STUDY OF PUNCHER MATERIALS FOR SINGULATION PROCESS IN SEMICONDUCTOR MANUFACTURING INDUSTRY

VIKRAM A/L NANTHANAR

FACULTY OF ENGINEERING
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STUDY OF PUNCHER MATERIALS FOR SINGULATION PROCESS IN SEMICONDUTOR MANUFACTURING INDUSTRY

ABSTRACT

Punching or Singulation is one of the most common processes used in many semiconductor industries as a separation process from a substrate which contain four to nine units. Having a basics understanding of the material to be used in the punching process can help to improve the tool life thus can increase the quality of the end product in various ways. In the high volume of production, improving the tool life such as puncher can save not only tooling material but also could reduce the change of the tool over the time. Even though the carbide material is in use for the past few years, it seems to fail during mass production. In order to improve the puncher material, the 440 C Martensitic Stainless Steel is introduced in this research to replace the existing carbide material. 440 C Martensitic Stainless Steel is a high carbon straight chromium high hardenability martensitic stainless steel, generally provided in the galvanized condition is fabricated with an appropriate angle of the puncher. The function of the puncher's angle is to have a gradual shearing force. When sufficient shearing force is applied, the shear stress in the material will exceed the ultimate shear strength and the material will fail and separate at the cut location. It was observed that the puncher using with 440 C Martensitic Stainless Steel able to sustain premature breakage thus improve the Overall Equipment Effectiveness (OEE).

MENGKAJI BAHAN PUNCHER UNTUK PROCESS SINGULATION DI INDUSTRI PEMBUATAN SEMICONDUCTOR

ABSTRAK

Sigulation atau proses pemisahan unit adalah satu proses yang paling biasa digunakan dalam kebanyakkan industri semikonduktor sebagai proses pemisahan daripada substrat yang biasanya mengandungi empat hingga sembilan unit. Dengan mempunyai pemahaman asas mengenai bahan yang akan digunakan dalam proses Singulation, ianya dapat membantu memperbaiki janka hayat bahan tersebut justeru dapat meningkatkan kualiti produk dalam pelbagai cara. Dalam jumlah pengeluaran yang tinggi, peningkatan jangka hayat perkakas seperti puncher dapat menyelamatkan bukan hanya alat perkakas tetapi juga dapat mengurangkan masa untuk penukaran sesuatu perkakas. Walaupun bahan Carbide digunakan sejak dari beberapa tahun dahulu, malangnya ianya masih gagal untuk bertahan semasa pengeluaran secara besar-besaran. Untuk memastikan jangka hayat bahan puncher, 440 C Martensitic Stainless Steel diperkenalkan dalam penyelidikan ini untuk menggantikan bahan Carbide yang sedia ada. 440 C Martensitic Stainless Steel mempunyai karbon tinggi, kromium keluli tahan karat dan keluli tahan karat yang tinggi, yang umumnya dicelup dengan galvanize serta direka bentuk dengan sudut yang sesuai. Fungsi sudut pada puncher adalah untuk memastikan pemotongan secara beransur-ansur. Apabila daya ricih yang cukup digunakan, tegasan ricih dalam bahan akan melebihi kekuatan ricih muktamad dan bahan akan gagal dan berasingan di lokasi potong. Semasa dalam pemerhation, ianya didapati bahawa puncher 440 C Martensitic Stainless Steel yang digunakan dalam kajian ini mampu mengekalkan kerosakan pramatang dan sekali gus dapat meningkatkan Overall Equipment Effectiveness (OEE).

ACKNOWLEDGEMENTS

As I hereby want to say thanks to the University of Malaya for giving an opportunity to do research which can improvise my technical career in the future.

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CHAPTER 1: INTRODUCTION

1.1 Background Study

Nowadays Malaysian industries are struggling for survival in a quality-based world. Because of the globalized economy, quality is essentially important for every company to set a high standard of quality and achieve it to enable them to compete nationally as well as international. This is important to improve the quality of a company; it is due to cost reduction and high-quality product, which is one of the main strategies for manufacturer competitive in the market and optimize their profit.

As mentioned above, improvement of quality is the key to a company competitive in the market and survives on it. In order to meet the target, there is a lot of technique and principal of Industrial Engineering tool can be used in the manufacturing process such as DOE, Six Sigma and another relevant method. All these techniques are a useful tool to improve the quality of a company. As a result, it is used to leading us to the source of the problem that makes defects occurs.

1.2 Introduction on Singulation Punching process

Singulation or punching is a forming process that uses a punch press to force a tool, called a puncher, through the workpiece to create a hole via shearing. Punching is appropriate to a wide variety of materials that come in sheet form, including sheet metal, paper, vulcanized fibre and some forms of plastic sheet.

Punching is commonly the most affordable technique for making holes in sheet materials in medium to high production volumes. When a particularly designed punch is used to create various usable parts from a sheet of material, the method is identified as blanking. Punch tooling (punch and die) is often made of tungsten carbide. A die is placed on the opposite side of the workpiece and supports the material around the perimeter of the hole and helps to localize the shearing forces for a cleaner edge.

There is a small amount of clearance between the punch and the die to prevent the punch from sticking in the die and so less force is needed to make the hole. The total of clearance needed is subjected to on the thickness, with thicker materials needing more clearance, but the clearance is always greater than the thickness of the workpiece. The clearance is also dependent on the hardness of the workpiece.

The punch press forces the punch through a workpiece, creating a hole that has a diameter corresponding to the punch, or marginally smaller after the punch is removed. All ductile materials elasticity to some extent during punching which often causes the punch to stick in the workpiece. In this case, the punch must be substantially pulled back out of the hole while the work is supported from the punch side, and this process is known as stripping. The slug from the hole falls through the die into some sort of container to either dispose of the slug or recycle it. Figure 1.1 shows the typical punch press tool (Art Hedrick December 12, 2006).

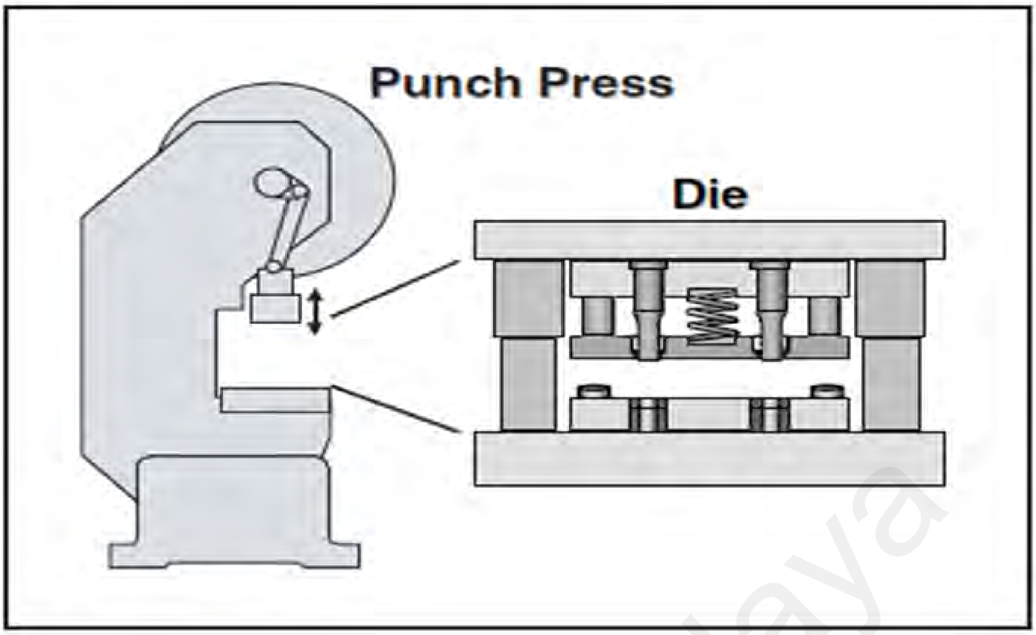


Figure 1.1: Typical punch press tool

1.3 Problem Statement

Manufacturers know that punching can be the most cost-effective process for making holes in the strip or sheet metal. However, as the part material increases in hardness to accommodate longer or more demanding runs, greater force is placed on the punch and the die button, resulting in sudden shock, excessive wear, high compressive loading, and fatigue-related failures. The results of some of these problems are;

1.3.1 Punch Chipping and Point Breakage

Chips and breaks can be caused by press deflection, improper punch materials, excessive stripping force, and inadequate heat treatment.

1.3.2 Slug Pulling

Slug pulling occurs when the slug sticks to the punch face upon withdrawal and comes out of the lower die button.

1.3.3 Slug Jamming

Slugs jamming is often the result of improper die design, worn-out die parts, or obstruction in the slug relief hole.

1.3.4 Punch Head Breakage

Punch deflection leads to punch head breakage. Cutting shear, press tonnage, the type of backing plate, alignment, and the types of punches and retainers all require careful consideration when designing a punch.

1.3.5 Punch Wear and/or Galling

Punch Die performance and longevity can be improved through the use of regular maintenance, as well as the use of lubricants and leading edge punch designs.

Punch problem during mass production can result in many issues such as unnecessary equipment downtime, high maintenance cost, product chipping or crack, this may affect the overall productivity. Therefore several factors which contribute to the premature failure or breakage of punches was done in a real situation such as die cutting clearance and punch design but there is no major improvement for this problem.

Figure 1.2: Broken Punch

1.4 Objective

The Objectives of the Project are:

a) To fabricate the new puncher to avoid premature broken during mass production in manufacturing semiconductor.

b) To compare the puncher life span of new puncher (440 c Martensitic stainless steel) with previous puncher (Carbide).

1.5 Scope and Limitation

a) A company case will be selected to be a case study.

b) One product of the company to be selected and proceed with improvement.

c) The quality of the selected product will be discussed in general but only the critical quality issue will be discussed in detail.

d) Only the critical problems will discuss in detail and these problems are limited to Industrial Engineering.

e) The case study solely focuses on one production line of a selected company.

f) The suggestion or solutions to solve the problems are merely a proposal.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction to Semiconductor PBGA Substrates

Plastic Ball Grid Array (PBGA) is one of the main products so-called high demand product in most automotive industries and it contributed to getting high earns. PBGA package is molded up on substrate where the die is attached to the substrate in an up manner. The wire bonded and complete assembly been over molded as the solder balls attached to the bottom of the package. Figure 2.1 and Figure 2.2 shows the typical PBGA package configuration.

Figure 2.1: Typical PBGA package

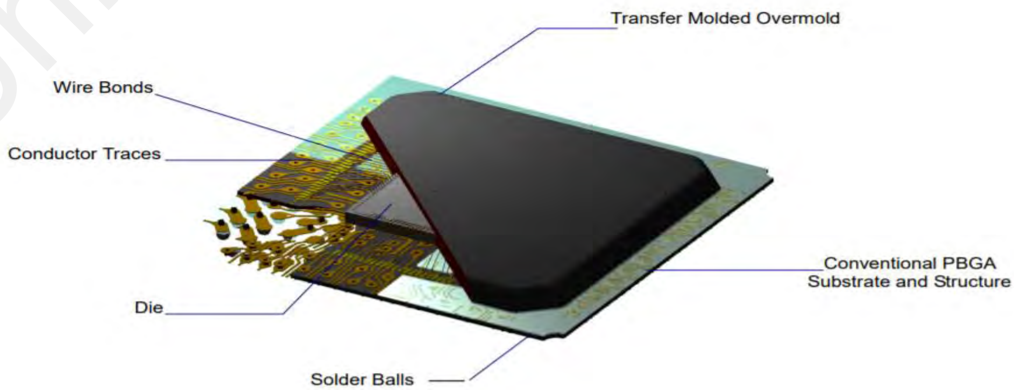


Figure 2.2: PBGA package configuration

This package provides high effectiveness on cost and higher density on traditional lead frame packages. The PBGA package is offered in a range of sizes from 17mm x 17mm to 35mm x 35mm, in ball pitch of 0.8mm and 1.0mm, to provide a ball count ranging from 208 to 976 balls (Rogers, 2019).

The laminated substrate or printed circuit contained by PBGA packages produced by an advanced version of the similar technology used to produce the motherboard. Conductor consisting of copper foil imprinted in effect bound to the polymer substrate.

Subsequently, PCB technologies allow BGA package having several layers of conductors and a plane with connections between the layers provided by plated through-hole vias. Electrical connection to the chip finally sent to various solder balls attached to the bottom of the substrate, which serves as a lead (Rogers, 2019). Table 2.1 shows the typical nominal dimensions of selected PBGA substrate features.

Table 2.1: Typical nominal dimensions of selected PBGA substrate features

Features	*Dimensions (mm)*	*Comments*
Substrates Thickness (2ML)	*0.56 +/- 0.04*	*Overall thickness (Core + SR + inner layer + outer layer)*
Substrates Thickness (4ML)	*0.61 +/- 0.05*	*Overall thickness (Core + SR + inner layer + outer layer)*
Copper Thickness	*0.015*	
Trace/Space Widths	*0.05*	*minimum*
Soldermask Thickness	*0.02*	*Over Copper*
Via	*0.2*	*Normal*
Solder Pad Cu	*0.60 ~ 0.65*	
Solder Mask Opening	*0.40 ~ 0.50*	

2.2 Singulation Punching Process

Singulation system is a mechanical process of cutting out the unit (workpiece) from the substrate to specified shape, dimension, and tolerance. The substrate has either 4 to 9 workpiece in a row. Punching is also called a basic sheet cutting process that has many different forms and applications in press working manufacture. The excess metal once punched out, is called a slug and is usually discarded as scrap. Refer to below illustrates on the punching process. Figure 2.3 shows the illustration of the punching process.

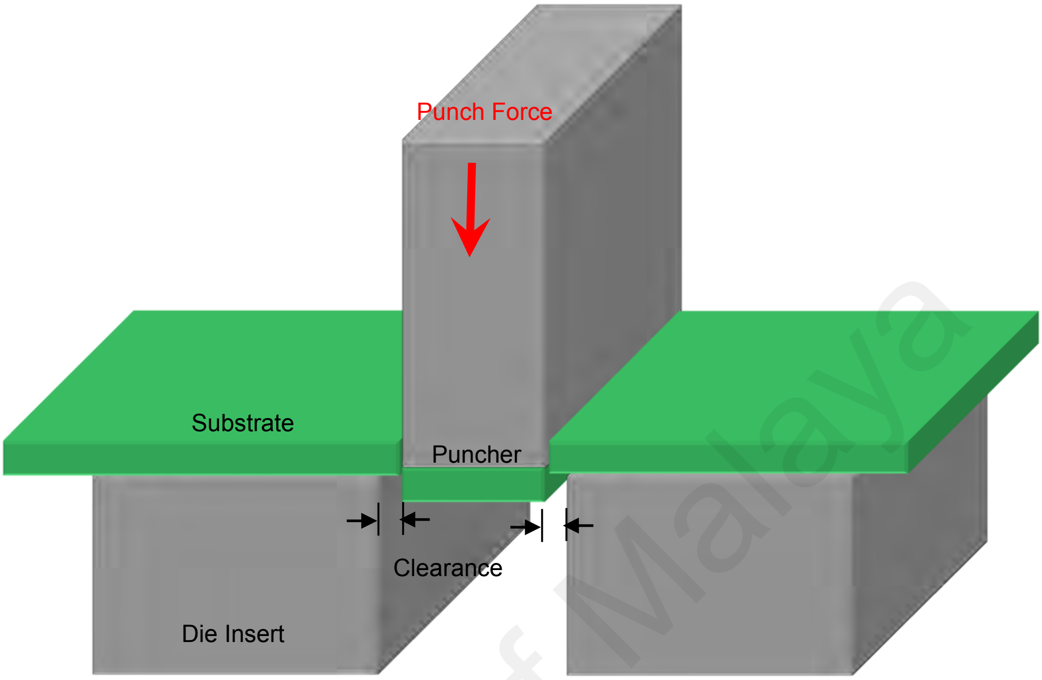


Figure 2.3: Illustration of the punching process

There are a number of important actions that take place during the punching process. The more we understand these events, the easier it is to identify the causes that contribute to problems during the punching cycle. One can experience galling, slug pulling, uneven tool wear, accelerated tool wear and/or tool breakage, etc. A basic understanding of what takes place during the punching process will better prepare to identify the cause of a problem and more easily determine a solution. Refer to below on understanding of fracture (B. Emche, 2012). Figure 2.4 shows the basic understanding of fracture.

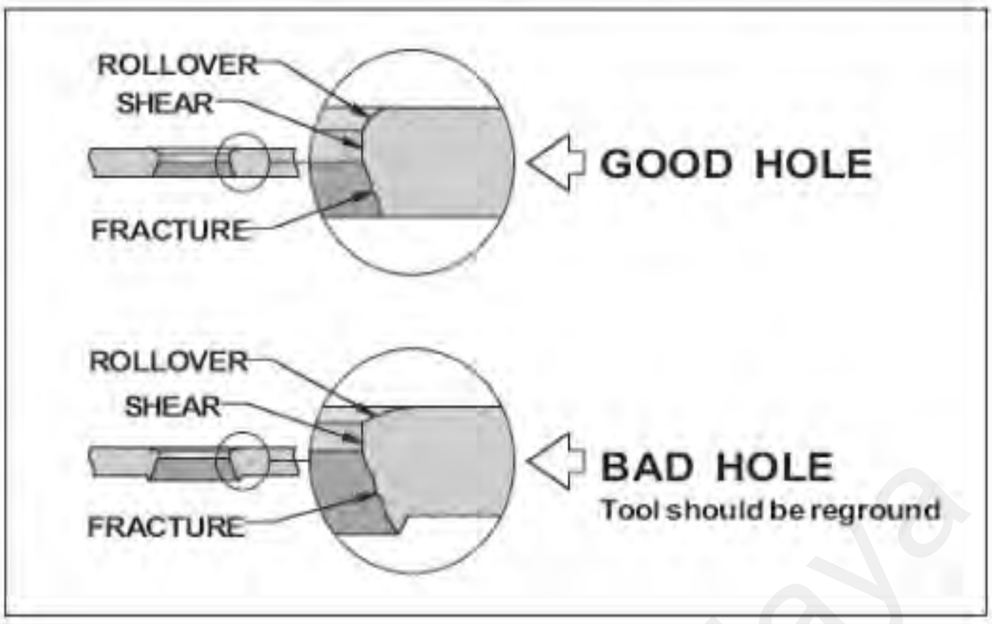
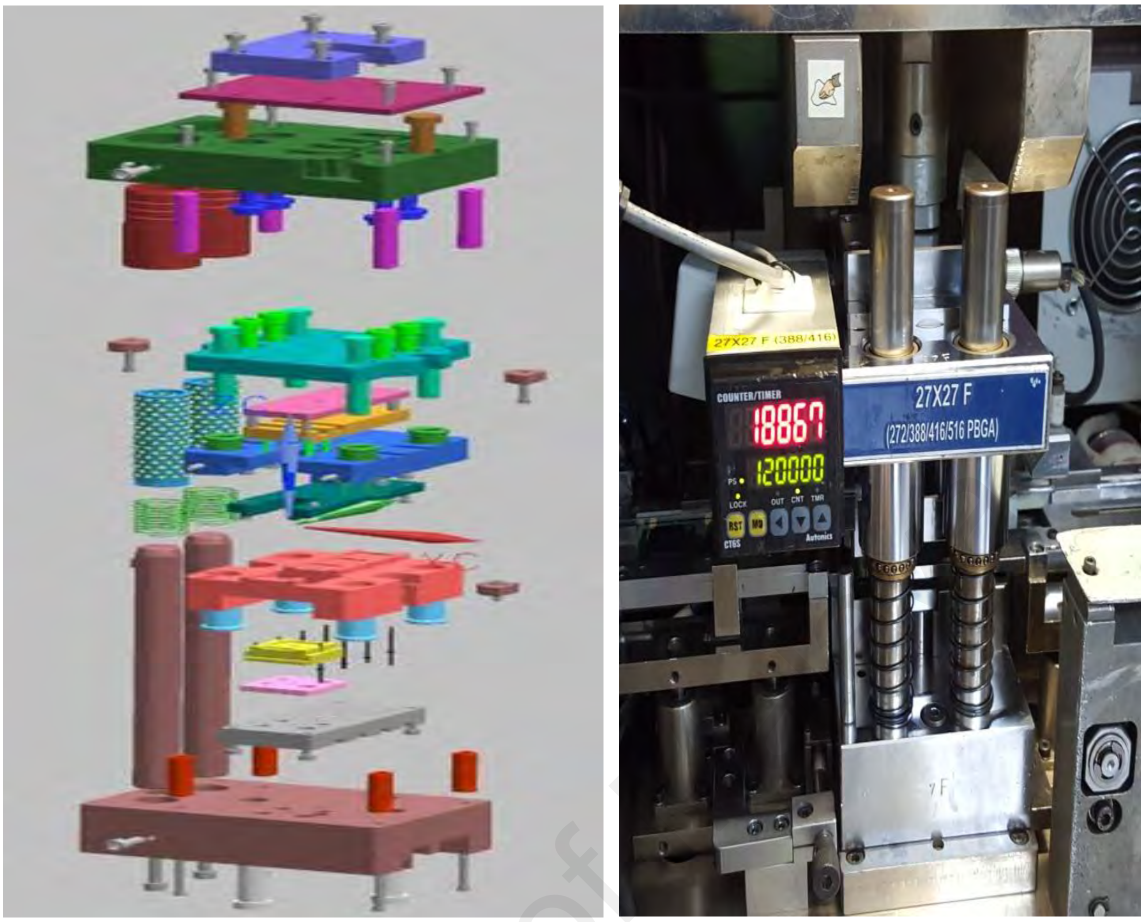


Figure 2.4: Basic understanding of fracture

2.3 Tooling System – Diet Set

Basically, tooling referred to the equipment that required to convert raw material into a required shape. Tool system or die set is very important in the punching process. Complete set of tool system contains punch, tool holder, stripper plate and die insert. If one of these components does not conduct wisely, it will damage the product or will face machine damage.

The best tool is defined as the strength of wear resistance and toughness in better quality and which is suitable to use for a particular application. To ensure the product is high quality and the process of manufacture can perform safely, the quality of the tooling component especially puncher is considered very important (Art Hedrick December 12, 2006). Figure 2.5 shows the Singulation Die Set.



a) 3D Illustration of Singulation Tool Assembly b) Singulation Tool Assembly

Figure 2.5: Singulation Die Set

2.4 Puncher

Puncher is the main component among the other where it contributes overall result for the workpiece to being cut out. During the punching process, puncher will experience compressive and tensile forces. The puncher tip which will apply pressure on the workpiece until it overcomes the materials tensile when it contacts punch area.

When the puncher penetrates the die insert whereby it will ensure to release the slug, the workpiece material starts to rub the puncher's flanks. Then, when the puncher reaches the bottom of the stroke, it quickly starts to retract from the workpiece. These two actions are the main contribution of tensile forces to the puncher tip.

If the punching relies on successful on features, then the tooling encounter moderate effects of these unavoidable forces. For instance, high-quality tool steels with metallurgical properties designed to resist chipping, cracking and edge wear even it is under extreme condition (Ahmad, A. 2019). Figure 2.6 shows the Singulation puncher.

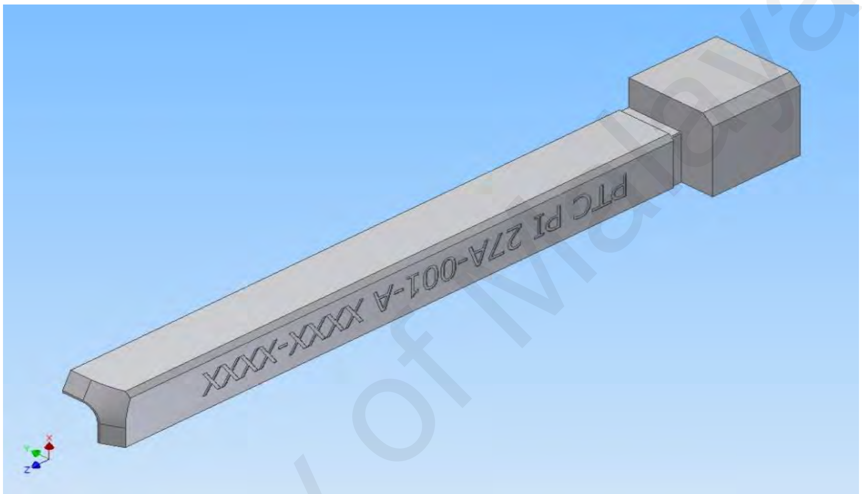


Figure 2.6: Singulation puncher

With the development of new, high-strength materials comes a dramatically increased failure rate for cutting punches. It's no secret that higher-strength materials require significantly more force to cut than the more traditional, softer grades of steel. Excessive force, deflection, or shock can cause cutting punches to break. A broken punch, if carried through an automated system such as a transfer or progressive die, can result in severe die damage, not to mention a great deal of downtime and prevention (Art Hedrick December 12, 2006).

2.5 Die Insert

Precision is a must in the punching process where it able to fit between the punch and the die insert. Good precision between the punch and die insert requires plus minus 20 microns. If the puncher can enter the die without any contact, then it is considered as good punch and die insert alignment.

Another concern is die clearance, the difference between dimensions of the punch and the die. Uniform die clearance around the punch's periphery is critical, especially in tools with sharp corners such as squares and rectangles.

Radius in the corners of the die will help to maintain a uniform clearance. When die clearance increase with material thickness, it automatically will affect the size of the radius. Thus, the proper radius is very important to ensure the quality of die strength (Andy Spence Parsons August 8, 2006). Figure 2.7 shows the Singulation Die Insert.

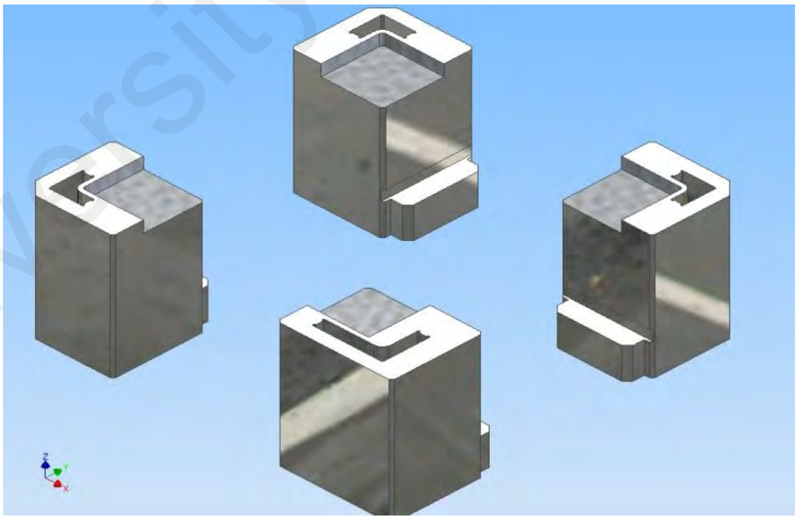


Figure 2.7: Singulation Die insert

2.6 Carbide Materials

The word carbide generally describes a group of materials characterized by high hardness and metallic properties. The first carbides, developed in 1921, were extremely simple and applied mainly in turning. A metallic gloss and relatively good electrical and thermal conductivity distinguish these materials decisively from the nonmetallic hard materials that were used as abrasive materials long before the introduction of carbides.

Carbide is a two-phase powder-metallurgical (PM) material consisting of a hard material phase and a binder metal phase. The hard material provides the necessary wear resistance, and the binder metal guarantees appropriate toughness. With their numerous possible combinations of metal binder content and grain size, carbides are used in many applications. The carbides most commonly used in the tool and die industry are made of tungsten carbide (hard material) and cobalt (binder metal) (Brian Ayers September 30, 2008).

2.6.1 Properties and Composition of Carbide

To select the appropriate grade for a tool and die application, it is important to have detailed knowledge of carbide and how its properties can be influenced. There are two main possibilities:

2.6.1.1 The average grain size

As the average grain size gets smaller, the carbide becomes harder, more wear-resistant, and more brittle. As the average grain size gets coarser, the material becomes softer and tougher.

2.6.1.2 The metal binder content

Higher binder content makes the grade softer and tougher, while lower binder content makes it harder, more wear-resistant, and brittle.

Another way to influence the properties is with other alloy components such as chromium carbide (CrC), vanadium carbide (VC), titanium carbide (TiC), and tantalum carbide (TaC), also called g-phases. These alloy components are used in minimum quantities, also called doping, and enhance properties like corrosion resistance, toughness, and strength at high temperatures or they can act as grain growth inhibitors during sintering. Because of brittleness and hardness, the material's homogeneity is extremely important in terms of transverse fracture strength of the material and homogeneous wear (Brian Ayers September 30, 2008).

2.6.2 Other essential properties of Carbide

Corrosion resistance: Because of carbide's heterogeneous structure, corrosion causes the metal binder to be removed. This can occur during machining (wire erosion in the dielectric, grinding with emulsion), but also during the application of corrosive lubricants.

2.6.2.1 Edge stability

A carbide grade with high hardness may have insufficient fracture toughness so that the high dynamic stress on the cutting edges causes edge chipping. When a carbide grade with insufficient hardness showing a similar picture of failure is applied, cutting edge deformations caused by wear may occur. Nonhomogeneous carbide structures also can lead to local chipping or uneven wear even in a suitable carbide grade.

2.6.2.2 Tendency to adhesion

The tendency of the cutting material to stick depends on the material to be cut, the surface quality of the tool, cutting clearance and tool geometry, and the lubricant applied.

2.7 Stainless Steel Materials

Stainless steel is a group of iron-based metal containing at least 10% chromium (alloy metals). The layer is too thin to be detectable, meaning the metal stays shiny. It is, however, resistant to water and air, protecting the metal beneath. Also, when the surface is scratched this layer quickly reforms.

The purpose of stainless steel is to provide hard steel material highly resistant to stain, rust and corrosion and resistance against:

a) Adverse atmospheric conditions such as carbon dioxide, moisture, electrical fields, sulfur, salt, and chloride compounds
b) Natural and artificially produced chemical (e.g. ozone)
c) Extremes of weather such as cold temperatures

2.7.1 Stainless Steel Classification

According to the main chemical composition can be divided into chromium stainless steel, chromium-nickel stainless steel, chromium manganese nitrogen stainless steel, chromium-nickel molybdenum stainless steel and ultra-low carbon stainless steel, high molybdenum stainless steel, high purity stainless steel, etc.

According to the properties of steel and the classification of application, it can be divided into the nitric acid (nitric grade) stainless steel, the stainless steel resistance, the stainless steel, the stress stainless steel, the high-strength stainless steel, etc.

According to the functional characteristic, it can be divided into low-temperature stainless steel, non-magnetic stainless steel, easy cutting stainless steel, ultra-plastic stainless steel, etc.

It is usually classified as a metallographic structure. Classified by the metallographic structure are ferrite (F) stainless steel, martensite stainless steel (M), austenitic stainless steel, austenitic type (A)-ferritic duplex stainless steel (A-F) and austenite to martensite duplex stainless (A-M) and precipitation hardening stainless steel (PH) (Skliarov, Vladimir & Zalohin, Maxim. (2017).

2.7.2 Types of Stainless Steel

There are over 150 grades of stainless steel, of which fifteen are most common. The AISI (American Iron and Steel Institute) defines the following grades among others:

a) 200 Series - austenitic iron-chromium-nickel-manganese alloys
b) 300 Series - austenitic iron-chromium-nickel alloys
c) Type 301 - highly ductile, for formed products. Also hardens rapidly during mechanical working.
d) Type 303 - free machining version of 304 via the addition of sulfur
e) Type 304 - the most common; the classic 18/8 stainless steel
f) Type 316 - Alloy addition of molybdenum to prevent specific forms of corrosion
g) 400 Series - ferritic and martensitic alloys.

2.7.3 400 Series Ferritic and Martensitic Alloys.

Both ferritic stainless steels and martensitic stainless steels are regarded as 400 series of stainless steels and classified by phase constituent of microstructure. Both of their resistance to rust is worse than austenitic stainless steels.

Ferrite is soft and ductile, while pearlite is hard and brittle. As the overall content of carbon increases, the proportion of pearlite becomes higher and the bulk strength increases. Furthermore, ferritic stainless steels are unable to be hardened by heat treated

On the other hands, martensitic stainless steels are a meta-stable phase that is formed when high-temperature austenite is quickly quenched below a critical temperature (that changes depending on chemistry). It is characterized by its extremely high strength, low fracture resistance, and low ductility. It can be held at an intermediate temperature for various times, in a process called tempering, to reduce strength while vastly improving toughness and ductility. Martensitic can be achieved in both alloy and stainless steels. Figure 2.8 shows the chemical composition chart.

Stainless Steels	Chemical Composition, %									
TYPE	C	Si	Mn	P	S	Ni	Cr	Mo	Cu	Free-cutting element
416	≤0.15	≤1.0	≤1.25	≤0.060	≥0.015	≤0.60	12.00~14.00	≤0.6		
420J2	0.26~0.40	≤1.0	≤1.0	≤0.040	≤0.030	≤0.60	12.00~14.00			
420F	0.26~0.40	≤1.0	≤1.25	≤0.060	≤0.15	≤0.60	12.00~14.00	≤0.060		
430	≤0.15	≤0.75	≤1.00	≤0.040	≤0.030	≤0.60	16.00~18.00			
430F	≤0.12	≤1.0	≤1.25	≤0.060	≥0.15	≤0.60	16.00~18.00	≤0.060		
440C	0.95~1.20	≤1.0	≤1.25	≤0.030	≤0.030	≤0.60	16.00~18.00	≤0.75		
416FC	≤0.15	≤1.0	≤1.25	≤0.060	>0.15	—	12.4	—		Added
DSR7	0.7	≤0.25	≤0.3	≤0.25	—	—	<12	Added	—	

Figure 2.8: Chemical composition chart

2.7.4 440 C Martensitic Stainless Steel

440 C Martensitic Stainless Steel is a high carbon straight chromium high hardenability martensitic stainless steel, generally provided in the galvanized condition with a maximum Brinell hardness of 269 (Rc29) or galvanized and cold drawn with a maximum Brinell hardness of 285 (Rc31). Characterized by good corrosion resistance in mild domestic and industrial environments, including fresh water, organic materials, mild acids, various petroleum products, coupled with extremely high strength, hardness and wear resistance when in the hardened and tempered condition.

440 C due to its excellent hardenability is capable of being through hardened up to Rc60 depending upon carbon content and section size. Small sections can be air cooled and quite large sections oil quenched for maximum through hardness. Used for parts requiring a combination of excellent wear resistance, plus reasonable corrosion resistance. Typical applications are ball bearings and races, bushings, cutlery, chisels, knife blades, pump parts, surgical instruments, valve seats, etc (Nagendran Sathish and J. David Rathnaraj 01 February 2014).

2.8 Stresses on Tools

In order to choose the appropriate steel for an application, it is vital to be aware of the tool stresses that arise during individual operations. The diagrams below and on the pages that follow illustrate the relevant principles. Figure 2.9 shows the stresses on tools.

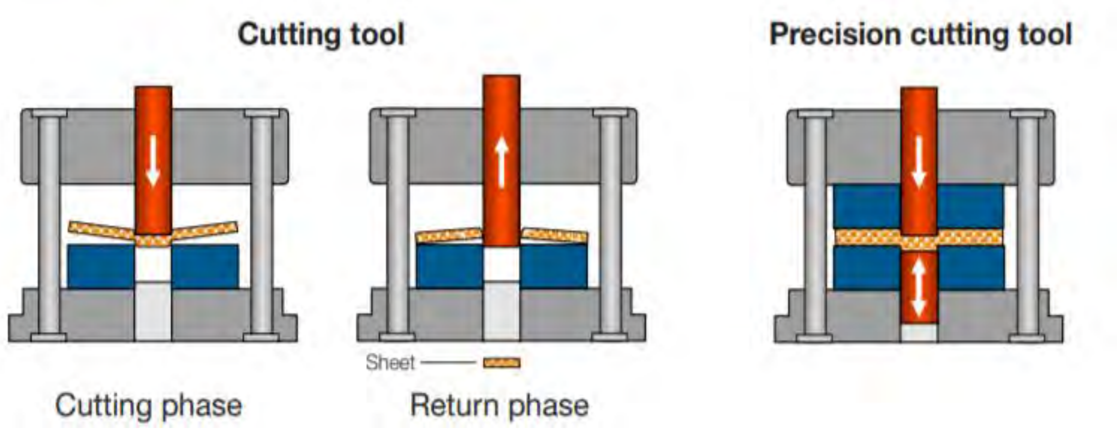


Figure 2.9: Stresses on Tools

The cutting surfaces of the punch and cutting plate penetrate the sheet to be cut, initially deforming it elastically and later plastically in the shear zone. When the deformability of the material to be cut is exceeded, fine cracks form at first which spread out and expand as cutting continues. Eventually the material fractures and separates. Because around only a third of the sheet thickness is cut during the cutting process (the rest breaking off due to tensile stresses), a burr appears on the pieces. This may snag on the tool when the cutting punch is pulled back so that the punch comes under undesired, dangerous tensile stresses. Corrective action can be taken here by using precision cutting tools which significantly reduce this burr.

Cutting tools are subjected to pressure during the cutting process. If cycle times are high, this stress may occur suddenly. Materials suitable for cutting tools not only need high compression strength; they must also provide adequate resistance to impact. Relative movements that occur between the tool's cutting surfaces and the sheet to be cut always result in friction, and therefore wear and tear, when pressure is applied simultaneously.

Depending on the tool area that is affected, distinctions are made between wear to the end face, lateral surfaces, and crater wear. Marked wear to the lateral surfaces can be particularly unfortunate because it requires intensive regrinding. This is why there is a demand for high wear resistance when it comes to tool steels used for cutting tools. From this brief description, it can be concluded that tool steels for cutting tools should exhibit the following properties: (Andy Spence Parsons August 8, 2006)

a. High hardness
b. High compression strength
c. Adequate impact strength
d. High wear resistance

2.9 Summary

Choosing economical steel does not in any way involve using the cheapest steel. It is far more important to select the most suitable material for the intended purpose. If the wrong material has been chosen, this often only emerges when the tool is in operational use, potentially resulting in significant extra costs. When selecting tool steel, it is important to keep in mind that the tool must not break during use or chip around the cutting edge. Similarly, permanent deformation and premature changes to the tool surface as a result of wear and tear or corrosion need to be excluded.

Steel availability should also be checked. Due to the cost situation, steel manufacturers are being forced to limit their product ranges. In recent years, however, various highly versatile tool steels have been developed, which enable tool steel portfolios to be restricted without compromising on technical properties. This ultimately has considerable benefits for toolmakers.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter explains about the particular approach of performing research on selected material (440C Martensitic Stainless Steel) and then explains about the process flow of conducting this research by collecting the data on the puncher material and discussed to consider the collected data. Diagrams are included to simplify the process flow, phases and stages of the complete research.

3.2 Process Flow in Conducting Research

To achieve the objectives requirement, it is necessary to have a time period, so that the works can be completed on time. Figure 3.1 shows the process flow in conducting research.

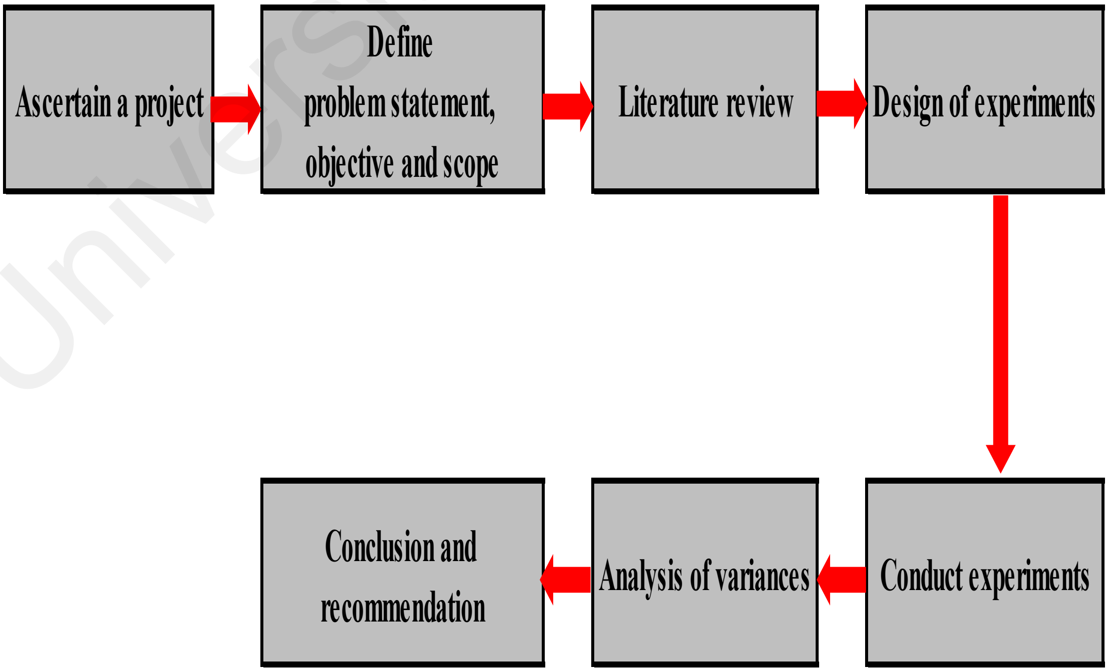


Figure 3.1: Process flow in conducting research

3.3 Project Planning Activities

The Gantt chart in Table 3.1 below, highlighted all the important project activities had been done to complete this research. Basically, it will cover all the highlighted process flow based on a dateline basis for the project. As the progress of this project, it will end with a progressive report and report submission.

This is a lay down as the significant aspect of this project together with the Gantt chart. Gantt chart is also used to confirm whether all timeline is meet and whether any corrective action is required to be done and to make any changes on a current deadline so that the whole project activities can be completed exactly according to the planned schedule.

Table 3.1: Gantt chart (Project Planning Activities)

Task \ Week	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10	11 - 12	13 - 14	15 - 16	17 - 18	19 - 20	21 - 22	23 - 24	25 - 26	27 - 28
Research	■													
Proposal Preparation & Submisson	■	■												
Material Selection		■	■	■										
Overall Part Fabrication				■	■	■								
Simulation & Improvising Puncher						■	■	■	■					
Verification Of New Puncher Material									■	■	■	■		
Results												■	■	
Final Report Preparation & Submission													■	■

3.4 Design of Experiment (DOE)

Fundamentally there are five basic stages in conducting this research. The phases are planning experiments (start), data collection of the developed method, data recording of the current method, data analysis, decision making and documentation the data. Otherwise, if there is an improvement or corrective action needed, then the step would be repeated until meeting the goal set. Figure 3.2 shows the data analysis in conducting research.

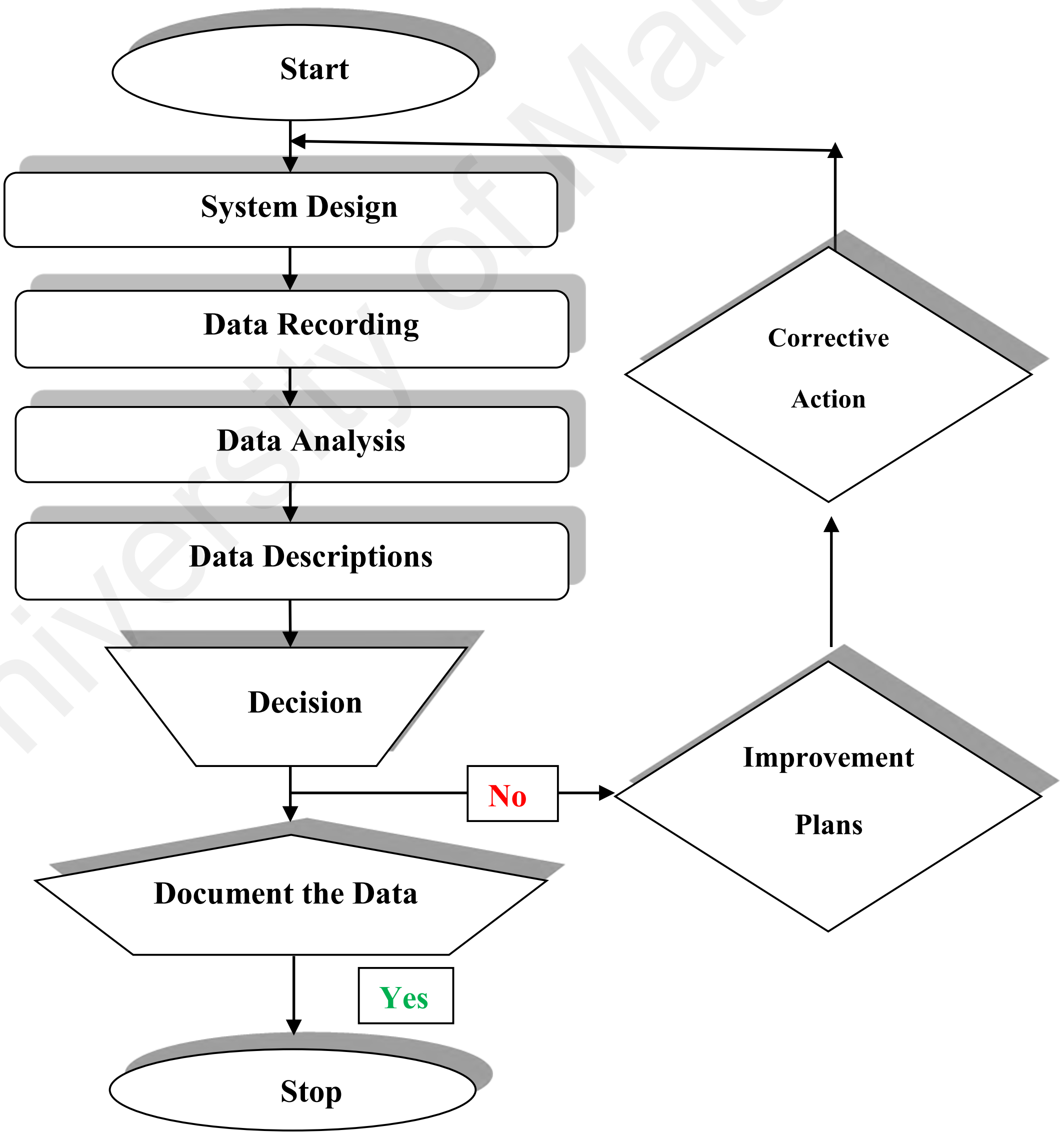


Figure 3.2: Data analysis in conducting research

3.5 Identification of the problem

Fishbone diagram below refers to the possible errors which lead to the existence of puncher breakage. There are 4 main factors been detected which are Machine, Man, Method and Material to find out the ultimate root cause of the puncher breakage. Figure 3.3 shows the Fishbone analysis Diagram.

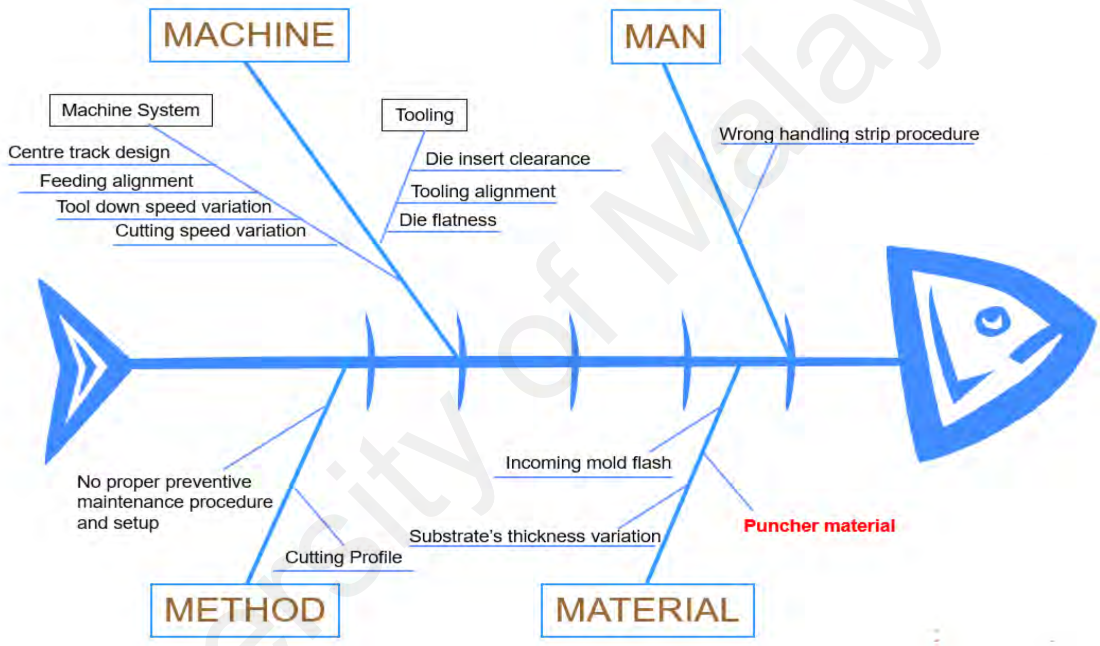


Figure 3.3: Fishbone analysis diagram

3.6 Machine Specification

The angle of the puncher is taken into account whereby fabrication of puncher using 440C Martensitic Stainless Steel is mounted into dieset. Punching test was carried out using the dummy substrate, in order to collect evaluation data. The test should meet all the specific criteria of the parameter. The ASM Punch Singulation machine specification explained about the critical parameters involved during the punch process. Figure 3.4 and Table 3.2 shows the list of critical machine parameter.

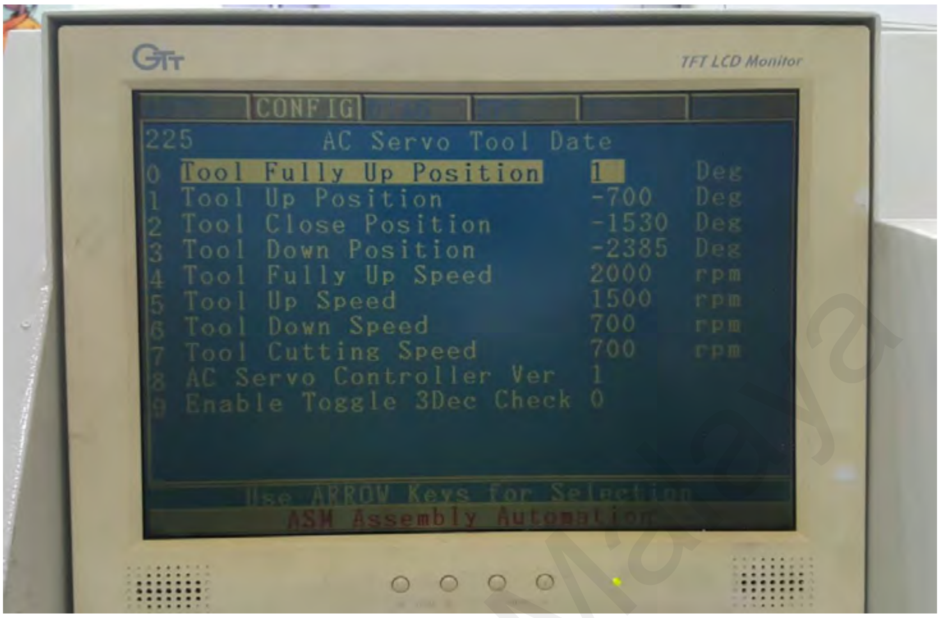


Figure 3.4: List of machine parameter

3.6.1 Angle Specification

Once the problems were identified, the corrective action is taken whereby the angles of the puncher is designed and fabricated with new material 440 C Martensitic Stainless Steel. Figure 3.5 below shows that the 4 angles which are designed with Autodesk Inventor and fabricated in a machine shop. There are 3 types of puncher angle designed by stages and tested in the production line for a time of period to get the ultimate best results. Thus the appropriate puncher angle is fabricated as shown in Table 3.3.

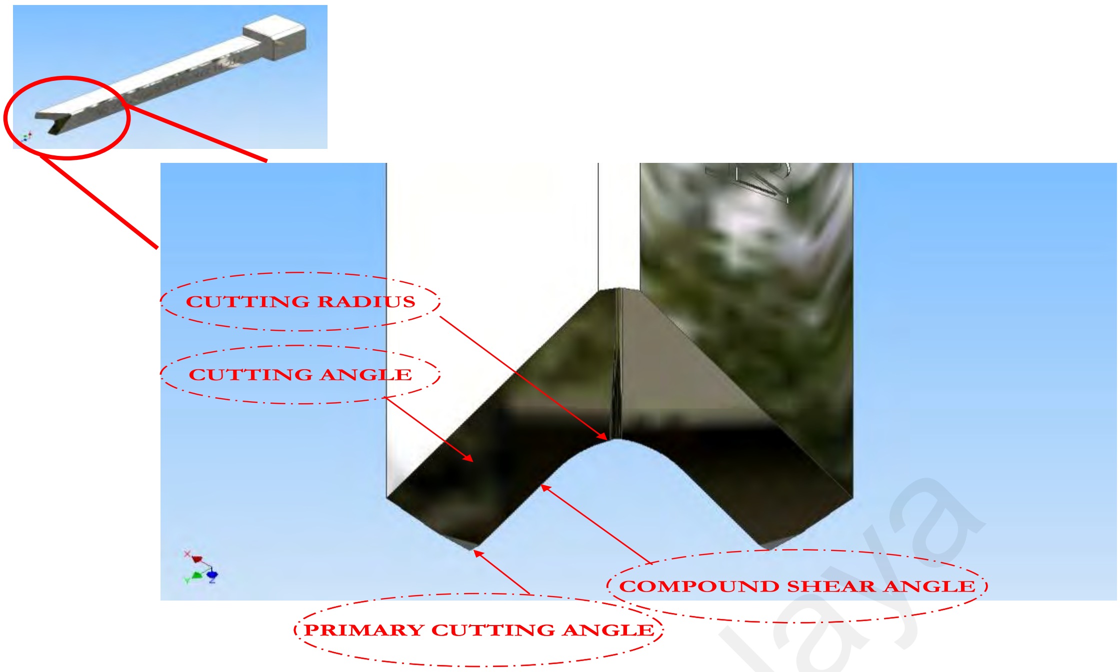


Figure 3.5: Shear angle puncher

Table 3.2: Fabricated puncher angle specification

Specification	***Unit***	***Size***	***Tolerance***
Cutting Radius	*mm*	*0.750*	*+/- 0.005*
Length	*mm*	*33.500*	*+/- 0.020*
Thickness	*mm*	*1.000*	*+/- 0.005*
Clearance Angle	*Deg*	*16 - 15*	*+/- 0.01*
Compound Shear Angle	*Deg*	*54.500*	*+/- 0.01*
Primary Cutting	*Deg*	*10.000*	*+/- 0.01*

3.7 Shearing Cut Method

Shearing method is a process of cutting off of sheets (substrate) using a punch and die insert by applying a force to cause the material to fail. Shearing happens by severe plastic deformation locally followed by fracture which propagates deeper into the thickness of the blank. The clearance between the die and puncher is an important parameter which decides the shape of the sheared edge. Large clearance leads to burr. Burr is one of the defects where the workpiece goes through the imperfect cut edge (Ahmad, A. 2019).

The shearing load is also higher for larger clearance. For harder materials and larger sheet thickness, required larger clearances. Generally, clearance can vary between 2% and 8% of the sheet thickness. Usually, shearing begins with the formation of cracks on both sides of the blank, which propagates with the application of shear force. A shiny, burnished surface forms at the sheared edge due to rubbing of the blank along the shear edge with the punch or the die wall. Shear zone width depends on the speed of punch motion.

Larger speed leads to narrow shear zone, with smooth shear surface and vice-versa. A rough burr surface will be formed if clearance is larger. Similarly, a ductile material will have burr of a larger height. Shearing a blank involves plastic deformation due to shear stress. Therefore, the force required for shearing is theoretically equal to the shear strength of blank material. Due to friction between blank and tool, the actual force required is always greater than the shear strength (Mitsomwang and Nagasawa, 2015).

Figure below shows that the typical punch-penetration in shearing. The area under the curve is the work done in shearing. The shape of the curve depends on process parameters and material properties. Figure 3.6 shows the relantionship of stress and strain.

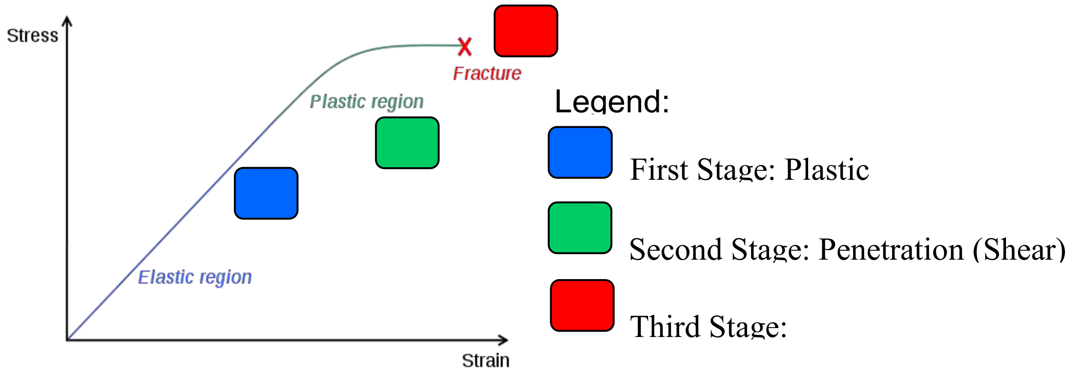


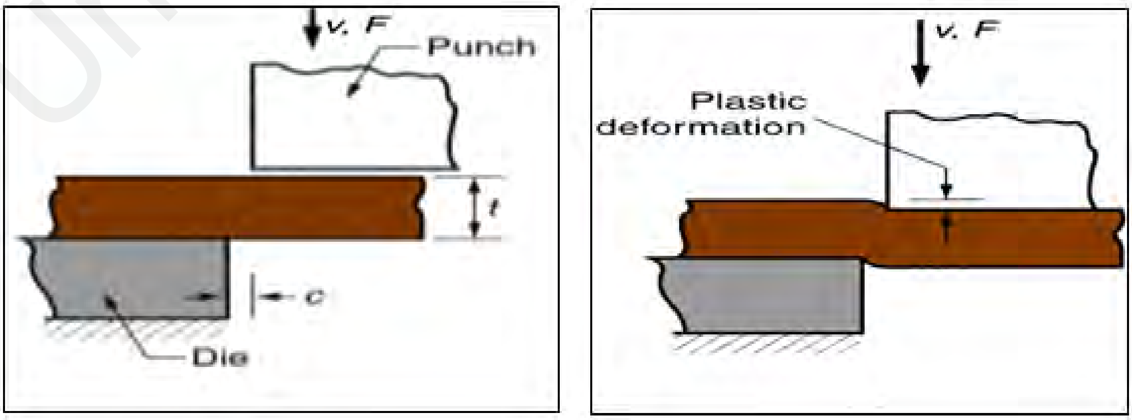
Figure 3.6: Relationship of stress and strain

3.8 Gradual Shearing Cut Method Stages

The gradual shearing method has three stages where stage 1 Plastic Deformation, stage 2 Penetration (Shear), and stage 3 Fracture.

3.8.1 Plastic deformation

This is the stage at which the puncher contacts the substrate and exerts pressure on it. When the elastic limit of the substrate is exceeded by the load and plastic deformation takes place. Figure 3.7 shows the first stage of plastic deformation.



a) Before the punch contacts work b) Punch begins to push into work

Figure 3.7: First stage (Plastic Deformation)

3.8.2 Penetration (Shear)

The puncher is forced to penetrate the substrate, and the slug is displaced into the die opening and thus the shearing of the slug from the substrate starts. Figure 3.8 shows the second stage of penetration (Shear)

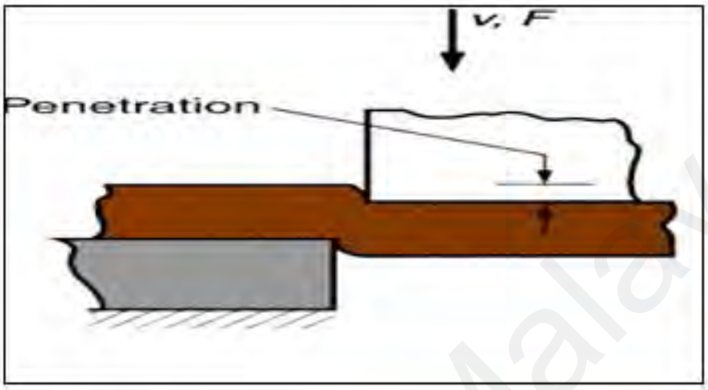


Figure 3.8: Second stage penetration (Shear)

3.8.3 Fracture

Further continuation of punching pressure then causes a fracture to start at the cutting edges of the puncher and die insert. As the fractures meet the slug is cut out of the substrate. Figure 3.9 shows the third stage of Fracture

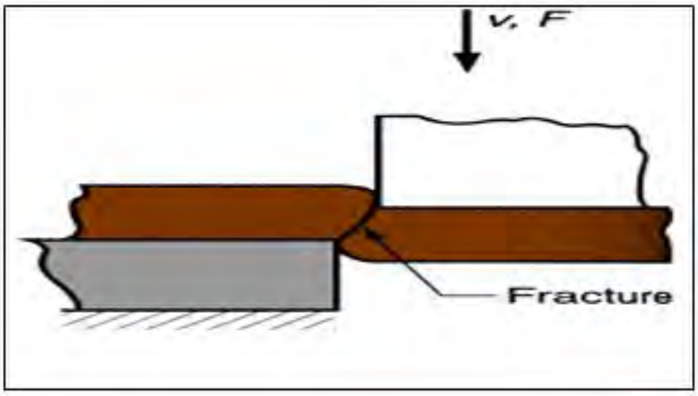


Figure 3.9: Third stage fracture

3.8.4 Gradual Shearing Cut Method Action

How does it work?

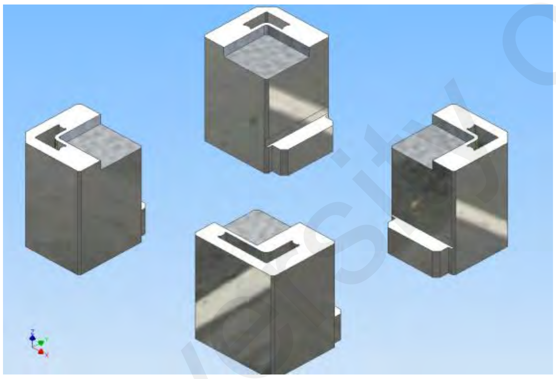
a. The substrate is placed on the die insert.

b. The puncher descends by the downward stroke of the singulation machine.

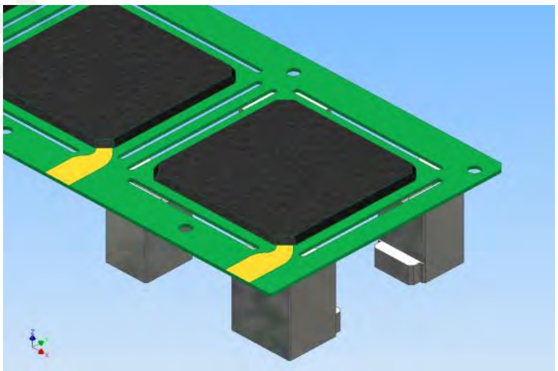
c. The cutting action takes place in 3 stages from the point the puncher touches the substrate to the point of the unit is singulated away from the substrate.

d. The gradual shearing takes place when the applied load exceeds the ultimate shear strength of the substrate material.

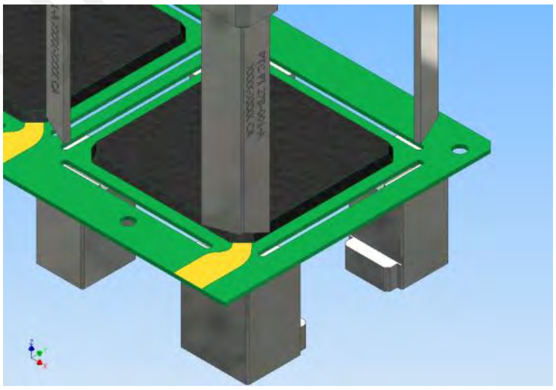
The figure 3.10 below shows the illustrations of gradual shearing cut method action



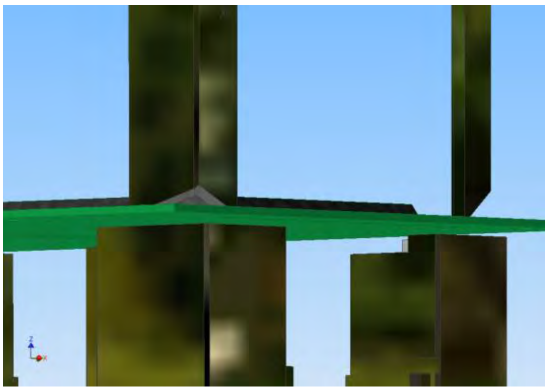
(A) Die Insert assembly



(B) Substrate landing on die insert



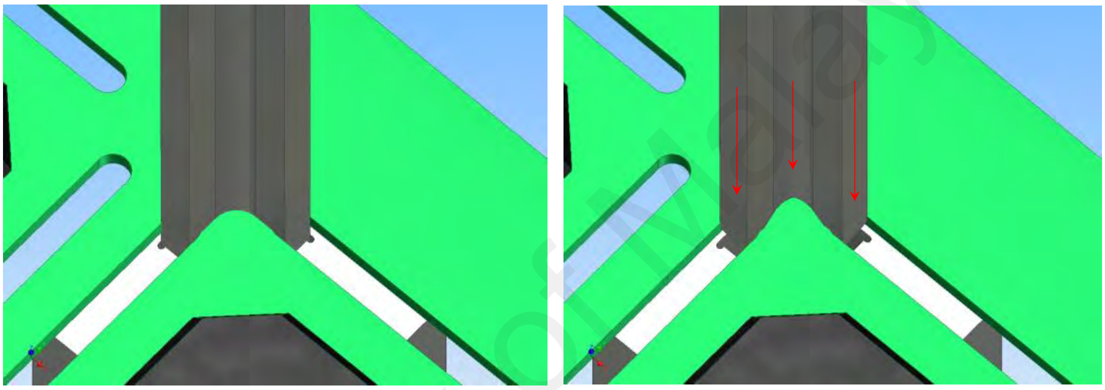
Top view



Side view

Top view Side view

(C) Shearing in action 70%



(D) Shearing down to cut 70% (E) Shearing down to cut 100%

(F) Shearing in action 100%

Figure 3.10: 3D View of shearing method stages

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Puncher Life Span

A study was conducted to make sure that the ultimate puncher life span can be sustainable until reaching the failure point. It has been measured on the quality of puncher by a few stages. This puncher material is able to sustain until 120k stroke count which means equivalent to 120k output produce without premature breakage. The punch broken trend also shows the significant results after the new 440 C Martensitic Stainless Steel took place.

0 to 50k	50k to 75k	75k to 100k	100k to 125k

Figure 4.1: Puncher quality measurement obtained from experiment

4.2 End Product Results

As refers to the below table, it has been measured from 0k to 50k and from 50k to 100k. After the implementation of 440c Martensitic Stainless Steel material, it had been monitored and deviated into two groups. During this two period, not much defects been highlighted compared to Carbide puncher. Quality of cutting profile started to show defects after it went cross 120k.

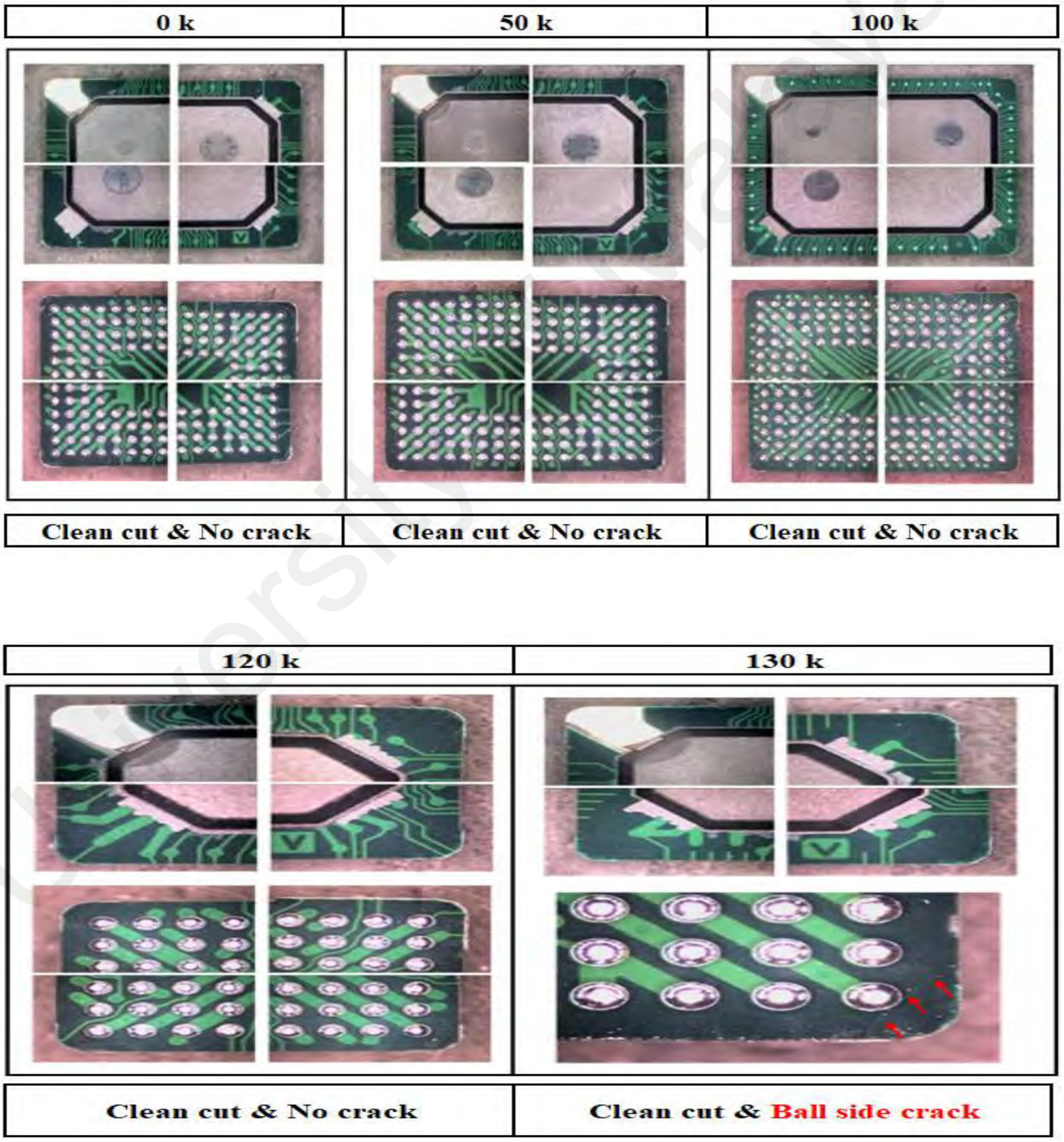


Figure 4.2: Deformation Behavior during Punching Obtained from Experiment

4.3 Output Counts

Output per month = 300,000 units x 4 weeks

= 1,200,000 units

Actual output = Target output - Reject output

4.3.1 Machine Alarm before implementation

The table 4.1 shows that the data collected for machine error from July 2018 to November 2019 before implementation of 440 C Martensitic Stainless Steel.

Table 4.1: Machine errors from July to Nov 2018

Month	Jul-18	Aug-18	Sept-18	Oct-18	Nov-18
Target Output	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000
Reject Output	1,777	1,224	2,839	2,086	3,321
Actual Output	1,198,223	1,198,776	1,197,161	1,197,914	1,196,679
Machine alarms	19	13	30	22	35

4.3.2 Machine Alarm after implementation

The table 4.2 shows that the data collected for machine error from December 2018 to April 2019 after implementation of 440 C Martensitic Stainless Steel.

Table 4.2: Machine errors from December 2018 to April 2019

Month	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19
Target Output	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000
Reject Output	1,450	1,086	875	753	550
Actual Output	1,198,550	1,198,914	1,199,125	1,199,247	1,199,450
Machine alarms	15	11	9	8	6

4.3.3 Production targets (Mass production system)

The table 4.3 and table 4.4 shows that the data collected before and after implementation of material 440 C Martensitic stainless steel. The data collected based on weekly average production.

Table 4.3: Performance data before implementation (Weekly Average)

Data Collected Based on Higher PPM (Before Implementation)	
Shift Pattern	: Two shifts of 12 hours : 7 days/week : Break time = 30 minutes lunch + 2 times 15 minutes breaks/shift
<u>Breakdowns</u> 1. Punch Broken 2. Others	 : 35 breakdowns of 60 minutes each : 78 breakdowns of 10 minutes each
Set-ups	: 3 products changeover averaging 30 minutes each
Output	: 120,000 components produced plus 3321 units scrapped
Production Rate	: Allowed Time 108 hours

Table 4.4: Performance data after implementation (Weekly Average)

Data Collected Based on Higher PPM (After Implementation)	
Shift Pattern	: Two shifts of 12 hours : 7 days/week : Break time = 30 minutes lunch + 2 times 15 minutes breaks/shift
<u>Breakdowns</u> 1. Punch Broken 2. Others	 : 15 breakdowns of 60 minutes each : 78 breakdowns of 10 minutes each
Set-ups	: 3 products changeover averaging 30 minutes each
Output	: 120,000 components produced plus 550 units scrapped
Production Rate	: Allowed Time 108 hours

4.4 Overall Equipment Effectiveness Calculations (OEE)

4.4.1 OEE Calculation before Implements

a. Maximum time available, (Shifts x hours x days)

= 2 x 12 x 7

= 168 hours

b. Loading time, (Maximum time available - Break time)

= 168 - (60/60) x 2 x 7

= 154 hours

c. Availability losses, (Breakdown + Set-ups)

= (35 x 1) + (78 x 5/60) + (3 x 30/60)

= 35 + 6.5 + 1.5

= 43 hours

d. Total operating time, (Loading time - Availability losses)

= 154 - 43

= 111 hours

e. Availability rate (a), (Total operating time / loading time) x 100

= 111/154 x 100

= 0.721 @ 72.1 %

f. Production rate = 108 hours

g. Total speed losses, (Total operating time – Production rate)

= 111 - 108

= 3 hours

h. Net operating time, (Total operating time - Total speed losses)

= 111 - 3

= 108 hours

i. Performance rate (p), (Net operating time / Total operating time) x 100

= 108 /111 x 100

= 0.972 @ 97.2 %

j. Quality losses, (Net operating time x Scrapped/Total output)

= 108 x 3321/300000

= 11.95 hours

k. Valuable operation time, (Net operating time – quality losses)

= 108 -11.95

= 96.05 hours

l. Quality rate, (Valuable operating time / Net operating time) x 100

= 96.05/108 x 100

= 0.889 @ 88.9 %

m. OEE, (Availability rate x Performance rate x Quality rate)

= 0.721 x 0.972 x 0.889

= 0.623 @ 62.3 %

4.4.2 OEE Calculation after Implements

a. Maximum time available, (Shifts x hours x days)

= 2 x 12 x 7

= 168 hours

b. Loading time, (Maximum time available - Break time)

= 168 - (60/60) x 2 x 7

= 154 hours

c. Availability losses, (Breakdown + Set-ups)

= (15 x 1) + (78 x 5/60) + (3 x 30/60)

= 15 + 6.5 + 1.5

= 23 hours

d. Total operating time, (Loading time - Availability losses)

= 154 - 23

= 131 hours

e. Availability rate (a), (Total operating time / loading time) x 100

= 131/154 x 100

= 0.851 @ 85.1 %

f. Production rate = 108 hours

g. Total speed losses, (Total operating time – Production rate)

= 131 - 108

= 23 hours

h. Net operating time, (Total operating time - Total speed losses)

= 131 - 23

= 108 hours

i. Performance rate (p), (Net operating time / Total operating time) x 100

= 108 /131 x 100

= 0.824 @ 82.4 %

j. Quality losses, (Net operating time x Scrapped / Total output)

= 108 x 550/300000

= 0.198 hours

k. Valuable operation time, (Net operating time – quality losses)

= 108 - 0.198

= 107.8 hours

l. Quality rate, (Valuable operating time / Net operating time) x 100

= 107.8/108 x 100

= 0.998 @ 99.8 %

m. OEE, (Availability rate x Performance rate x Quality rate)

= 0.851 x 0.824 x 0.998

= 0.70 @ 70 %

4.5 OEE Discussion

Table 4.5 shows that the overall equipment efficiency (OEE) was increased by 7.7 % (70 % - 62.30 %) From the above table, we can see that the percentage of availability rate and the quality rate has been increased. The most important portion is the quality of the products had increased almost 11% from 88.90% to 99.8%.

Table 4.5: Percentage of OEE before and after implementation

Improvements / Rate	Before Implementation	After Implementation
Availability Rate	72.10%	85.10%
Performance Rate	97.20%	82.40%
Quality Rate	88.90%	99.80%
OEE	62.30%	70%

4.6 Discussion

The project was started and progressed as per scheduled timeline is given. Challenges encountered and more time consumed during part fabrication. It's mainly due to the fabrication done by a third party and some delaying in sending and receiving the parts. Consequently, it's affected buy off and verification of new puncher.

440 C Martensitic Stainless Steel puncher able to meet the objective of this research however the life span of the puncher is limited to 120 k stroke count since the puncher tip

easily blunt after 120k of units produced. Further studies need to conduct in order to archive the life span of a puncher.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Most of the industrial companies/manufacturer chase after good produce of quality. It resembles the power and credibility of certain companies/manufacturer. In order to place them on the right track, many ways had been used and been implemented as some been successful and some leads to failure.

An analysis is done in selected Semiconductor Manufacturing Company, Carbide puncher been used for a long period. The result of using this puncher had questioned the quality at the end of the day. Production within 120k stroke counts randomly faced with puncher broken issue which questioned the quality produced. Man, Material, Method, and Machine have compressed the factors of premature puncher breakage and also preventive ways.

440c Martensitic Stainless Steel material has been introduced and it displayed much improvement compared to Carbide material. CQI has been successfully reached zero defects since the implementation of this material took over.

By using 440c Martensitic Stainless Steel material, the issue on quality shall be deemed and satisfaction of customer shall rise. More manufacturer could see a profit and at the same time, less financial loss for them. Many manufacturers felt satisfaction and more goods to produce without any hesitation.

5.2 Recommendations

a) Puncher and die insert pairing change implemented and controlled at 120k stroke count based on evaluation results.

b) Systemic controls via the machine stroke count counter. Once the die set reached the set limit stroke, the machine will automatically stop. Therefore, the technician will swap spare ready die set and continue run production.

c) Implemented Singulation Die Set Checklist to fill up die set in and out. In any defect encounter from die set, they will mark at defect column.

d) Recommendation for future works, the puncher lifetime can be improved when coated with Physical Vapor Deposition (PVD) thin film coatings.

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