EFFECTS OF ANNEALING ON PUNCHES HEAD AND THE REPURCUSSION ON THE PRODUCT LIFECYCLE AND COST (UTeM)

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This report is submitted
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DECLARATION

I declare that this project report entitled "Effects of Annealing on Punches Head and the Repercussion on Product Lifecycle and Cost" is the result of my own work except as cited in the references

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature	: ....
Name of Supervisor	: ....
Date	: ....

DEDICATION

To beloved mother and father, family and friends.

ABSTRACT

Punches are still a main tool used all around in the metalworking industry. They are mainly used for punching sheet metal to form small form products such as rivet sockets and various complex forms. The punches are disposable tool most often thrown away after fracturing. This, in large amount, could potentially harm the environment in the long-term period.

Annealing is a heating process conducted on metal workpiece to reduce the hardness and stabilise the workpiece. The application of induction heating annealing could aid the punches head in reducing its hardness thus allowing it to sustain more impact forces before wearing out. Applying this process, the number of punches needed for a typical stamping and blanking process could be reduced significantly.

This study case intends to investigate whether annealing would reduce the number of punches needed for a typical blanking or punching situation and to determine whether annealing the punches head would reduce the overall cost and reduce the metal scraps from production.

ABSTRAK

Punches masih merupakan peralatan utama yang masih digunakan dalam industry pembuatan besi. Punches kerap digunakan untuk menumbuk lubang pada kepingan besi untuk menghasilkan soket rivet dan pelbagai bentuk lubang yang kompleks. Punches ialah satu peralatan yang sering dibuang selepas ia retak atau rosak. Keadaan ini, dalam kuantiti yang besar, berpotensi besar untuk merosakkan alam sekitar pada jangka masa panjang.

Annealing ialah proses pemanasan yang digunakan atas alat kerja besi untuk mengurangkan kekerasan dan menstabilkan alat kerja tersebut. Applikasi seperti induction heating boleh membantu kepala punches dengan mengurangkan kekerasan pada kepalanya supaya punches tersebut boleh mengekalkan keupayaan untuk diketuk sebelum patah dengan lebih lama. Mengaplikasikan proses ini, jumlah punches yang diperlukan untuk proses stamping dan blanking boleh dikurangkan dengan nilai yang banyak.

Kes kajian ini turut berhasrat untuk mengkaji sama ada annealing akan mengurangkan jumlah punches yang diperlukan dalam proses tipikal blanking atau punching dan menentukan sama ada annealing kepala punches turut mengurangkan kos keseluruhan produksi dan mengurangkan pembaziran besi dari aspek produksi.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to everyone who gave me their guidance and co-operation throughout the whole year of this Final Year Project; those who are involved has made this final year project very significant and memorable to my approach to handling a project. I also would like to dedicate a special thanks to my supervisor, Dr. Siti Nurhaida – whom has taught me a great deal regarding on how to approach and tackle a project from scratch and how to implement an engineer-like mindset all the while providing me with her insights on the matter at hand.

This knowledge will be appreciated and be put into good use in the future if I get the opportunity to apply it. Special appreciation to my parents who supported me morally and financially throughout this past year. Lastly, I would also like to thank all who gave their assistance and guidance to me in order to complete this final year project.

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INTRODUCTION

1.1 Background

Metal Shear Forming has been a long-time production process used to fabricate product through process such as shearing, stamping, parting, blanking and punching. In this study, punching is the focus. Punching is a process where a sheet of metal is inserted between an upper shoe and lower shoe which comprises of other components; punches being the main component here. The punches come into contact with these sheet metal and is applied force on the shank shearing the sheet metal to the shape of the punch – be it round, ellipse or custom shapes.

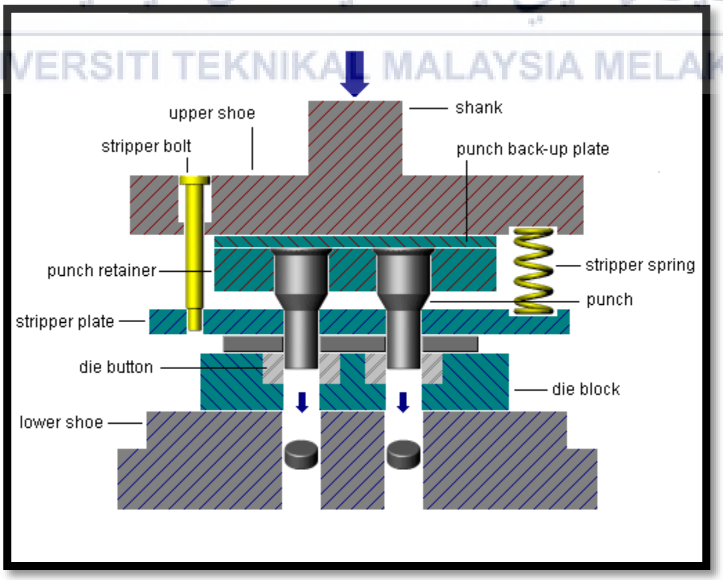


Figure 1.1.1 - Hole Punching Diagram Example

The punch is often replaced when it is broken and often it is ordered in a factory in large quantity to keep as reserved. There are two types of punches – standard and custom. More often than not, these punches are custom-made to meet with the unique dimensions of product to be produced. The punches often fail at the head as it is subjected to large amount of force from the shank through extensive usage of the punch; wear-and-tear is unavoidable and the same is applied to punches. There are multiple ways to prolong the lifespan of the punches – one of it being "annealing".

Annealing is a stress-relief process used to alter the mechanical property, hardness of a material and alter the physical properties by increasing the ductility. The process is essentially heating to high temperature and air cooling. There's a wide group of heat treatment processes and is executed mainly for homogenization, recrystallisation or relief of residual stress in typical cold worked or welded components. There is various method of annealing such as full annealing (conventional annealing), induction heating, isothermal annealing etc.

Mechanical properties affected by annealing in punches head is hardness as aforementioned. The decrease in hardness at the head of the punches will allow the punches to be subjected to force for longer usage before breaking thus extending the punches lifespan. This could lead to decrease of maintenance cost and reduces the waste of scrap materials.

1.2 Problem Statement

Punching is a manufacturing process that have been around since the Industrial Revolution in 1760 at Great Britain. Punching is also known as metal forming. The punches formed through manual production method such as lathing, grinding, surfacing etc. The mechanical properties of these punches are usually very similar to the raw material used to form aforementioned punches. Annealing the head of the punches reduces the hardness of punches head in which theory should prolong the lifespan of the punches; at an extra production cost. The problem is to determine the difference of cost between non-annealed punch and annealed punch and which is more cost-efficient and the effects towards the environment.

1.3 Objective

The objectives of this project are as follows:

1. To investigate the correlation of annealing on punches head to the number of cyclic loads attainable by the punches being subjected to a force and comparing the difference of standard and annealed punches in terms of cyclic loads.
2. To determine the performance difference of non-annealed and annealed punch and the worth of annealing to a punch's performance to cost ratio.
3. To estimate the increase of production cost when annealing punches.

1.4 Scope of Project

The scopes of this project are:

1. Only hardness will be considered as the manipulative variable in the simulation of the study regarding the difference of annealed punch and standard punch. The hardness will correlate to the failure of the punch.
2. Only one type of punch design will be used for the testing.

1.5 General Methodology

The actions that need to be carried out to achieve the objectives in this project are listed below.

1. Literature review

   Journals, articles, or any materials regarding the project will be reviewed.
2. Prerequisite for Machine Testing

   Data required for testing shall be obtained before the main test.
3. Testing

   A machine testing designed to emulate the real life working condition of the punching or stamping process will be conducted on the punches. The data will be related to real-life price of the punches and cost will be calculated between annealed punches and standard punches.
4. Report writing

   A report on this study will be written at the end of the project.

The methodology of this study is summarized in the flow chart as shown in Figure 1.5.

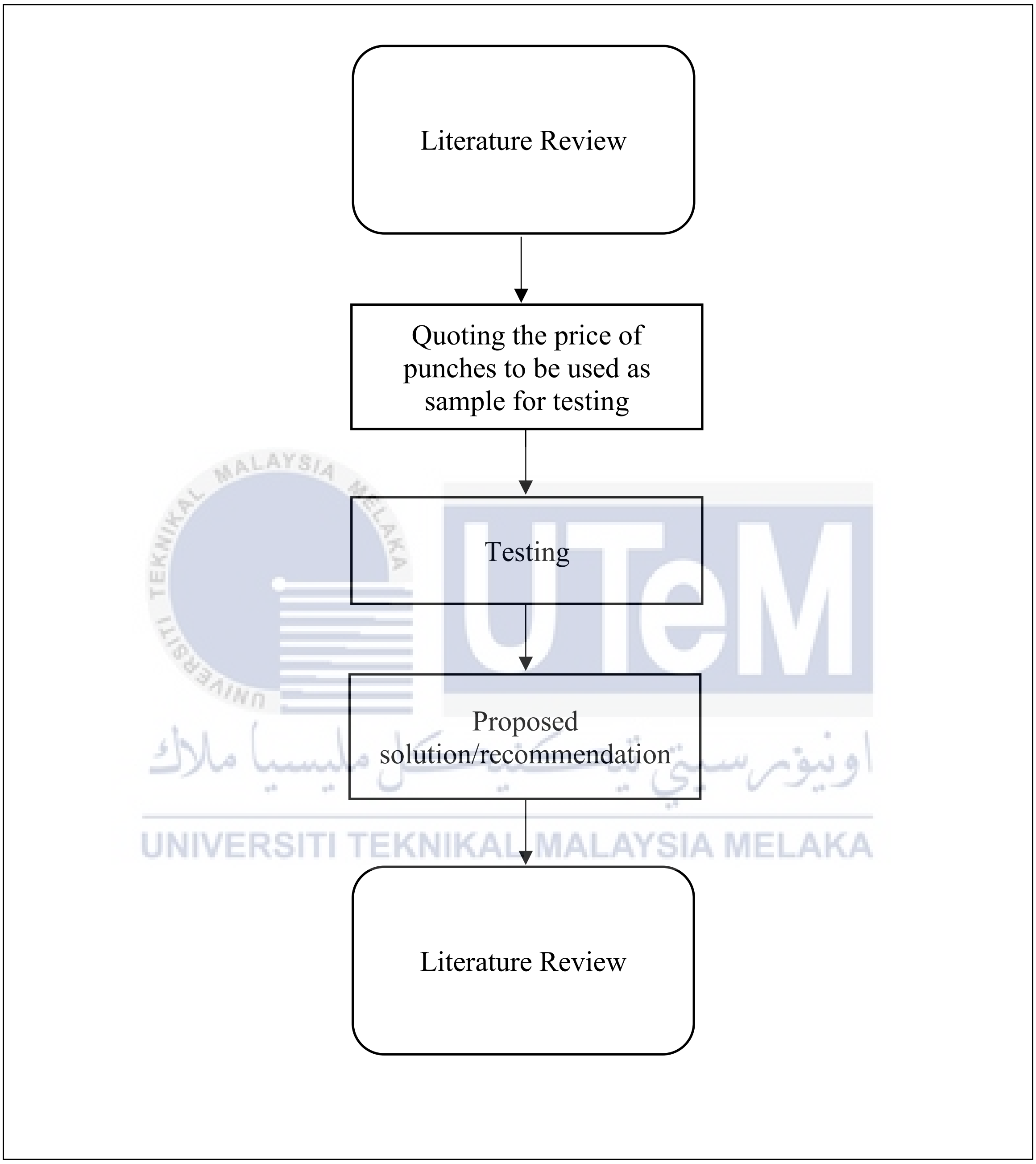


Figure 1.5.1 - Flow chart of the methodology

2 Chapter 2

LITERATURE REVIEW

2.1 Metal Working Manufacturing

Metal working is also known as metal forming which involves mechanical working of metal workpieces. Metal working operations are often executed to either create a new shape or to enhance the properties of the metal. Forming the solid workpiece are divided into two categories, non-cutting and cutting. Non-cutting forming involves process such as forging, rolling and pressing and cutting forming involves machining operations performed on various machine tools. The main objective of metal working is to shape the workpiece into desired shape and size while catering to the provided dimensions and specifications under the action of externally applied forces.

Metal workpiece are commonly worked by plastic deformation because the workpiece would benefit from the mechanical properties imparted onto it. The necessary deformation in a metal workpiece can be achieved by application of mechanical force only or by heating the metal and then applying a small force. The impurities present in the metal are then elongated with the grains and in the process, get broken and dispersed throughout the metal. This also decreases the harmful effect of the impurities and improves the mechanical strength. This plastic deformation of a metal takes place when the stress caused in the metal, due to the applied forces reaches the yield point. The two common phenomena governing this plastic deformation of a metal are (*a*) deformation by slip and (*b*) deformation by twin formation. In the former case it is considered that each grain of a metal is made of a number of unit cells arranged in a number of planes, and the slip or deformation of metal takes place along that slip plane which is subjected to the greatest shearing stress on account of the applied forces. In the latter case, deformation occurs along two parallel planes, which move diagonally across the unit cells. These parallel planes are called twinning planes and the portion of the grains covered between them is known as twinned region. On the macroscopic scale, when plastic deformation occurs, the metal appears to flow in the solid state along specific directions, which are dependent on the processing and the direction of applied forces. The crystals or grains of the metal get elongated in the direction of metal flow. However, this flow of metal can be easily being seen under microscope after polishing and suitable etching of the metal surface. The visible lines are called fibre flow lines. The above deformations may be carried out at room temperature or higher temperatures. At higher temperatures the deformation is faster because the bond between atoms of the metal grains is reduced. Plasticity, ductility and malleability are the properties of a material, which retains the deformation produced under applied forces permanently and hence these metal properties are important for metal working processes. (Singh, 2006)

As mentioned before, there are two types of forming; non-cutting and cutting. Non-cutting is when a sheet metal undergoes a process to change the overall shape of the metal sheet yet the quantity after the process is still one sheet metal just deformed or bent to desired shape and dimension. Forming operations covers bending, drawing and squeezing.

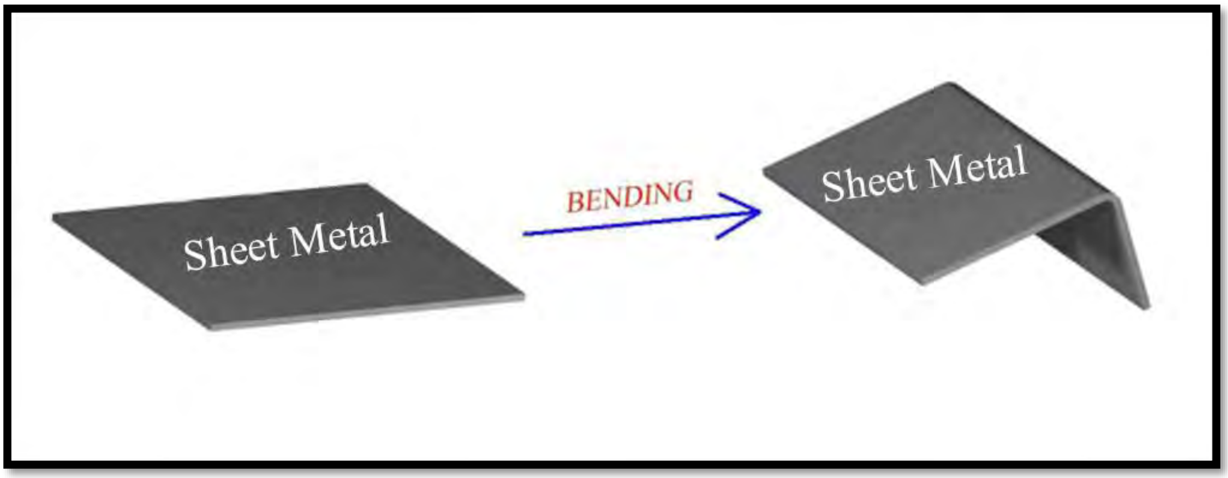


Figure 2.1.1 – Metal Sheet Bending Process

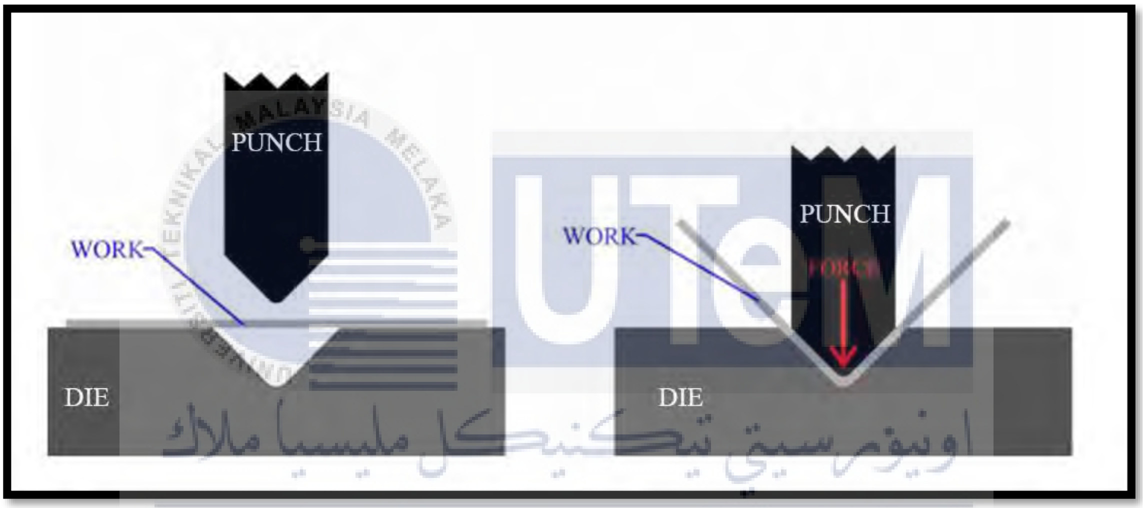


Figure 2.1.2 – Punching Process Example 1

Cutting forming, on the other hand, is when a piece of metal sheet metal subjected to a cutting process to form multiple pieces of smaller sheet metals. It does not necessarily require symmetrical cut, it could be any shape and the excess sheet metal is thrown away or recycled as waste material. This cutting process encompasses blanking, notching, perforating, trimming, shaving, slitting, lancing, nibbling and punching.

Figure 2.1.3 – Metal Sheet Cutting

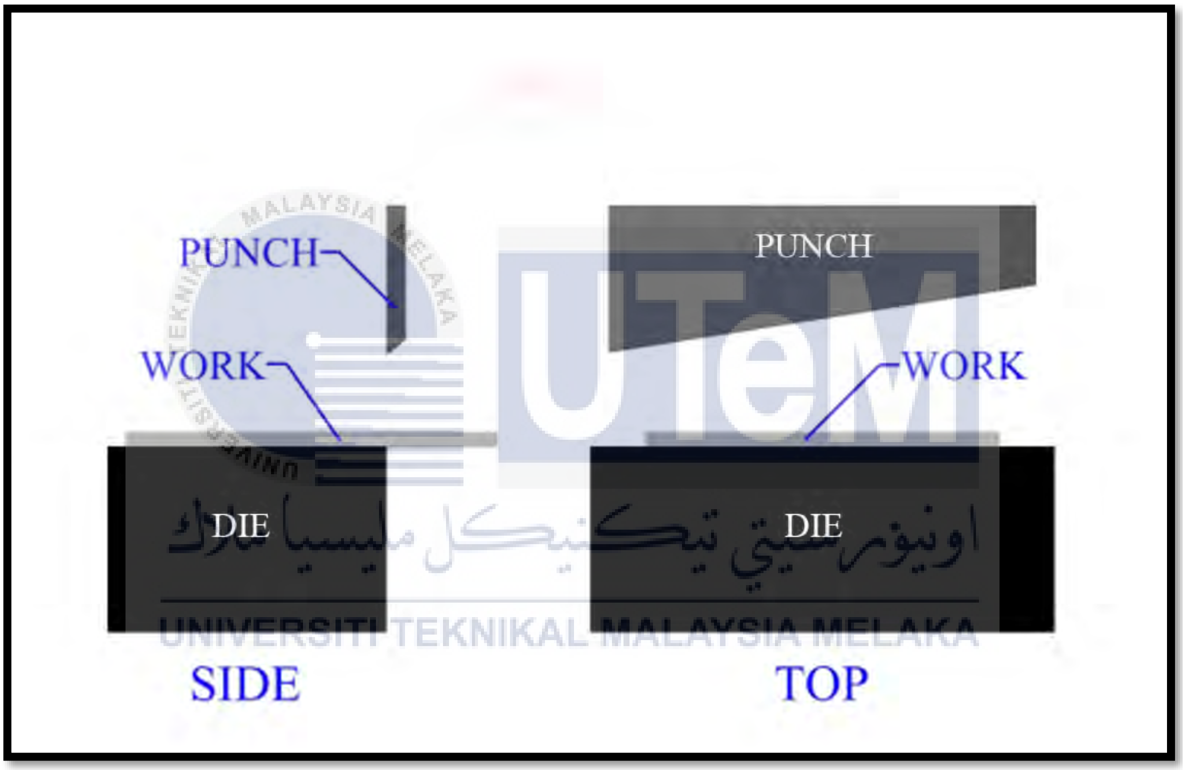


Figure 2.1.4 – Punching Process Example 2

In this case study, we will be focusing partly on punching process.

2.2 Punching (Shearing)

Punches are essentially a metalworking manufacturing technique that falls under cold working method specifically called cold extrusion. It is a cutting operation that require specific tools and tolerance for certain material; often a punch and a set of die. The punch will be piercing the material while the die limits the depth of the punch. This method of manufacturing is mainly used to make small components from ductile materials.

Impact extrusion of material is accomplished where the work blank is placed in position over the die opening the punch forces the blank through the die opening causing the material to flow plastically around the punch. (Singh, 2006)

Impact extrusion is a type of specialty cold forming used for larger parts with hollowed cores and think wall thickness; such as pins. The impact extrusion process begins with a tightly controlled metal blank that is placed in a die that is located on a vertical mechanical or hydraulic press. A punch being driven into a die by the force of the press causes the metal blank to flow (extrude) in a forward or backward manner. The process of impact extrusion means to pierce a metal blank at such force that it changes the metal into a plastic state that allows the metal to actually flow in to a die shape and around the punch. The challenges with impact extrusion are for the engineer to design a process for the impact extrusion shape with the minimum number of process steps. (St. Clair, 2017)

These punches are usually made up of hard metal but may be subjected to different materials such as Titanium Nitride (TiN); completely dependent on the material to be extruded. The material is dependent on the material that will be sheared or punched. If the blank metal sheets are made up of aluminium, for example, the hardness of the punch would not be so high as it would be an overkill and a wasted tooling used since the higher the hardness of the punch, the higher the price of the punch. Naturally, the punches would be higher in hardness than the material otherwise the blank metal sheets would not be able to be punched (sheared) because the plastic deformation of the metal sheets could not be achieved.

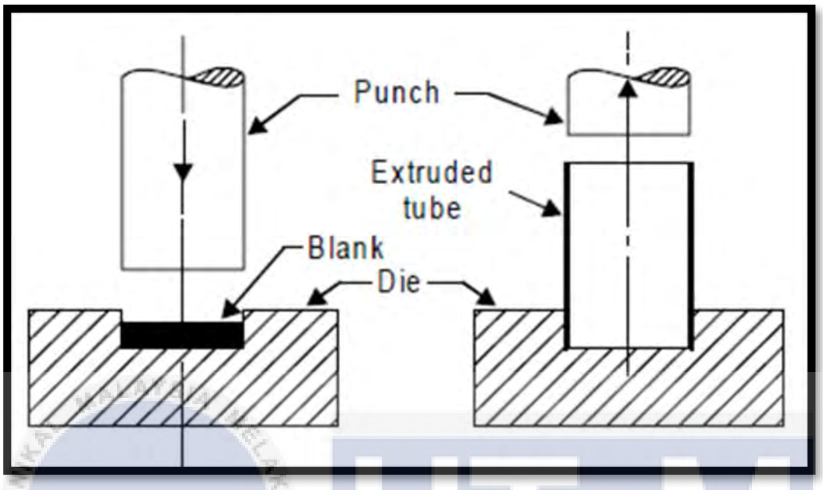


Figure 2.2.1 – Punching Process Cross-section

This process is can also fall under the category of metal shearing since the material to be "punched" are subjected to shearing force for the blank to be formed as shown in Figure 2.2.2

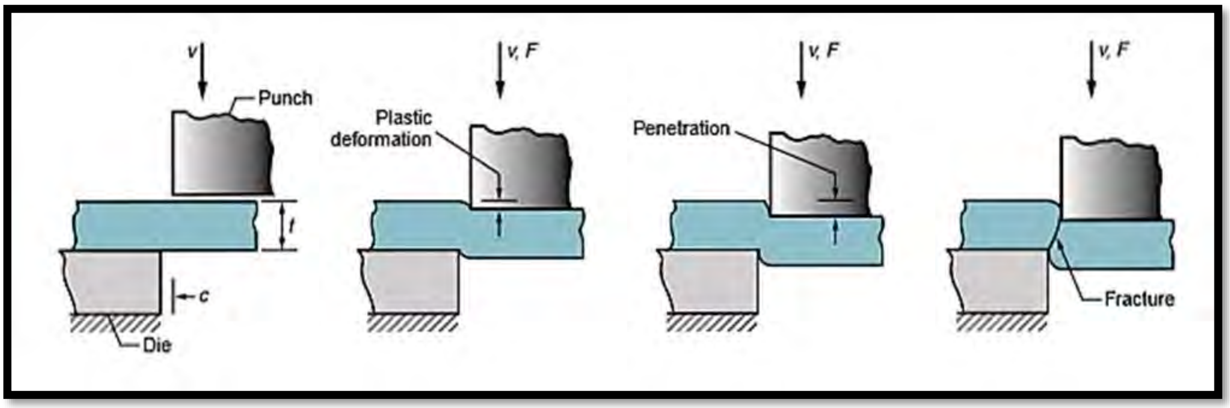


Figure 2.2.2 – Punching Process Shearing

Punches usually fail at the joint between the head of the punch and the bottom part of the punch (the part that is in contact with the working material). Punch head breakage can lead to serious problem mainly in heavy punching and fast speed punching because of the compression that occurs during cutting working condition. Rapid strain rates that occur in high speed stamping may increase the punching load from normal shear strength to the ultimate tensile strength which could lead to deformation. The crack or breakage at this part will lead to failure because the punch will no longer be able to withstand the heavy punching and fast speed punching as the force no longer can transverse through the body of the punch. Failed punches are normal and unavoidable, but if the lifespan is increased, it would bring down manufacturing cost and decrease waste product from tooling. (Hedrik, 2018)

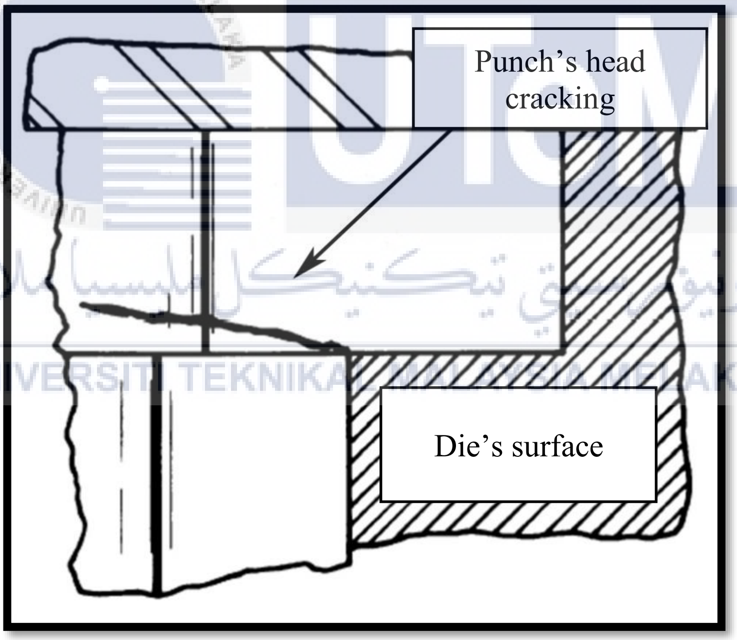


Figure 2.2.3 – Punch Failure Cross-section

Punches fail after extensive usage as they are subjected to impulsive force multiple times and the lifespan varies depending on the working material it is used with to form blanks. The higher the hardness of the punch material, the worse it will be when a crack forms. Higher hardness may allow the punch to shear the blank metal sheet better but the drawback is that the higher hardness also changes the mechanical property of the punch; it is brittle when the hardness is high. (Fehling, 2004)

As with anything this failure is inevitable but an alternate design could prolong the lifespan of the punches as shown in Figure 2.2.4

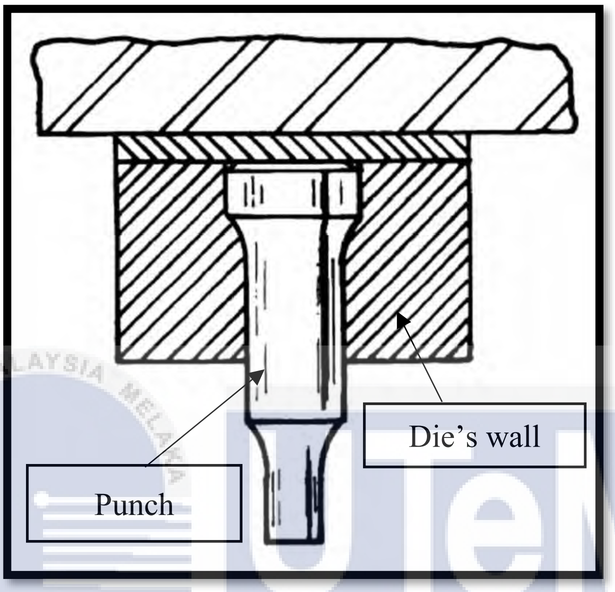


Figure 2.2.4 – Example of a Typical Punch Design

Punches are widespread used in many industries to produce various products, equipment, part-of-equipment etc. The usage of punches within one company is usually a lot and the punches are ordered in bulk or large quantities and are often replaced when they are broken. To save money and decrease waste product from tooling – since punches are used in high amount – the punches are subjected to post-treatment or have the design reconsidered to overcome this wastage. But is it worth it to enhance the punches with post-treatment (which increases the cost a fair bit) or skip the post-treatment and order more standard punches?

2.3 Annealing and Induction Heating

2.3.1 *Annealing*

Annealing is a heating process conducted on metal workpiece to reduce the hardness and stabilise the workpiece. There is another reason for annealing besides to reduce the stress and that is to homogenise the structure.

Every time a metal workpiece is machined or processed through machining, it accumulates stress and gets harder. After certain amount of process, the workpiece becomes too hard to work on or just too difficult to work on so that annealing is required to release the stress. (BOC, 2013)

The decrease in hardness of the workpiece would result in the workpiece being less prone to break because of brittleness.

Annealing is basically a very simple process. The metal is heated up, held at temperature for a time, then it is slow cooled. If the condition of the surface does not matter or cleaning takes place later then it can be done in air. If the surface finish does matter then a protective atmosphere is used. Typically, this would-be nitrogen with a small hydrogen addition. Steel is a bit different from the rest of the metals so it will be addressed separately. (BOC, 2013)

Annealing is done on many types of materials ranging from steel to ABS plastic. On steel, there are two types of annealing which are process annealing also known as normalising which is done in the austenitic range above 720°C and another type of steel annealing is subcritical annealing also known as sphereoidising which is performed at ferritic range below 720°C. (BOC, 2013)

As discussed before, the goal of annealing is to soften a material in the least amount of time. The resulting effect would not be as apparent to the naked eyes but instead on the microstructure of the material. This could be seen in Figure 2. below.

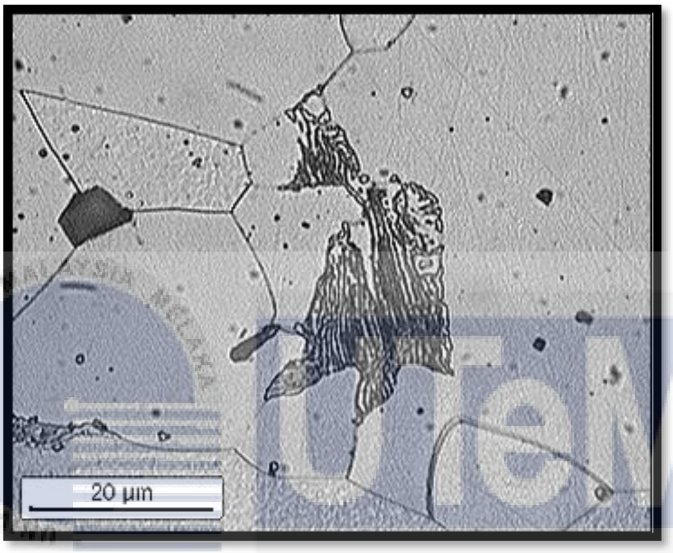


Figure 2.3.1.1 – Microstructure of Ferrous Metal after Annealing

The lighter grains are soft ferrite (iron) and the dark grains are pearlite; the former is made up of alternating layers of hard iron carbide and soft ferrite. If we imagine the microstructure as glass plates with a plasticine in between, then it would still appear as fairly stiff. Through sub-critical steel annealing (sphereodising), the layers of iron carbide into globules would be coalesced hence producing a very soft material (for steel). Continuing the previous analogy about glass and plasticine, now there are marbles in plasticine; which is a much more malleable material. (BOC, 2013)

2.3.2 *Induction Heating*

Induction heating is an annealing method that utilises alternating current in driver coils to induce currents in an object and create heat through precise placement and transient excitation pattern. Similar to aforementioned purpose of annealing, Induction heating is mainly targeted to release stress or reduce hardness localised at specific part of a metal body (may be applied to other materials as well). In this study, the induction heating is applied to punches head. The punches would be set upon a specified jig as shown in Figure 2.5 below:

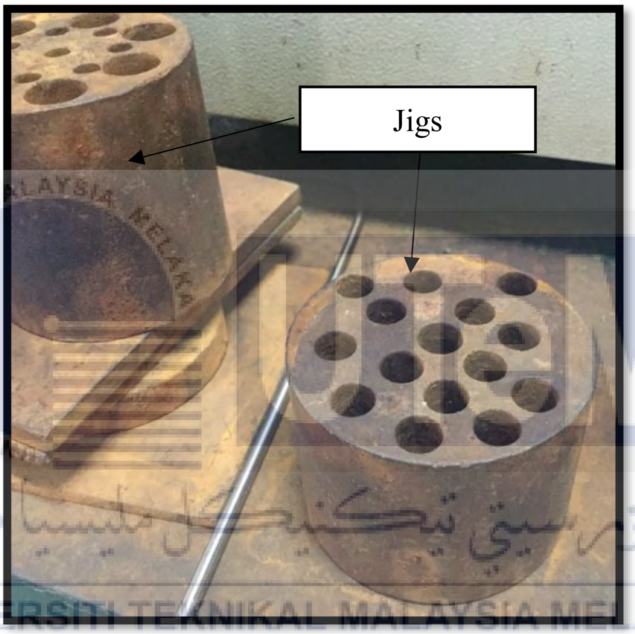


Figure 2.3.2.1 – Jigs for annealing

The punches bottom part would go into the holes to prevent them reacting with the induction heating; the targeted part is the head to reduce the hardness and release the stress. There are different jigs for different dimension of punches or special jigs for special shapes.

As for the induction heating, it is mainly constructed from a copper tube shaped into a coil. Inside the tube, chilled water is circulated as long as the machine is running.

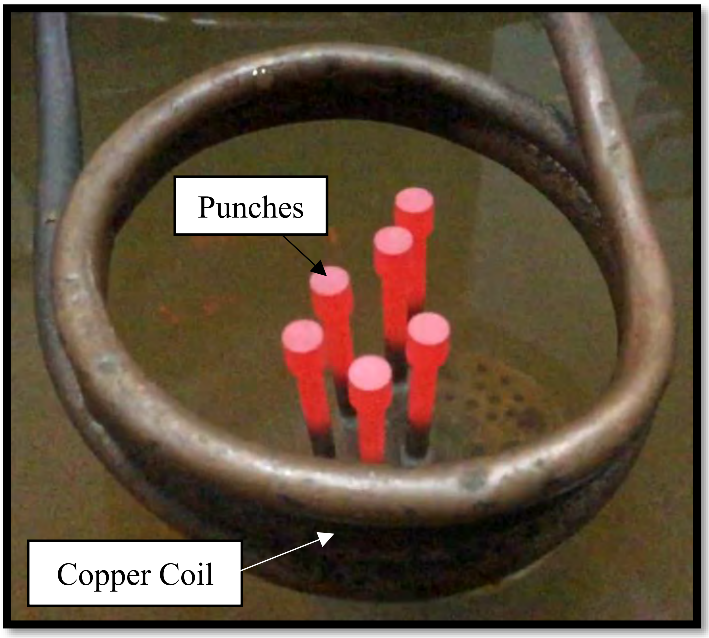


Figure 2.3.2.2 – Annealing in Progress

The punches when heated are glowing red at a high temperature. The induction heater is regulated using a region of frequencies. A typical induction heating application involve this coil driven by a high current at some kilohertz (KHz) frequency and a conductive target object is place in between the coil to induce currents and create heat. The copper coil is not heated at all during induction; it is actually cold enough to touch safely without getting burned. The punches in the middle however is subjected to induced heat. As seen in Figure 2.6, the punches are glowing at the top part while the bottom part are submerged in water as to retain their mechanical properties. After the induced heating is done; which is usually 10 seconds for punches with Ø3-4 mm, about one minute for punches with Ø20-30 mm, the heated punches head are left to air quenched (air cooling). This will release the stress build-up and reduce the hardness.

Induction heating was first noted when it was found that heat was produced in transformer and motor windings. The theory of induction heating was studied so that motors and transformers could be built for maximum efficiency by minimizing heating losses. The development of high-frequency induction power supplies provided a means of using induction heating for surface hardening. The early use of induction heating involved trial and error with built-up personal knowledge of specific applications, but a lack of understanding of the basic principles. Throughout the years the understanding of the basic principles has been expanded, extending currently into computer modelling of heating applications and processes. Knowledge of these basic theories of induction heating helps to understand the application of induction heating as applied to induction heat treating. Induction heating occurs due to electromagnetic force fields producing an electrical current in a part of workpiece. The parts heat due to the resistance to the flow of this electric current. (Haimbaugh, 2001)

Induction heating is utilised by a lot of metalworking industries. The usage is as mentioned before, to relieve stress from the workpiece, but the usage depends on the industry application; some may use it as solely to reduce stress, others might use it to homogenise the internal structure of the workpiece to which would make the workpiece more reliable and delivers almost consistent performance. Digressing from the metalworking, there had been some experiment with the recent technologies like 3D printing as well where the fused-deposition model is induced with high temperature as to laminate the composition with vertically stacked layers consisting of material fibres with voids. Through annealing, the voids in the 3D printed part reduces in the void size and increases in its tensile strength; though the shape is slightly deformed in the process. Getting back to metal, this concept of closing the gap between the molecules in the workpiece is a great tool to modify the mechanical properties of many materials. (Zinn & Semiatin, 1988)

2.4 Industrial Training Experience (19^{th} June – 25^{th} August)

2.4.1 *Broad World Precision Industry*

From 19^{th} June to 25^{th} August, an industrial training at Broad World Precision Industry (M) Sdn Bhd for ten weeks was fulfilled. This is as partial fulfilment for bachelor degree for mechanical engineering (with honours). The objective there was to gain experience in real-life working environment and practice the right working attitude as well as to try apply knowledge learned in addition to gaining new skills or knowledge and be aware of current technologies.

A brief history about the industry, Broad World Precision Sdn. Bhd. is a Taiwan based industrial company which specialized in manufacturing precision bit, punches and bushes first (during their early years). They were previously called Mega Jourder as they are a part of the Jourder industry, their branches are available in China and in Taiwan as well; this particular company was the pioneer of this manufacturing type before they are overshadowed by their larger counterpart. Nowadays, instead of opting for large quantity order, Broad World Precision accept highly specialized design and usually comes at less than 10 pieces per order. They now operate under new idea which is quality of quantity. Highly specialized orders are very precise and comes at myriad of tolerances and design. They almost never manufacture the same work piece twice. Broad World Precision (BWP) was founded in year 1982 and they just celebrated their 30^{th} anniversaries on 2012. Through perseverance, continuous improvement and creative innovation, the company has grown to become one of the leading manufacturers of components for Mold & Dies industry. Spreading their wings worldwide, BWP Malaysia was established in 1989 to meet the ever-growing market demand. They have evolved from being just a manufacturer of Mold & Die components to a globalized company that provides precision parts and solutions to meet the rising challenges in the ever-changing global market. They specialized in manufacturing special punches and dies made to their customers' specification for various industries ranging from metal stamping, plastic injection molding, automation, electrical and electronic appliances, medical, oil and gas to automotive industry. Today, their affiliates synergize with their effort to provide customer product and service excellence has made them the most preferred supplier among their customers'.

The production department workplace was divided into two main departments that are Lathe Section and Grinding Section. Lathe section – in brief – is the place where the materials are taken from and shaped into the general dimension with high tolerance before going into heat treatment. Grinding section is the department where the heat-treated workpiece is grinded to the exact dimension with very small tolerance.

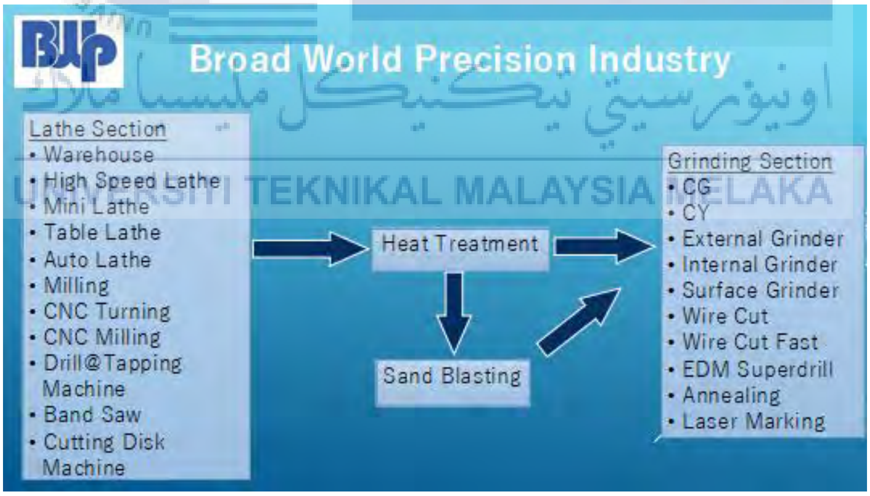


Figure 2.4.1.1 – Brief Overview of the Production Department

In the grinding section, there is an annealing machine located within the same premise.

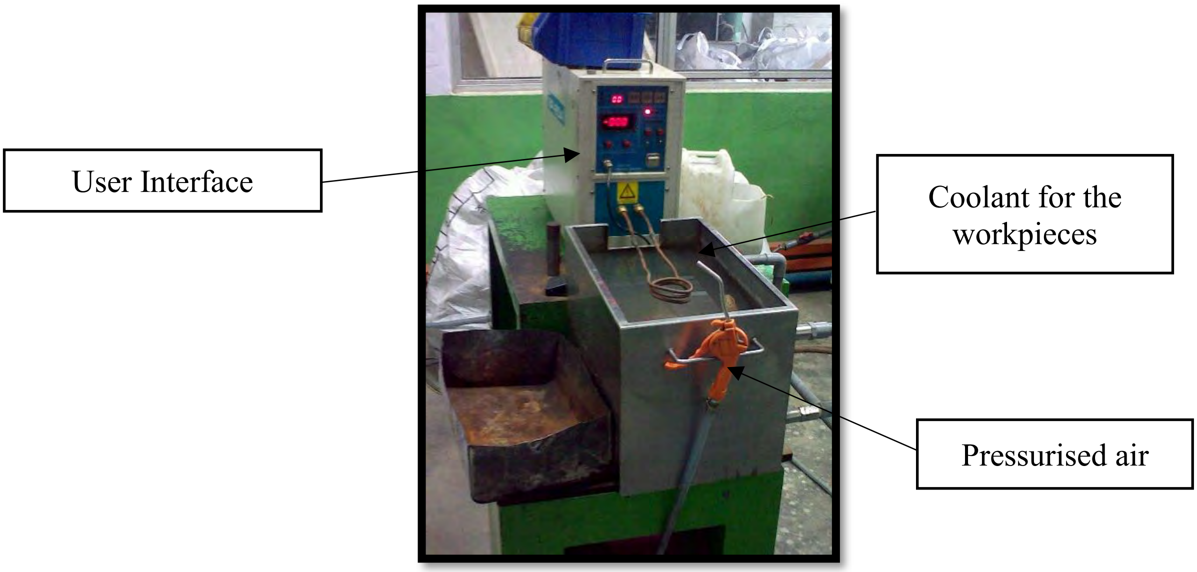


Figure 2.4.1.2 – Annealing Machine

The process that this annealing (SP-25A) machine does is to decrease the hardness of the workpiece to around 40 HRC; it is often used on punches head. The largest diameter of punch it can operate on is Ø30 mm and the smallest it can operate on is Ø3 mm (note that this limitation is set by the limitation of the jigs and the copper coil)

Annealing is also a process which relates to tempering and heating; annealing is a process in which a metal is heated to a particular high temperature, held there for a period of between several hours and several days, and allowed to cool. In order for the annealing process to occur correctly, this cooling process must be slow in steels and other ferrous metals. Metals are generally annealed at a temperature slightly above the point at which recrystallization occurs. Special furnaces are used in the annealing process. Conditions in these furnaces are tightly controlled to ensure that the expected changes are taking place.

Annealing has several uses. Annealing can increase ductility and alleviate internal stresses that contribute to brittleness. Annealing can also increase toughness and homogeneity of metals. Furthermore, metals may be annealed to prepare for further heat treatment, in order restore ductility to the metal prior to further working. Physically, the annealing process involves diffusion of particles within a material. The material must be heated sufficiently to allow free movement of particles; in steels this critical temperature is approximately 723 degrees Centigrade. Steels must be cooled slowly to allow for adequate diffusion of molecules. In fact, the speed of cooling is a critical difference between annealing and tempering. Finally, the environment in which a material is annealed is critical. Steels can be annealed in a carbon-rich environment to facilitate carburization, which has certain desirable advantages. However, if carburization, oxidation, or other defects are to be avoided, annealing must be carried out in an environment free of such elements. (Hinrichsen, 2011)

2.4.2 *Customer Order*

Stationed in Production Department main office, an opportunity to help out in terms of managing the work order and aid the supervisor (En. Zalliq bin Khalid) in-charge was presented. There were many types of order for various parts and designs but punches are the main order encountered in the production department.

For a typical punch order, the design and dimensions are provided by the customer but it required some adjusting and inquiring back and forth with the customer to compromise with the production department machine limitations and achievable tolerances. The order came in multitudes of various shapes and tolerances; ranging from something large as Ø30 mm to something small as Ø0.4 mm.

The order came from both local and oversea customers. The noticeable difference – to my observation – is usually that the customer from oversea always includes annealing in their punches order but their orders are usually fewer in quantity while the local order often order in large quantity but skips on annealing. Factoring out the materials both local and oversea companies ordered, this piqued an interest. Oversea orders are usually from European countries such as German, Spain, Italy, France etc.

Inquiring with the supervisor in-charge regarding this practice of skipping annealing and ordering in large quantity rather than the proper method, the supervisor in-charge explained that this a method customer use to save on tool cost – more processes involved to produce a finished workpiece would increase the price of individual workpiece – and this practice is common in Malaysia.

A quantification of the exact amount of money saved through this wasting and non-environment friendly practice compared that to the ones used by oversea companies could be determined through a simulation. Moreover, this practice of ordering large amount of punches in bulk is using more material compared to the heat induction alternative. Since the punches are disposable, the larger the amount of punches ordered are used, the more broken punches (waste material) is produced; which have unrepairable environmental effects. These waste materials require additional process to be processed back into usable material which involves processes such as smelting, shredding, magnetizing to differentiate the types of metals (ferrous and non-ferrous) etc. These extra work leads to more energy expended, more manpower used and increased cost; which all could have been avoided if early steps had been taken.

2.5 Metal Recycling Rates

Recycling metals is a fruitful sustainability strategy, but the information regarding recycling metal is scarce. There are various recycling rates for up to 60 types of metals which include various recycling metrics, aspects of recycling processes and present current estimates on global end-of-life recycling rates. Over the years, the metal usage in various industries increases over time and long metal in-use lifetimes also increases. Because of relatively low efficiencies in the collection and processing of most discarded products, inherent limitations in recycling processes and the fact that primary material is often relatively abundant and low-cost which thereby keeps down the price of scrap. (Graedel et al., 2011)

Recycling is a good environmental-friendly practice that should be implemented by most industries, including metal scraps recycling. While recycling is a good practice, it costs money to properly recycle any material including scrap metals which should be considered into financing. The more ideal step would be to prolong the product's life as much as possible before recycling it as a secondary source material.

Metals are subdivided into two distinct sources, primary sources and secondary sources. Primary source metals are those that come from the traditional sense of obtaining metal ores such as mining and excavating from the Earth's natural resource. Secondary source metals are the by-products of the scrap metals from primary source which no longer serves their original purpose. The environmental benefits of increasing reliance on secondary metal production include saving energy, the environment and reducing waste streams. Only through a concerted effort can society recover a maximum amount of metal from the industrial system to benefit the environment. (Wernick & Themelis, 1998)

2.6 Justification

Considering the previous subchapters, the study case regarding the effects of annealing on punches head is covered. To study the repercussion on the product lifecycle and cost, however, requires simulation and experimentation. This will be further investigated in future chapters utilising various testing machines.

3 Chapter 3

METHODOLOGY

3.1 Introduction

This chapter – in essence – describes the methodology used in this case study to obtain data related to the study case. In this chapter, explanation in detailed descriptions will be provided for implementations and achieving the main objectives as stated in previous Chapter 1. The stages of this case study are explained and described. The purpose of this chapter is achieved through the usage of detailed flow chart and Gantt chart – and other supporting diagrams or figures – which directs the study case and provides an overall view of the general work process and any aspects involved.

3.2 Methodology Flow Chart and Gantt Chart

A flowchart is a tool to better deliver a sequence of operations through illustration to get to the solution of the problem. Flowcharts are generally drawn in the early stages of a project/assignment before the actual process is even started. Flowcharts are easy to understand and could be interpreted by various different people yet still maintaining the essence of the thing need to be done; without the risk of being misinterpreted or lost in interpretation.

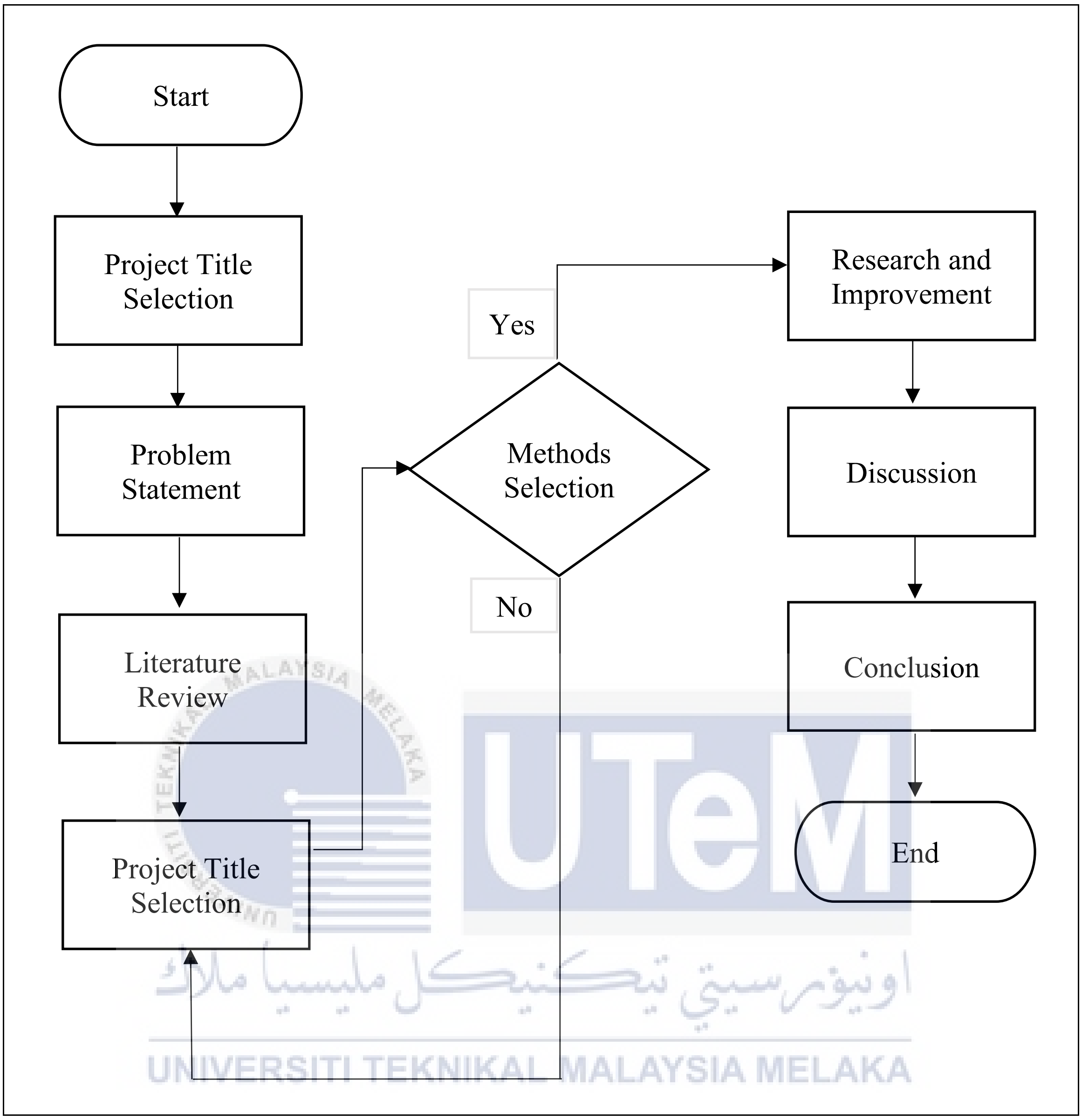


Figure 3.2.1 – Flow Chart for Overall PSM

Gantt chart is a productivity tool that aids in developing a plan for achieving the end-goal of the objectives. A Gantt chart is constructed with a horizontal axis that act as the total time span of a project, it is divided into small parts depending on the total time required. The vertical axis signifies the tasks that constitute to the fundamentals of the project such as: selecting PSM topic, topic verification, setting the objectives, collecting data and information etc. Using this tool, a clear illustration of the project status is achieved at any point of the actual progress; whether the project is delayed or right on time.

NO	TASK	Week														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Selecting PSM topic															
2	Topic Verification															
3	Objectives, Scope of Research and Problem Statement															
4	Collecting Data and Information															
5	Research (Journal)															
6	Flow Process															
7	Literature Review															
8	Methodology															
9	Preparation of Draft Report of PSM I															
10	Submission Report of PSM I															
11	Preparation of Presentation															
12	Presentation															

Table 3.2.1 - Gantt Chart for PSM I

NO	TASK	Week														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Discuss changes for PSM II															
2	Inquire Test Material Costing															
3	Inquire Machine Specifications for Testing															
4	Real Test															
5	Collect Data															
6	Analyze Data															
7	Preparation of Draft Report of PSM II															
8	Deadline (Supervisor)															
9	Revision of Final Report for PSM II															
10	Submission of Final Report for PSM II															
11	Preparation of Presentation															
12	Presentation															

Table 3.2.2 - Gantt Chart for PSM II

3.3 Literature Review

Literature and Journal review is a process of learning the fundamentals of the underlying concepts related to the study case. These underlying concepts are attained through internet search, library and UTeM online library service; which provided many paid contents available to the students; often these concepts are found in academic-oriented written material such as thesis and journal. Literature review usually come before experimentation or execution of project as to ensure that the reader is up-to-date with the current understanding of the study case.

In this study case, the literature review comprises of background metal working manufacturing, punching, annealing and induction heating, and a brief history on previously done industrial training that led to the idea of this study case. The literature review chapter also explains the main purpose of this study case.

3.4 INSTRON 5585 Compression Testing System

The INSTRON 5585 is a mechanical based machine for compression and tension testing application. The machine can be affixed with certain jigs to enable certain type of testing method required. This machine is used for determining the yield strength of the punches in this study case.

3.5 INSTRON 8802 Fatigue Testing Systems

The INSTRON 8802 machine is a high stiffness servo hydraulic testing system that can test up to 250KN. It is located in UTeM Faculty of Mechanical Engineering Fasa B in the static lab. The machine is 4-year-old and is heavily used by a lot of the undergraduates, postgraduates and lecturers of UTeM since it is the highest load fatigue machine available on campus. Since it is a hydraulic based machine, it is capable of both Low-Cycle Fatigue and High-Cycle Fatigue testing without deterioration of the results provided.

4 Chapter 4

RESULTS

4.1 Revision from PSM I

Upon discussing regarding the panels' comment from PSM I with Dr. Siti Nurhaida, a hands-on approach is chosen for testing and obtaining data. The previous approach regarding simulation was argued to be inaccurate compared to a physical testing; simulation only represented 20% accuracy. So, a sample of SKD-11 punches – eight pieces annealed and eight pieces non-annealed – was ordered in accordance to the budget set by UTeM (RM 200). The sample is ordered from Broad World Precision Industry.

Figure 4.1.1 – SKD-11 Punches Sample (non-annealed and annealed)

4.2 Testing Methods and Samples

4.2.1 Compression Test

The method of testing is decided to be fatigue loading under compression loading at the yield strength of the punches (non-annealed). This method was chosen as there is no impulse-type testing method available anywhere in any facility in UTeM; thus, this is the closest to real-life application achievable. The non-annealed shall be used as datum as it has not undergone any extra process such as annealing and it will be compared to the annealed punches; which based on literature review should yield better life-cycle than the non-annealed counterpart. There is prerequisite prior to the fatigue loading test which is to obtained the yielding strength of the non-annealed punches.

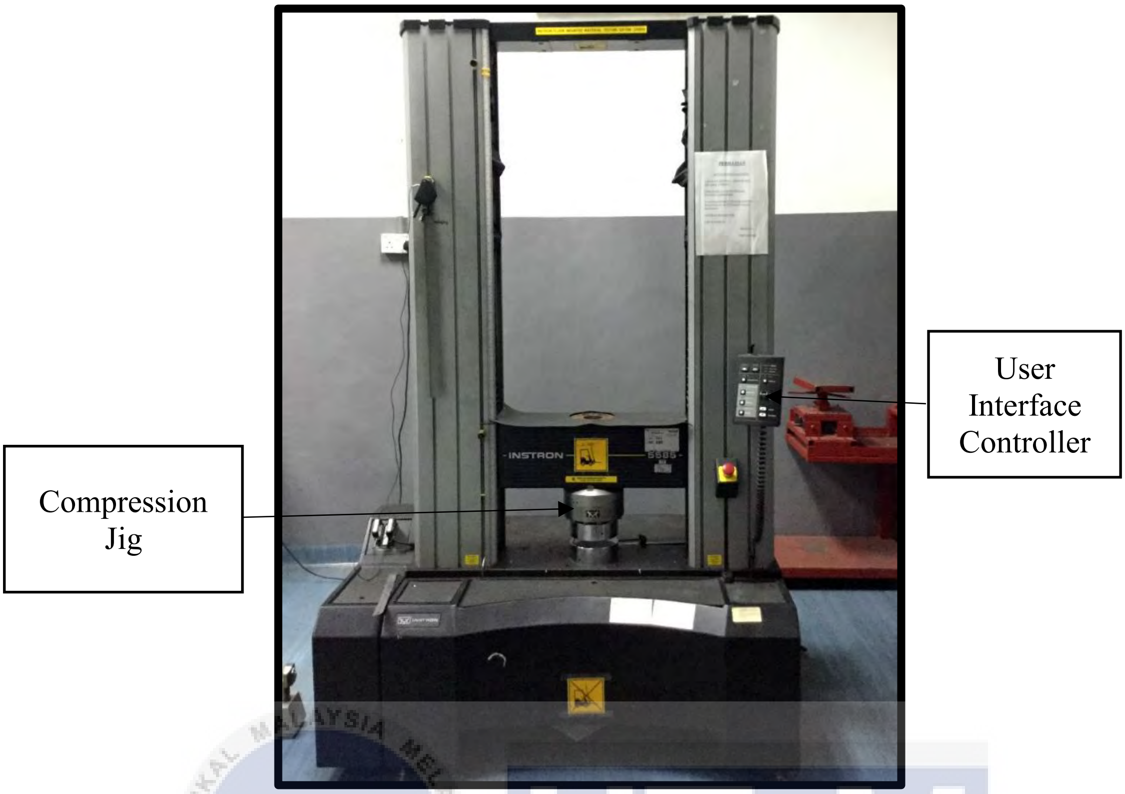


Figure 4.2.1.1 – Instron Machine for Compression Test

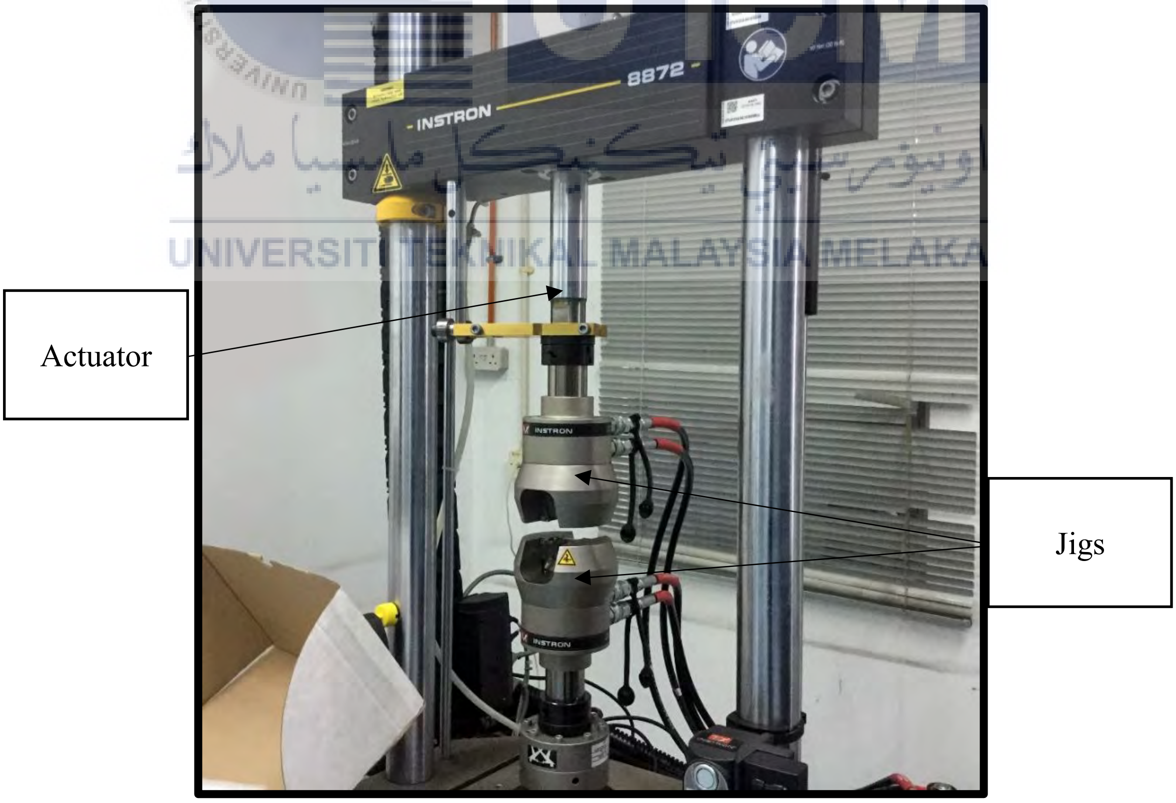
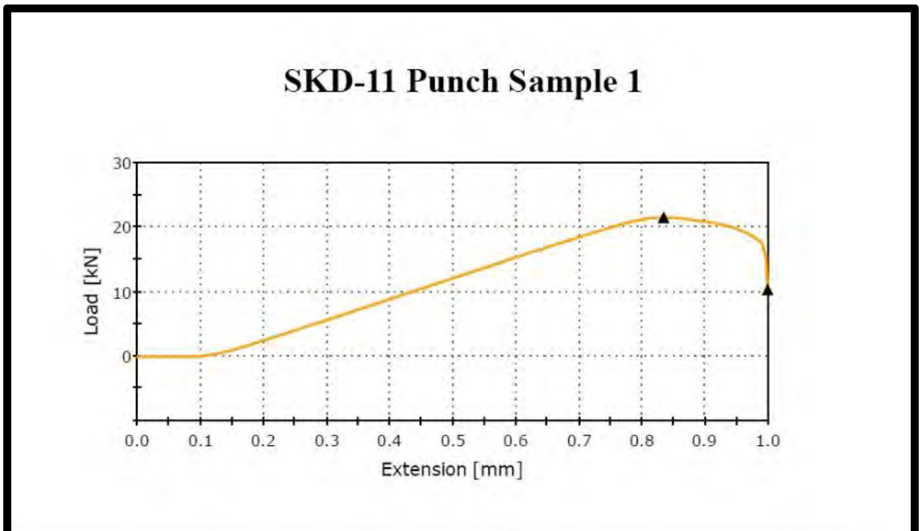


Figure 4.2.1.2 – Instron Fatigue Loading Test Machine (25KN)

Three of the non-annealed punches is subjected to compression test and yield the following results:



	Max Load [kN]	Compressive stress at Maximum Load [MPa]	Compressive strain (Extension) at Maximum Load [mm/mm]	Compressive extension at Maximum Load [mm]
1	> 21.4765	> 1093.79	> 0.01	> 0.83

	Energy at Maximum Compressive stress [J]
1	8.04

Figure 4.2.1.3 – SKD-11 Punch Sample 1 Result

Sample 1 of SKD-11 punch was the first specimen and served as the benchmark for the rest of the test. It was maintained at 5 mm/min. The testing was stopped as soon as the sample showed bending and the yield strength is measured at 21KN.

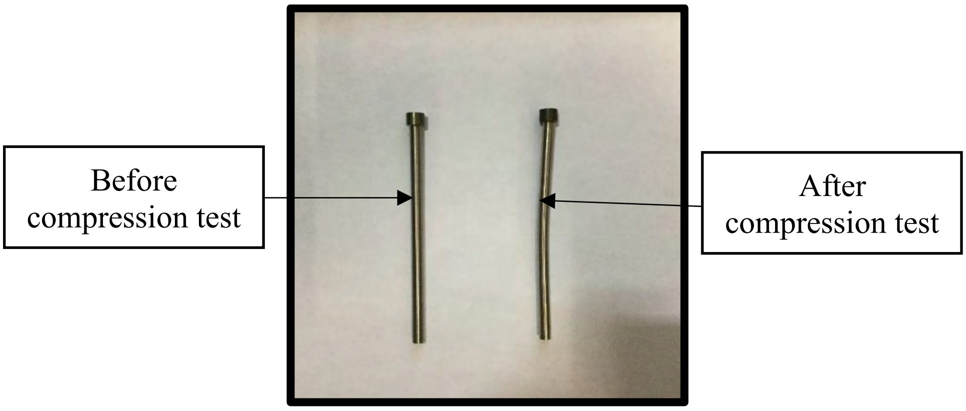
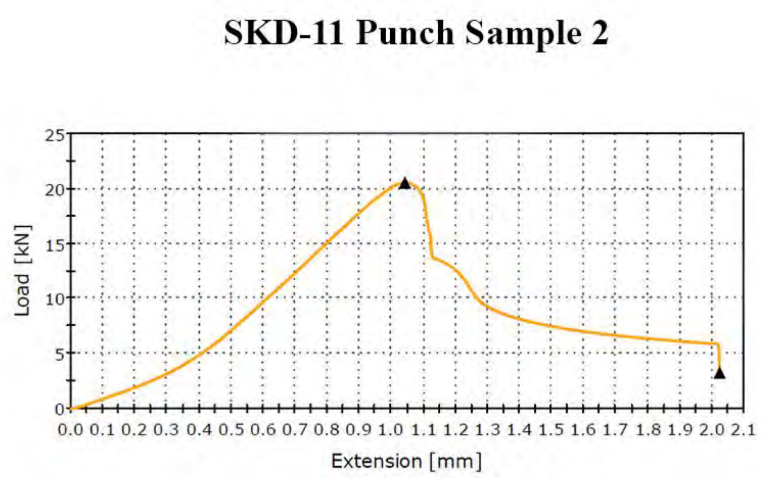


Figure 4.2.1.4 – SKD-11 Punch Sample 1 Comparison (Before and After)



	Max Load [kN]	Compressive stress at Maximum Load [MPa]	Compressive strain (Extension) at Maximum Load [mm/mm]	Compressive extension at Maximum Load [mm]
1	> 20.5122	> 1044.68	> 0.01	> 1.04

	Energy at Maximum Compressive stress [J]
1	9.13

Figure 4.2.1.5 – SKD-11 Punch Sample 2 Result

Sample 2 of SKD-11 punch underwent the same parameters set in sample 1. It was maintained at 5 mm/min. The testing was stopped as soon when the punch had buckled. The yield strength still maintains at 20KN.

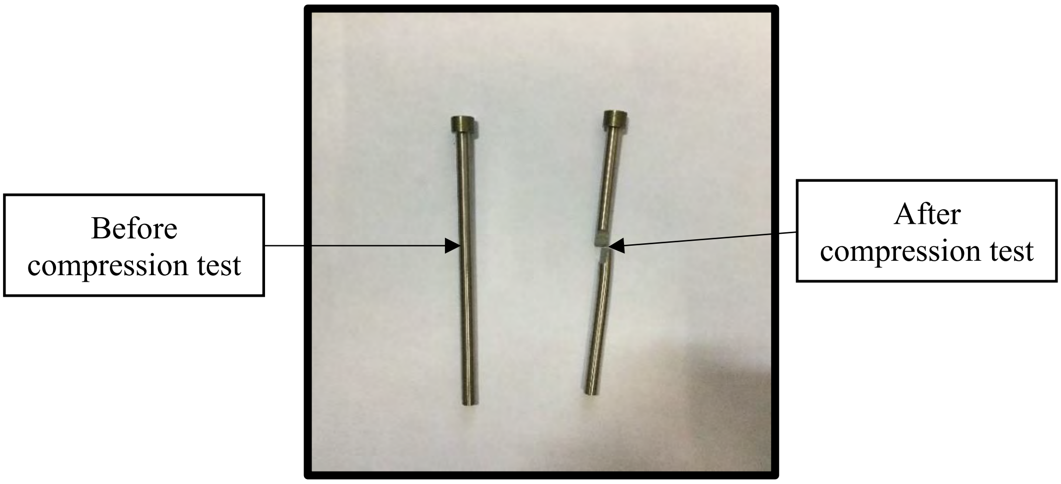
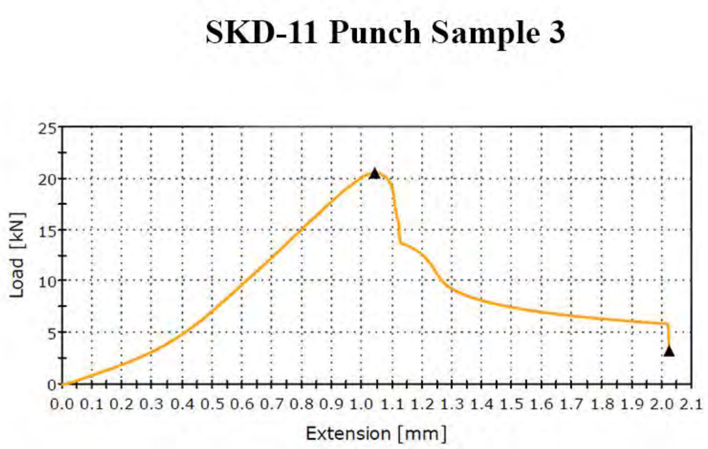


Figure 4.2.1.6 – SKD-11 Punch Sample 2 Comparison (Before and After)



	Max Load [kN]	Compressive stress at Maximum Load [MPa]	Compressive strain (Extension) at Maximum Load [mm/mm]	Compressive extension at Maximum Load [mm]
1	> 20.5122	> 1044.68	> 0.01	> 1.04

	Energy at Maximum Compressive stress [J]
1	9.13

Figure 4.2.1.7 – SKD-11 Punch Sample 3 Result

Sample 3 of SKD-11 punch underwent the same parameters set in sample 1. It was maintained at 5 mm/min. The testing was stopped as soon when the punch had buckled. The yield strength still maintains at 20KN. It is identical to the sample 2 as the position placed on the jig was marked before.

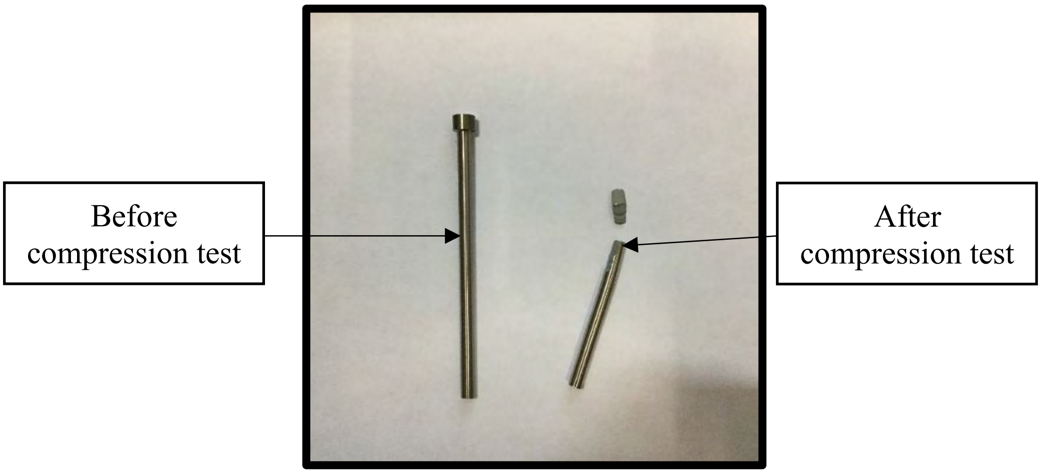


Figure 4.2.1.8 – SKD-11 Punch Sample 3 Comparison (Before and After)

4.2.2 Fatigue Loading Cyclic Test

Through the yield strength determined in the compression test, a fatigue loading cyclic test could be carried out to determine the lifecycle of the punches both annealed and non-annealed. The machine used is as follow:

Figure 4.2.2.1 – Fatigue loading test machine (250KN)

There are limitations to the machine due to unforeseen circumstances such as not capable of a full fatigue test – S and N graphs among other functions were not available due to the Instron software and the User Interface (UI) is damaged hence the machine were configured from the control panel between the machine and the computer.

Figure 4.2.2.2 – Control Panel of the Fatigue Loading machine

The control panel allows the test to be conducted and the data read through the display as purely cyclic loads. The cyclic load is the determined with a force constrained at 80% of the yield strength and the compression displacement set to 95mm of the punch’s total length as to avoid the force to keep applying when the punches are already in failure; cracks and deformation.

The calculation of the Cyclic Load Compression test is as follow:

$\sigma_{Yield,1}$= 21.4765KN $\sigma_{Yield,2}$= 20.5122KN $\sigma_{Yield,\ average}$= 20.8336KN $\sigma_{Yield,3}$= 20.5122KN P_{max} = 80% ($\sigma_{Yield,\ average}$) P_{max} = -16.6669KN Ratio = 0.1, P_{min}= -1.6667KN P_{amp} = [-16.6669 – (-1.6667)] / 2 P_{amp} = [-7.5001 KN] P_{mean} = [-16.6669 + (-1.6667)] / 2 P_{mean} = [-9.1668 KN] To sum up: at 80%, P_{max} = -16.6669KN P_{min}= -1.6667KN P_{amp} = -7.5001 KN P_{mean} = -9.1668 KN	

Table 4.2.2.1 – Calculation of Parameters Required for Fatigue Testing

80% of the yield strength was used due to the short time of availability for the fatigue loading machine and the estimated large cyclic load from the SKD-11 punches. Hence a Low-Cycle Fatigue (LCF) is used instead of High-Cycle Fatigue (HCF) – the latter which could provide a better simulation of the long-term usage for the punches was simply not applicable due to time constraint of the machine.

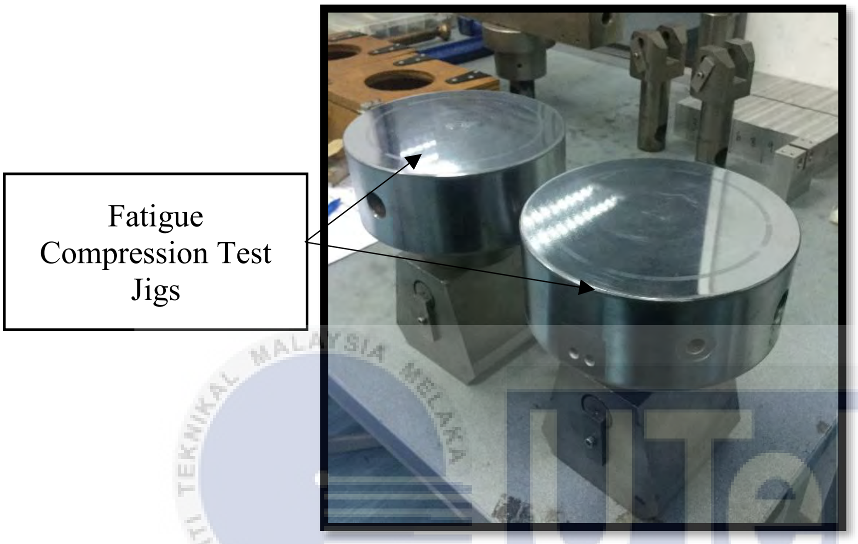


Figure 4.2.2.3 – Jigs used for Compression Fatigue Loading Test

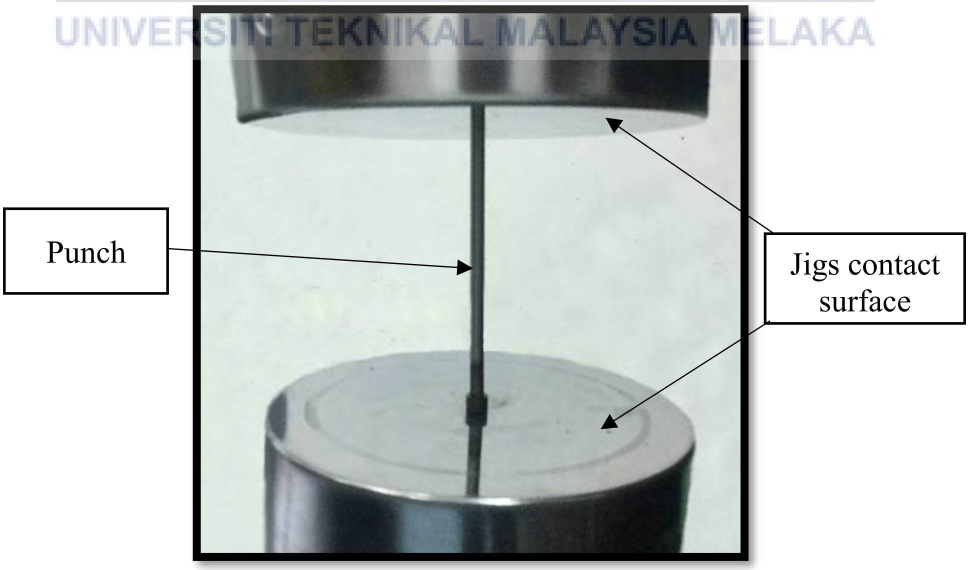


Figure 4.2.2.4 – Close-up of the Test Setup

At 80% load, the results obtained are as in the following tables:

Non-annealed punches

	Cyclic Load
Sample 1	20972
Sample 2	19697
Sample 3	21269

Table 4.2.2.1 – Result for non-annealed Punches Cyclic Load

Average Cyclic Load for Non-annealed Punches are as follow:

[20972 + 19697 + 21269] /3 = 20646 cyclic loads at 80%

Annealed punches

	Cyclic Load
Sample 1	21924
Sample 2	22047
Sample 3	31509

Table 4.2.2.2 – Result for Annealed Punches Cyclic Load

Sample 3 is not considered in the calculation as it was an anomaly caused by an error during the test setup which caused the abnormally high cyclic load.

Average Cyclic Load for Annealed Punches are as follow:

[21924 + 22047] /2 = 21985.5 cyclic loads ≈ 21986 cyclic loads at 80%

Thus, annealed punches performed 6.49% better than non-annealed punches in terms of cyclic loads.

4.2.3 Performance to Cost Ratio

Using the average cyclic loads obtained from the compression fatigue loading for both the non-annealed punches and annealed punches, the relation with price of both types of punches shall be conducted. This enabled the analysis of the extra process, annealing to be beneficial from a cost-effective standpoint.

For SKD-11 from Broad World Precision (BWP),

Price of non-annealed punches : RM10/piece

Price of annealed punches : RM11/piece

As with any manufacturing production, additional processes equate to additional cost due to increased working manhour. Hence, annealing increased the cost of a standard high-precision SKD-11 punch by RM1. To determine the worth, a performance per cost ratio is determined – where the performance is the cyclic loads the punches could handle as to simulate a real working environment and the cost being the price paid for a punch.

For standard non-annealed punch = [20646 cyclic load / RM10]

= 2064.6 cyclic load / ringgit

For annealed punch = [21986 cyclic load / RM11]

= 1998.7 cyclic load / ringgit

Hence, non-annealed punches gave a higher performance to cost ratio at a 2064.6 cyclic load per ringgit. It's a 3.297% better in term of performance per cost for a 10% cheaper in comparison to the annealed punches.

4.3 Discussion

4.3.1 Performance Comparison

From a pure performance comparison of the cyclic loads for both type of punches, the annealed punches performed 6.49% better compared to the standard non-annealed punches. The annealed punches yielded higher cyclic loads per number of punches which could reduce the number of punches needed for a typical punching or stamping process in a manufacturing process. Less number of punches used relates to less number of broken punches disposed hence reducing waste product from the manufacturing process from the tooling.

A reduced number of scrap metal from the used and broken punches would contribute to a better effect on the environment since there are less waste materials to be processed and disposed. In a small-scale view, this would seem trivial and redundant but in the larger scope of manufacturing industry as a whole this could make a difference in terms of reducing the number of scrap metals from just this one type of manufacturing process.

4.3.2 Price Comparison

From a financial standpoint, the standard non-annealed punches are the better choice since it provided more cyclic load per ringgit spent at 2064.6 cyclic loads per ringgit. The standard non-annealed punches are 10% cheaper than the annealed counterpart while providing a slightly higher performance to cost ratio at 3.297% cyclic loads per ringgit.

In terms of saving costs on tooling, it is understandable the reason most manufacturing companies in Malaysia to opt for the standard non-annealed punches rather than slightly more expensive annealed punches which don't present an increment in terms of performance to cost ratio.

4.3.3 Testing Method

The testing method used in this case study was chosen as to emulate as closely as possible to the real working environment of a typical punching and stamping process upon the punches; the tests chosen were compression test and fatigue loading test. Both of the tests were conducted in-house using UTeM's Faculty of Mechanical Engineering equipment as these machines are the most similar to the real working environment that is available as of the date of writing this report. An impulsive force type fatigue testing such as *impact fatigue* or *metallic angled orthopaedic fracture fixation* testing would be ideal and more relevant to this case study.

The results showed a difference between the two types of sample used hence proving the testing method is fairly effective. The standard non-annealed punches and annealed punches clearly showed a difference of cyclic loads it can handle before failing i.e. bending and cracking. A better test result could be obtained if more time on the machine was available for a Low-Cycle Fatigue testing and more samples could be used as to get a more accurate average reading thus reducing the disparity in the result.

4.3.4 Hypothetical Premise

For a hypothetical situation, assume a manufacturing company uses SKD-11 punches – 5mm diameter and 100mm length – for their punching/stamping process as a part to produce their products. The company regularly requires about 1000 punches per six months on average to meet with their requirements. After a month they will resupply their stock on the machine punches as the punches have failed and be disposed.

For a standard SKD-11 punch, they would be paying RM100,000 every six months which could yield them a total of 20646 cyclic loads of stamping the materials required for manufacturing. After this half year period, the punches would be disposed and new tooling punches would be ordered totalling the company a total of RM200,000 annually. Whereas for annealed SKD-11 punch, they would be paying RM110,000 every six months which could yield them a total of 21986 cyclic loads of stamping and totalled to RM220,000 annually.

Using the standard SKD-11 as the baseline at 1000 punches used and disposed, the annealed SKD-11 punches equivalent would be approximately 939.05; rounded off to 939 annealed punches used. That would save 61 punches wasted from becoming scrap metals every 6 months; 122 punches per year saved. That is a 6.1% save on metals from being disposed. Consequently, scrap metals are required to be disposed or recycled within a proper procedure which adds to the cost. By reducing the scrap metals, less pollution will be released to the environment.

5 Chapter 5

CONCLUSION

5.1 Conclusion of Case Study

To conclude, the objectives were met in this case study as the investigation of relationship between the presence of annealing on punches head and the cyclic load were determined and proved to have a difference compared to the standard SKD-11 punch; the annealed punches performed 6.49% better than the standard punches. The performance to cost ratio was also determined with standard punches being higher at 3.297% than the annealed punches.

5.2 Recommendations for Future Research

For future research, it is recommended to revisit this case study with an impact fatigue machine testing as it will provide a better and more relevant result in terms of the cyclic loads. Furthermore, it is recommended to use High-Cycle Fatigue instead with more samples as it will provide less disparity in the result.

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7 Appendices

BROAD WORLD PRECISION INDUSTRY (M) SDN. BHD.
(Co. No. 189535 D)
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TEL: 07-2365287 & 2365292 FAX: 07-2363358
GST NO : 001586200576

TAX INVOICE

CASH SALES

INVOICE NO: S 3 4 5 4 2

DATE: 2018-03-01

Tel: Fax:

PAYMENT TERM:

OUR REF	YOUR P/O NO.	DESCRIPTIONS	QUANTITY	UNIT PRICE	AMOUNT
T35467		STRAIGHT PUNCH			
T35467		JHD 5-100L	16	6.20	99.20
T35467					
T35467		COURIER FEE	1	15.00	15.00
				Sub Total	114.20
				GST@6%	6.85
		Total :	17	RM	121.05

DR. SITI NURHAIDA BINTI KHALIL
Pensyarah Kanan
Fakulti Kejuruteraan Mekanikal
Universiti Teknikal Malaysia Melaka

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PERSON CONTACT:

BROAD WORLD PRECISION INDUSTRY (M) SDN. BHD.
SALES DEPT.

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TEL: 07-2365287 & 2365292 FAX: 07-2363358
GST NO : 001586200576

DELIVERY ORDER

CASH SALES

D/O NO: S 3 4 5 4 2

DATE: 2018-03-01

Tel: Fax:

PAYMENT TERM:

OUR REF	YOUR P/O NO.	DESCRIPTIONS	QUANTITY	
T35467		STRAIGHT PUNCH		[redacted]
T35467		JHD 5-100L	16	6. [redacted]
T35467				
T35467		COURIER FEE	1	15 [redacted]
				Sub [redacted]
				GST [redacted]
		Total	17	

DR. SITI NURHAIDA BINTI KHALIL
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Fakulti Kejuruteraan Mekanikal
Universiti Teknikal Malaysia Melaka

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Standard Terms and Conditions

1. Standard quotation prices are Ex-Factory, and exclude engineering drawings, jig and fixtures developed solely for specific products or inquiries, incidentals and etc.

2. Standard quotation and offer only valid for thirty (30) days upon official quotation date, unless specified otherwise. Standard quotation and offer only valid for order placed within the validity period and shall not be applicable for repeat or subsequent orders.

3. Engineering drawings, jig and fixtures, concepts, procedures, instructions, processes developed are strictly the exclusive intellectual and property rights of Broad World Precision Industry (M) Sdn Bhd.

4. Standard payment term is Cash on Delivery.

5. Payment made are not refundable.

6. Broad World Precision Industry (M) Sdn Bhd reserves the right to charge interest at the rate of 1.5% per month (or part thereoff) or at prevalent bank rate whichever is highier on overdue accounts.

7. Broad World Precision Industry (M) Sdn Bhd or its appointed agent(s) reserves the right to repossess the goods, if payment is not made within the agreeable period.

8. Standard goods are under manufacturing defects warranty for three (3) months from the invoice date. This manufacturing defects warranty does not cover wear and tear, inappropriate application, handling, mounting, assembling and etc. This manufacturing defects warranty shall cease in validity upon further modification, touch up, dressing, machining and etc.

9. Broad World Precision Industry (M) Sdn Bhd is not liable for consequential losses (e.g. delay, quality & quantity issues, failure, efficiency, down time, accident, damages, claims & etc) arrise from usage, delivery and handling of products.

10. All goods are manufactured based on explicit drawings or written specifications agreed or deem agreed in good faith.

11. Any discrepancies, dispute, defects, failures, non-conformance & etc should be made in writing within seven (7) days upon receipt of goods.

12. Broad World Precision Industry (M) Sdn Bhd only offer limited contract services with services render in good faith and does not cover for the costs of materials supplied or any other incidentals nor consequential costs, expenses, claims & etc. Any failure in achieving the services result, outcome and standard even if arise as a direct result of any wilful act or neglect or default by Broad World Precision Industry (M) Sdn Bhd, it will only be limited to RM500.00 (Ringgit Malaysia Five Hundred Only) per batch OR the re-service costs whichever is lower.

13. Any additional terms or conditions explicit agreed upon or superseded any Standard Terms and Conditions, do not invalid the remaining Standard Terms and Conditions.

14. The invalidity or unenforceability of any particular terms or conditions or portion thereof shall not affect the other terms and conditions or portions thereof; and, this Terms and Conditions shall be construed in all respects as if any such invalid or unenforceable terms and conditions or portions thereof were omitted and the remaining Terms and Conditions shall remain in full force and effect.


MADE IN MALAYSIA