling process using computer programming to produce the desired design. The CNC punching and drilling are commonly implanted for mass production as it is fast and reliable (Petunin et al., 2019).

CNC machine is widely used due to decrease human errors, increase productivity and save time. As both processes are common in the sheet metal manufacturing process, it makes it easier to have the punching and drilling CNC machine. The combined machine of punching and drilling reduces the cost of two separate machines needed as punching and drilling is commonly used in the manufacturing process (Petunin et al., 2019). By reducing machine setup time, the efficiency of these machines increases, which increases company income (Kušar et al., 2010).

A hybrid machine is a machine that combines two processes. This research combines the punching and drilling process. This hybrid CNC machine is a modified machine from a CNC milling machine. It is modified into a machine that combines the two processes of punching and drilling. The obstacle for this machine is that there is no research about this machine or manual for it. The challenge of the hybrid machine is to integrate the two processes that have different components and software. There is no existing manual for the machine which makes it hard to learn.

1.2 Project background

This CNC hybrid machine is a combination of two processes that are punching and drilling that integrates using the CNC. The main function of this machine is to make a hole for the composite panel. It is causing the composite panel will usually have a lot of defects when making a hole independently using the method of punching or drilling. This machine can reduce the time as it will not need to use two different machines. As it is integrated with the CNC, it eases the use of the machine. Figure 1.1 is the machine used for this research.

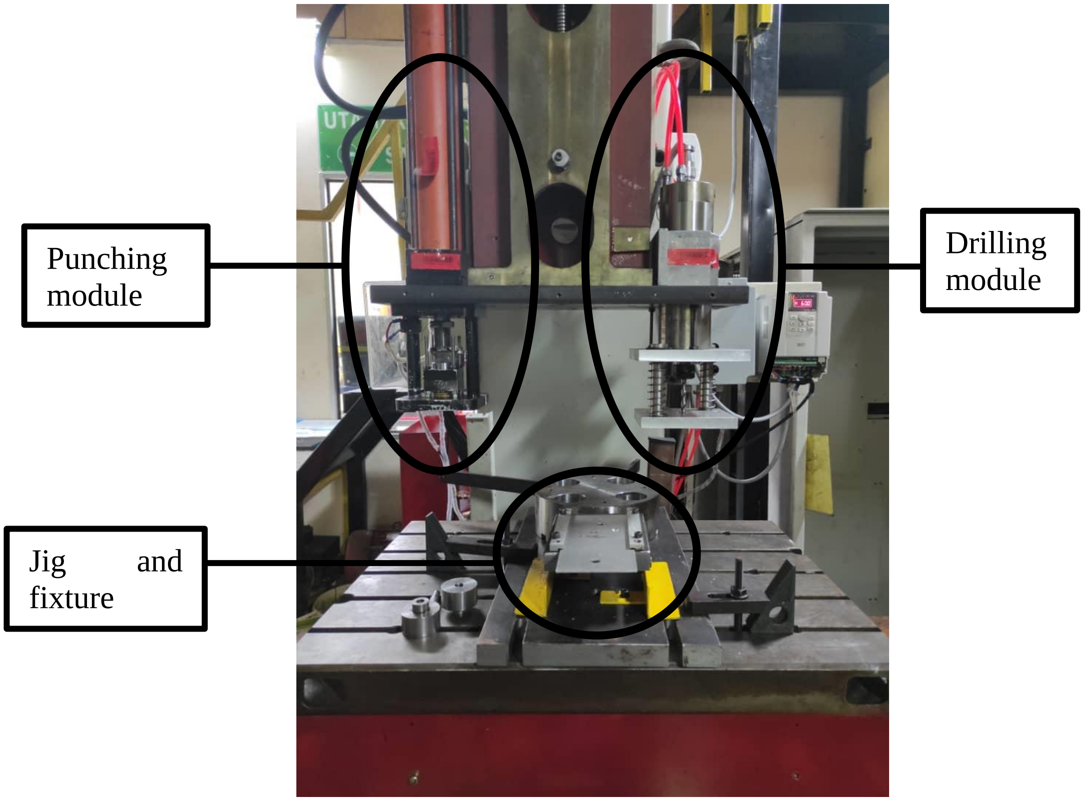


Figure 1.1: Hybrid machine for combined punching and drilling processes.

1.3 Problem Statement

Cycle time plays an important role in an industry as it will affect the price of the product. The more time required, will increase the price of the product and reduce efficiency. The current cycle time of hole-making operation using combined punching and drilling machine is 42.04 seconds. However, it is still high compared to the common hole-making process practising in the industry.

The objectives of this project are:

- To study the current CNC hybrid machine for the punching and drilling system and performance.
- To improve the cycle time, setup time and accuracy of hole making of the machine.

1.4 Scope of Project

For this project, optimization of the tool path for the punching and drilling CNC machine will be done experimentally by improving bottleneck and all done in the forging lab. The cycle time for the process of the machine will be focsed for this project. The hole-making process will be performed on easily find material like aluminium as a substitution for industry-grade composite panels, which is expensive and difficult to be obtained. An aluminium 5052 is used to replace the composite panel as this research is to record the cycle time, setup time and the accuracy of the hole-making.

1.5 Organization of the thesis

The content of this paper is categorised by the chapter. There are five chapters that consist of an introduction, literature review, methodology, result and discussion and conclusion. In the introduction, it will discuss the problem statement, objectives and a brief introduction to this research. A literature review is the comparison and is used as a guide from the existing research paper. For methodology part, it discusses the machine component and the response variable that will be recorded. The result and discussion are to show the result recorded and the modification that had been done. The conclusion is to conclude the finding of this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

It is known that composite materials feature exceptional mechanical qualities, which enables them to considerably enhance their use in building and makes it possible for them to play a larger role in the industry. Due to the significant reduction in weight and the resultant improvement in dynamic properties, sectors such as aeronautics, vehicle manufacturing, train travel, and maritime transportation stand to benefit the most from the usage of these materials (Durão et al., 2008). Modern metal alloys have already been replaced by fiber-reinforced composites made primarily of carbon in many structural components of high-end sports automobiles and commercial aircraft. As more automobiles become electrified, mass-produced vehicles will need to be lighter, which will increase the use of carbon fiber reinforced composites (Valorosi et al., 2020).

The extraordinary mechanical properties of fibre composites, in particular the rare combinations of low density with high strength and stiffness that can be achieved with these materials, have not only stimulated in-depth research into the mechanical properties of composites but also the development of highly advanced technology. In particular, the uncommon combinations of low density with high strength and stiffness that can be achieved with these materials include (Durão et al., 2008). Metal particles that are evenly distributed throughout a polymer make up a brand-new substance that has been created. Under compression, stress, or twisting, this composite turns into a conductor. It has a resistance range of one trillion to one and follows a smooth, reproducible curve. The substance is employed in a wide variety of switches and sensors, as a substitute for traditional components, as well as in cutting-edge applications.

When composite materials are machined, strange behaviours can be observed in the materials. The process that is utilised most frequently to produce holes is drilling. When drilling through a composite material, the entry and exit regions of the workpiece being drilled are the area most likely to have delamination defects. It may have something to do with the total amount of force that was applied when the drill was first begun. Drilling with laser beams, drilling with water jets, drilling with ultrasonic waves, and drilling with an electrical discharge are all examples of alternative machining techniques. Despite this, traditional drilling is still used often for a variety of practical applications (Tsao & Hocheng, 2003).

High purity aluminium is a highly malleable metal that also has strong resilience to fatigue. Many people consider aluminium a material that readily lends itself to being moulded into the plastic. Aluminium, on the other hand, has a low hardness, which contributes to its reputation as a soft metal. Additionally, its mechanical strength is significantly inferior to that of most industrial metals. Because of this, it is not recommended to make this metal using machining techniques that involve high-purity aluminium. Modifying the bad qualities to make aluminium parts through the machining process is essential. This can be performed through heat treatments, work hardening, alloying, or, in most cases, a combination of at least two of these processes. Heat treatments are the most common method (M.S. Carrilero & M. Marcos, 1996).

2.2 Hole Making Methods on Composite

There are various methods of hole-making on composites. In this chapter, only two of the most method used for hole making will be discussed. The methods for making a hole discussed in this research are punching and drilling methods.

2.2.1 Drilling

It is required to produce holes with a greater degree of precision to maintain the structural integrity of the fasteners without compromising the strength properties of the composite. The procedure is considered to be time-consuming because drilling instruments need to be replaced on a fairly regular basis (A. B. Abdullah et al., 2019). The influence of drilling process parameters on the machinability and machining of various composite materials was the subject of a significant number of research. According to the results of Sonkar's (2014) investigation on the best methods for optimising the drilling process in glass fibre reinforced polymer (GFRP) composites. Researchers concluded that TiAlN coated solid Carbide drill bits should be used for defect-free drilling based on the minimum of the thrust forces, torque, surface roughness, and damage factor based on the findings of the study (Sonkar et al., 2014).

2.2.2 Punching

The production of a hole in the material can also be accomplished via punching, which is another technique that makes use of shear force. The tool that is used for punching experiences less wear than the tool that is used for drilling, which is one of the contributing factors to the superior overall quality of the holes that are made by punching as opposed to drilling. Another factor that contributes to the superior overall quality of the holes that are made by punching as opposed to drilling is the fact that punching is more costeffective. Because the fibre is oriented in multiple directions, holes created by partial shearing will have poor edge quality. This will occur because the fibre is multi-directional. The diameter of the entry hole is not much impacted by die clearance, according to research done by Abdullah and colleagues (2019), and the double shear-type puncher yields the highest quality shearing.

2.3 Comparison between drilling and punching

Punching and drilling are both procedures that can be used to generate holes in composite materials. However, in the research that Abdullah and his colleagues are currently carrying out (2016). a comparison is being made between the two techniques. The identification of defects is what sets these two approaches apart from one another. During the process of drilling, a fuzzing defect is found, however during the process of punching, fraying and chipping defects occur. After giving it a lot of thought, it was concluded that the process of making holes by punching has the potential to become more widespread and take the role of drilling in some situations. Table 2.1 is the summary comparison between the drilling and punching methods of hole-making.

Table 2.1: Summary of comparison between drilling and punching

Drilling	Punching
Use the spindle speed to rotate the drill bit	Use shear force to punch the workpiece
More frequent tool wear	Less frequent tool wear
Defects of fuzzing can occur	Defects of fraying and chipping occur.

2.4 Accuracy in making a hole on composite panel

Even though composite materials are widely employed, a stress concentration is nevertheless generated along the hole-fastener boundary as a result of the load that is transferred via the fastener. This particular concentration of stress has the potential to hasten the system's overall breakdown at an earlier point. The quality of the hole is directly impacted by various input process factors, such as the cutting parameters, tool geometries, and materials. Tool wear has an impact, in addition to affecting the quality of the holes produced by the machining process, on the frequency with which tools need to be grinded and replaced. Because of this, the production cycle ends up being inefficient, which drives up the overall cost of manufacturing (M. S. Abdullah et al., 2020). The quality of work that goes into drilling holes is directly linked to the efficiency with which mechanical fastening methods are applied. As a direct result of this, improved methods of manufacturing quality holes are required to guarantee the structural integrity of the fasteners while yet maintaining the beneficial properties of the composite material (Zain et al., 2016).

Particularly, procedures for precision assembly depend heavily on the accuracy of dimensional measurements. Every component is given a standard set of tolerances and ranges when it is designed. Components are only accepted for assembly if they fall within these ranges; those that are outside the range are not acceptable. To determine whether or not the dimensions are accurate, a comparison is made between the upper and lower diameters, as well as the components out of roundness. The presence of high values for these parameters suggests that the dimensional accuracy is low. (Ibraheem et al., 2015).

During the assembly of composite laminates with other components, numerous cutting procedures are utilised extensively for the production of riveted and bolted joints. These junctions may also be welded. For both riveted and bolted joints, the components need to have exact holes drilled in them to guarantee high joint strength and precision. (Abrão et al., 2007; Teti, 2002).

2.5 Advantages of a combination of processes

In general, a combination of processes in performing a certain task will give advantages in terms of efficiency and quality, however, it may increase machine complexity and in most cases will increase the machine price (Canan Tokuz, 1992). It has been demonstrated that the combination of two methods of hole making, namely the punching method and the drilling method, results in a difference in the delamination factor that is significantly less significant (Norisam & Abdullah, 2019). To create a hole in a composite material, researchers are investigating yet another possibility that involves merging the drilling and punching processes. This procedure might be able to offer a solution for the defects that were found on the workpiece as a result of the limitations of the drilling and punching processes taken separately. It was proved that the hole has a similar quality and degree of surface roughness and that Ra is less than 3 micrometres (μm) thanks to the combination of the two processes. It is possible to conclude the conclusion that the utilisation of the combined approach has resulted in a significant enhancement of the hole quality produced by the punching technique (M. S. Abdullah et al., 2020).

2.6 Hybrid System

Typical hybrid machines consist of hardware for the processes, and software for programming the movement and execution of the processes (Canan Tokuz, 1992). The cost of materials and the number of tools used in the hybrid process are significantly reduced it is possible to say that there are many applications like this case the hybrid process has a big advantage compared to the conventional way, if all parts of the product are not necessary to be manufactured from the same high-valued material (Yamazaki, 2016).

2.6.1 Hardware

In a typical hybrid system, hardware is usually consisting of various processes that can be controlled in a modular way. A computer numerically controlled machine, also known as a CNC machine, is an example of the type of mechanical device that has seen widespread use and also incorporates a microcomputer. CNC machines are utilised for a variety of mechanical tasks including but not limited to cutting, engraving, and drilling. The use of computer technology allows specific items to be controlled, parsed, and carried out in response to commands sent by users. In the field of manufacturing, the utilisation of CNC machines has a significant impact on the rise in overall production (Ginting et al., 2017). The success of CNC machining is heavily reliant on the cutting parameters, which have been determined and evaluated by arduous effort, processes that take a significant amount of time, and a high level of necessary engineering from the calculation, simulation, or experimental operations. (Abas et al., 2020; Solarte-Pardo et al., 2019; Yu & Chen, 2020).

2.6.2 Software

The most important software required is programming and "G-code" is one of them. The file can be generated on a computer by utilising a programme that is either Computer-Aided Design or Computer-Aided Manufacturing (CAD or CAM). The G-code that is output by the CAM system is sent to the Machine Controller so that it can be interpreted and, as a result, tool motion may be controlled (Nguyen et al., 2020). In general, a G-code file for CNC machines can be created using one of three fundamental programming method types: the human programming method, the automatic method, or the macro or parametric programming approach. The manual programming method is the most common and has been around the longest. The first technique does manual programming with the use of fundamental G-code commands and cycles. Because it requires a numerical coordinate for every programming point in every G-code block, this method is difficult to employ for automated programming and hence presents a challenge. The automatic technique makes use of CAD and CAM software to generate G-code files based on toolpath methods that the users themselves have established (Nguyen et al., 2020). Integration of the two systems is one of the challenges in this research as the to integrate it with CNC machines.

2.7 Tool Path Strategy

Many parameters can be optimized to obtain obtainductivity such as tool path strategy. Travelling Salesman Problem (TSP) is one of the choices that are popular for tool path optimization more than 90% of researchers applied this method. This method assumes that the tool is the salesman and will visit n number of the city which is the stop the tool must follow and the salesman must return to the original place. (Onwubolu, 2004) There is more complexity to using the TSP method although it sounds as simple to optimize the problem. The complexity increases with the increasing number of holes. The solution of TPS lies in the possibility of the distance between cities combination. (Khodabakhshi & Hosseini, 2021)Most of the research mentions the TPS method in the optimization of tool path strategy and reducing the production time or cycle time.

2.8 Summary

Based on the literature reviews, the punching and drilling process is one of the ways to make a hole for composite material. It is a combination process using a CNC machine that will help to increase the accuracy of the punching and drilling process.

CHAPTER 3

METHODOLOGY

3.1 Overview

The flowchart in Figure 3.1 shows the methodology throughout the project.

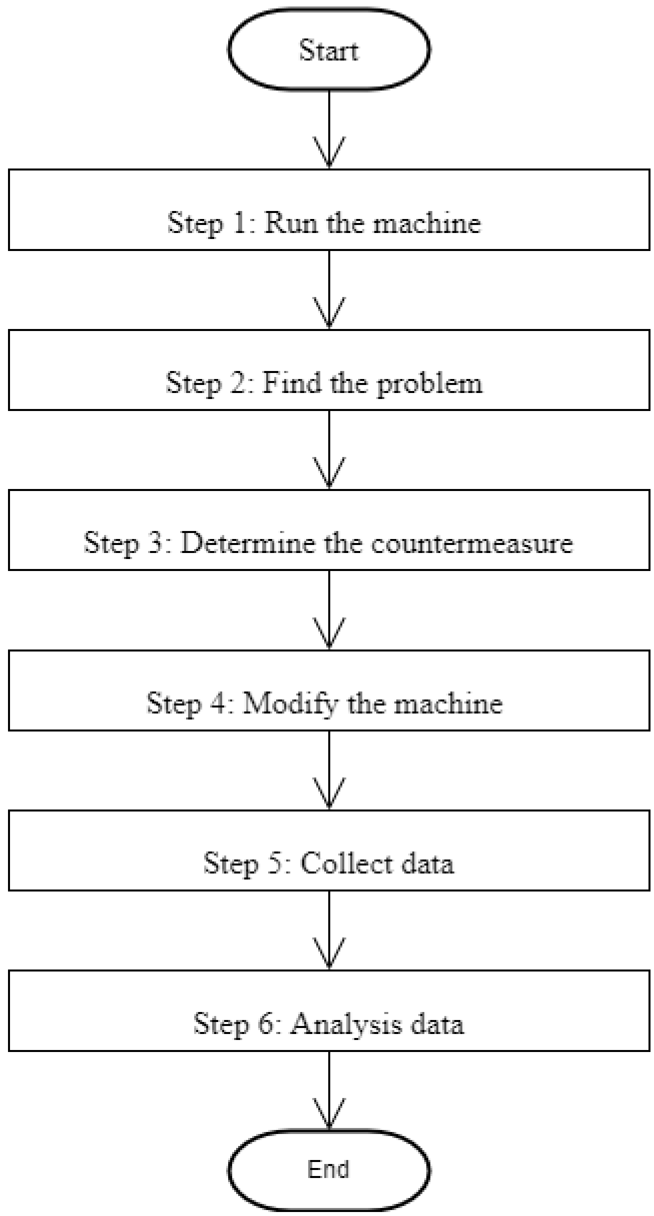
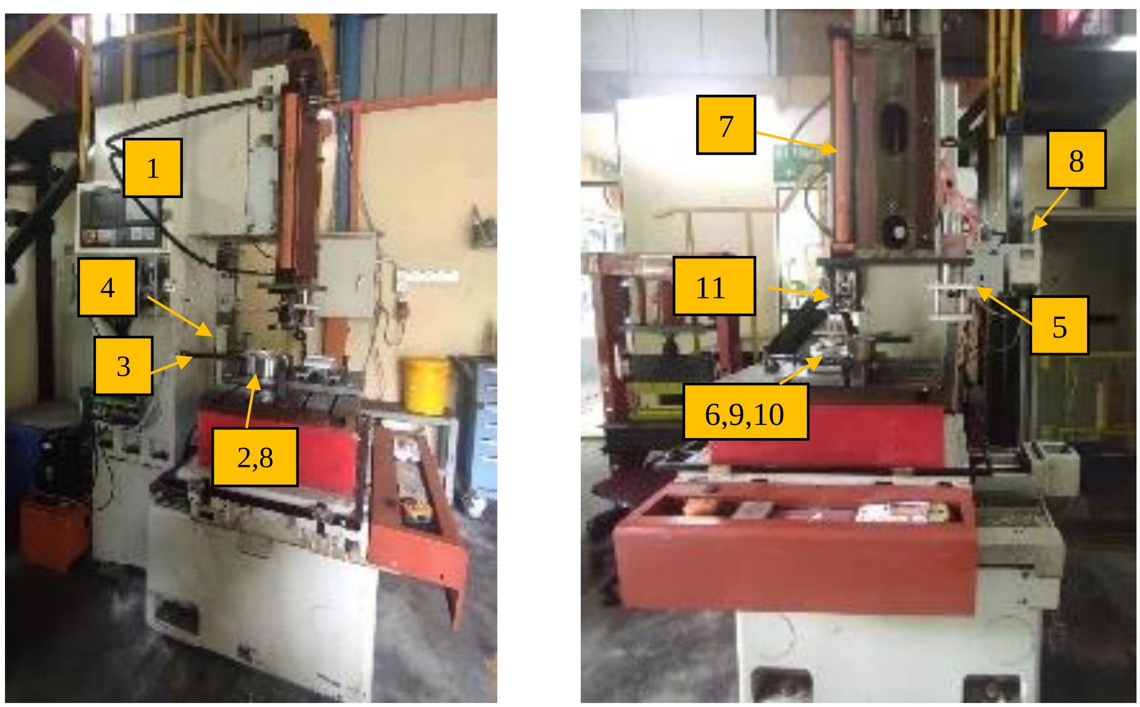


Figure 3.1: Flowchart of the methodology throughout the project

3.2 Understand The Machine

The machine is studied to know the capability and limitation of the machine and the opportunity to improve the process. Figure 3.2 is the side and front view of the machine. The machine is used for punching and drilling operations with the CNC integrated to help it operate using the coding inserted. The machine consists of different components. For the punching process, a hydraulic cylinder is used. A controller for the operation can be seen from the side view of the machine. The component for the machine is also shown in the detail below as in Table 3.1. In Figure 3.2 the components are labelled as in the number in Table 3.1.



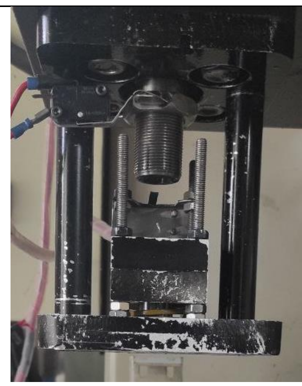
(a) (b)

Figure 3.2: CNC machine (a) side view (b) front view

Table 3.1: Components and their function

No.	Components	Component Figure	Function
1	Controller		To control the motor and drive components of the machine axes the programme inserted
2	Die		To allow the tools to go through it to punch and drill the plate
3	Rods at a rotary fixture		To rotate the rotary fixture by colliding it with the divider at the table
4	Divider at table		To rotate the rotary fixture by colliding it with the divider at the rotary fixture
5	Drilling module		To create a hole on the plate

6	The base of the plate holder			To hold the plate holder
7	Hydraulic cylinder			An actuator generates mechanical force for the punching operation by pressing it
8	Hydraulic power switch			To switch on the power for the hydraulic cylinder
9	Rotary fixture			To rotate and change the die set according to the operation

9	Plate		A plate in the dimension of 87 mm × 200 mm × 3 mm
10	Plate holder		To hold the plate tightly during the punching and drilling process
11	Puncher		To punch the plate

The operation of the CNC machine operation and the button on the controller is different as it is a modified machine. The button and the operation that is done are shown in Figure 3.3. The axes button is the same as the operation. The difference is in the operation of chuck and coolant that is used for the punching operation. The operation that can be done with the machine is to move the axes of the table into three axes that are X, Y and Z axis. It also can do it manually by step or automatically. The operations that can be done using the CNC machine are listed in Table 3.2

Figure 3.3: Controller for the CNC

Table 3.2: List of the operation that can be done using the CNC machine

Button	Operation
Chuck	Punch the hole
Coolant	End the punching process
SP-CW	Spin rotates clockwise
SP-STOP	Stop the spindle
SP-CCW	Spin rotates counterclockwise
Auto	Automated movement
Manual	Manual movement
MDI	Manual data input mode
Single	Step-by-step automatic control

3.3 Process Flow

3.3.1 CNC Controller

The flowchart shows the process flow of the punching and drilling process for the machine. It is shown in Figure 3.4. It starts by switching on the power supply until the machine starts running.

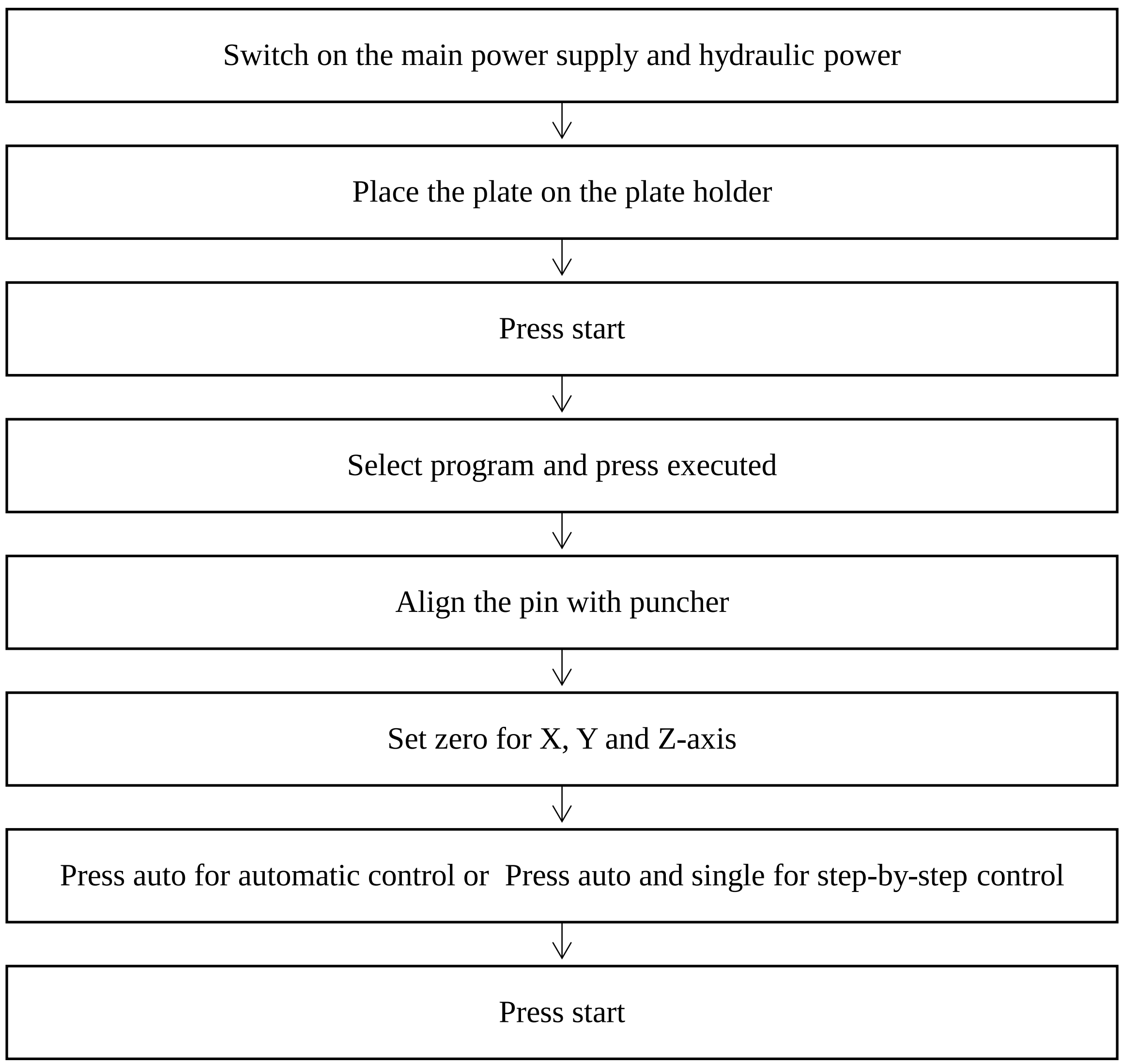


Figure 3.4: Flowchart of the process flow

There are two pins that can be inserted at the rotary fixture with the puncher and drilling module. To set the origin, the pin at the rotary fixture must be aligned with the puncher. This is an important step as it is used to ensure that it will punch and drill at the die set at the rotary fixture. The pin also needs to be set to be aligned at the drilling module, the value of the x-axis needs to be correct with the pin that is aligned. Figure 3.5 is the pin that is inserted in the rotary fixture and needs to be aligned with the puncher.

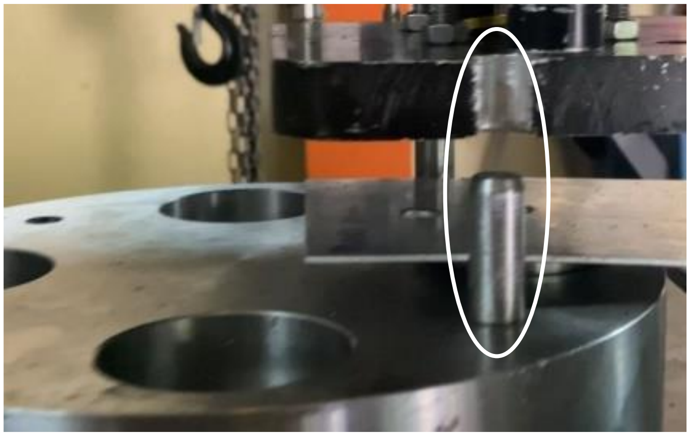


Figure 3.5: Pin inserted in the rotary that needs to be aligned with the puncher

3.3.2 Programming

Based on the flowchart in Figure 3.6, shows the step by step of programming. It starts at the origin which is zero at the X, Y and Z-axis. The origin is determined as the pin aligns with the puncher. The cycle ends with the table back to the original location that had been set.

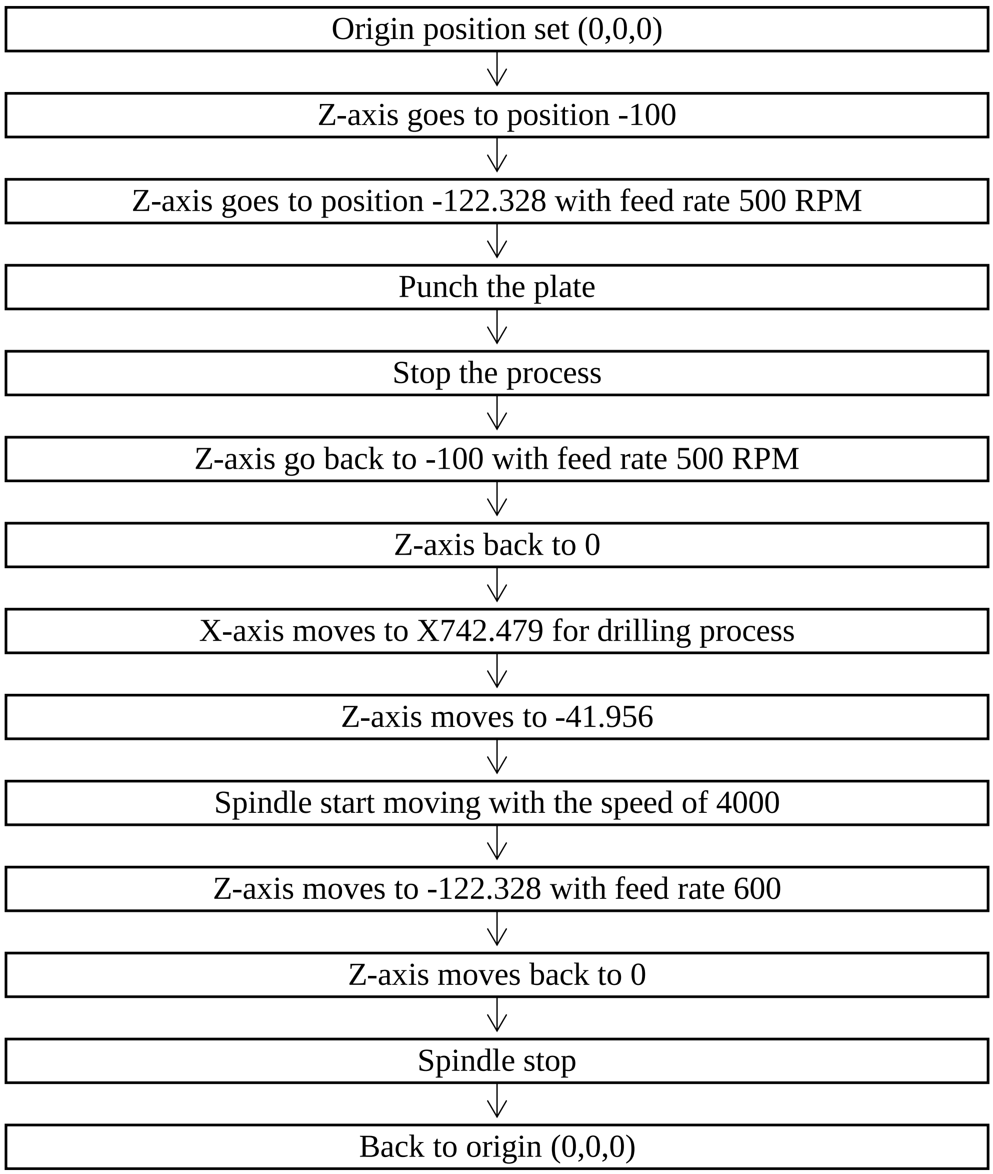


Figure 3.6: Flowchart for the programme

The original code and the one used in the programming are different as the machine has gone through modification. The original model of the machine is a CNC milling machine. The punching and drilling process is embedded in the CNC to easily made a hole for the composite material. Table 3.3 shows the code used in the programming G-code for the punching and drilling machine (*G-Code Cheat Sheet + MDI: Your CNC Secret Weapon*, n.d.). Figure 3.7 is the programme that is used for the operation of punching and drilling.

Table 3.3: Code used in the programme

Code	Description
G00	Rapid position
G01	Move in a straight line
M05	Stop spindle
M08	Flood coolant (to stop punching)
M09	Turn off the coolant (to bring back puncher up)
M03	Spindle clockwise
S	Spindle speed
P	Dwell time at bottom of the hole.
F	Cutting federate

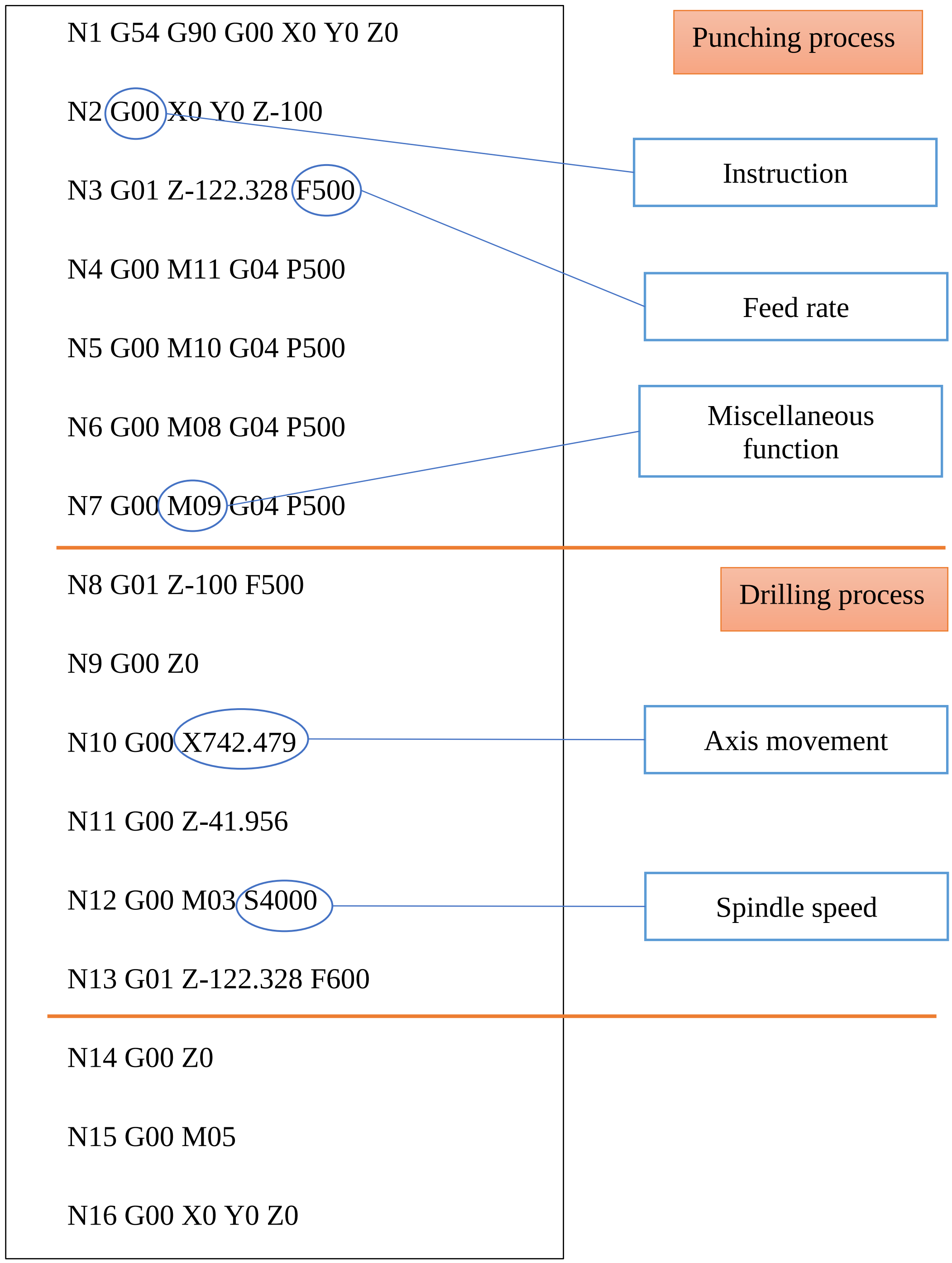


Figure 3.7: Programme for the punching and drilling process