INSPECTION OF DRILL BIT POINT ANGLE USING IMAGE PROCESSING METHOD

by

AMIRA SYUHADAH BINTI AHMAD YUSNI

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ENDORSEMENT

I, Amira Syuhadah Binti Yusni @ Ahmad Yusni hereby declare that all corrections and comments made by the supervisor and examiner have been taken consideration and rectified accordingly.

__________________________________________________
(Signature of Student)
Date:

__________________________________________________
(Signature of Supervisor)
Name:
Date:

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(Signature of Examiner)
Name:
Date:
DECLARATION

This thesis is the result of my own investigation, except where otherwise stated and has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any other degree.

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(Signature of Student)

Date:
ACKNOWLEDGEMENT

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INSPECTION OF DRILL BIT POINT ANGLE USING IMAGE PROCESSING METHOD

ABSTRACT

This research presents the inspection of drill bit point angle using a digital microscope and based on computer measurement which is by using image processing method. This project is to support Spirit Aerosystems Sdn. Bhd. in determining the lifespan of a drill bit and to provide a system that can detect wear or changes in the drill bit geometry specifically, point angle. Images of wear drill bit are captured and later on analyzed using MATLAB software to measure the point angle. There are two lighting setups used in this project which are focused light and ring light. Both setups are set to create backlight effect in order to enhance the edges of the drill bit. Besides having two setups of lighting, two methods of analyzing the data also presented in this thesis. The first method is binarization method and the other one is by using Sobel filter method. Both methods showed a similar trend of results where the system is capable of detecting the changes in point angle. This project is divided into two parts which are the hardware and software part. For the hardware, a close setup is designed and fabricated meanwhile for the software part, the images need to be imported into MATLAB software to be analyzed by both methods. The algorithm used is being referred to an example given by Math Work and being adapted into this project to suits the objective of this project. Within this project, we could observe the changes in the drill bit point angle by using both binarization and Sobel filtering methods.
PEMERIKSAAN PENJELASAN BIT POINT MENGGUNAKAN KAEDAH PEMPROSESAN IMEJ

ABSTRAK

perubahan sudut titik bit gerudi dengan menggunakan kedua-dua kaedah ‘binarization’ dan penapisan Sobel.
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<th>Description</th>
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<tbody>
<tr>
<td>Bhd.</td>
<td>Berhad</td>
</tr>
<tr>
<td>CCD</td>
<td>Charge-coupled Device</td>
</tr>
<tr>
<td>CFRP</td>
<td>Carbon Fiber Reinforced Polymers</td>
</tr>
<tr>
<td>D</td>
<td>Dimensional</td>
</tr>
<tr>
<td>DBMS</td>
<td>Drill Bit Monitoring System</td>
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<td>DEFROL</td>
<td>Deviation from Linearity</td>
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<tr>
<td>FLE</td>
<td>Fixed Leading Edge</td>
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<tr>
<td>HSS</td>
<td>High-speed Steel</td>
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<tr>
<td>JPEG</td>
<td>Joint Photographic Experts Group</td>
</tr>
<tr>
<td>LED</td>
<td>Light-emitting Diode</td>
</tr>
<tr>
<td>mm</td>
<td>Millimeter</td>
</tr>
<tr>
<td>PNG</td>
<td>Portable Network Graphics</td>
</tr>
<tr>
<td>rev</td>
<td>Revolution</td>
</tr>
<tr>
<td>RGB</td>
<td>Red, Green, and Blue</td>
</tr>
<tr>
<td>rpm</td>
<td>Revolution per minute</td>
</tr>
<tr>
<td>Sdn.</td>
<td>Sendirian</td>
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<tr>
<td>SOP</td>
<td>Standard of Operation</td>
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<tr>
<td>USM</td>
<td>Universiti Sains Malaysia</td>
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<tr>
<td>V-RAM</td>
<td>Video Random Access Memory</td>
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LIST OF SYMBOLS

° : Degree
\theta : Angle
\mu : Mean
N : Number of iteration
\sigma : Standard Deviation
CHAPTER 1
INTRODUCTION

1.1 Research Background

In aviation industries, Carbon Fiber Reinforced Polymers (CFRP) composite has been widely used and it is getting wider. The use of composite materials has stood out due to their outstanding mechanical properties in which they are highly specific in strength and stiffness which almost as same as metal. Holes need to be drilled in order to join and fasten the composites during the assembly process.

Drilling is the most common material removal process in composite machining. Even small jet aircraft requires 245,000 holes to be drilled and the number increases for large aircraft. The tool used which in this case a drill bit will be wear when hundreds of thousand holes are being drilled. Tool wear eventually leads to material degradation issues such as delamination, fibre fracture, fraying, and burr formation. Many research has been done regarding on the development of the techniques in measuring tool wear because tool wear will affect the condition of the material.

Generally, there are two methods for measuring the tool wear which is a Direct and Indirect method. It is known as a direct method because the cutting edge of the tool wear is being measured using a vision system such as digital microscope which the image is processed (image processing). Noted that by using direct method, the tool needs to be detached from the machine during the measuring process.

Meanwhile, the indirect method measures the tool wear by processing the signal during the drilling process. As mentioned previously, tool wear will affect the condition and quality of the material, hence, a proper inspection system is needed to prevent from using wear tool that leads to cost increments such as time and money.
1.2 Problem Statement

In Spirit AeroSystems Malaysia Sdn. Bhd., there is an issue regarding drill bit usage where there is no proper benchmark or manual to prove that the drill bit usability. The drill is used until something happens to the material, usually delamination, then only it will be changed. This is obviously not a good way to determine whether the drill is still usable.

Cost spend for drilling process increases due to damage material since one material used to make part of the aircraft is expensive. Imagine having approximately twenty materials in just one part of the aircraft, giving example, the wing. However, sometimes the drill is changed even before the wear occurs in which it is considered a waste of money. The drill might go up to thousand more holes but instead, it is being thrown because no standard of operation (SOP) says so.

A system ought to be developed to overcome this situation that can help in terms of inspecting the degree of tool wear. The previous study had been done regarding monitoring system for drill bit wear such as a digital microscope is placed facing the drill and image is captured from the top. The image is then being processed to obtain a percentage of wear.

This new developed system is built to provide alternative in the inspection method. The drill bit wear not only can be monitored from the top, but also from side view. Moreover, measuring drill bit wear from side view (point angle) have its own importance as point angle affects the composite. Normally, drill bit with 135º point angle is used to drill composite. Once the point angle reduces, it affects the composite integrity which can lead to delamination. Hence, it is important to monitor the drill bit wear from point angle view.
1.3 Research Objective

The objectives of this research are:

i. To develop a system to inspect drill bit wear specifically point angle.

ii. To obtain point angle by applying image processing method during the inspection of the aircraft assembly line drill bit.

iii. To test performance and capability of the inspection system of the aircraft assembly line drill bit.

1.4 Thesis Outline

There is a total of five chapters in this thesis that includes an introduction, literature review, research methodology, results and discussions and finally conclusions and recommendations. Chapter 1 introduces the main idea of the project which is briefly described and some information regarding the method used. Besides, the motivation of this project is also explained in the problem statement and objectives of this project also being pointed out to have a clear view of the path of this project heading toward to. Then, in thesis outline, each chapter is being defined to give the reader of flow of the project.

In Chapter 2, the nomenclature of the drill bit is explained in detail and where usually wear occurs. Also, what are the effects of point angle towards the drilling process itself and the workpiece material. Previous studies regarding inspection system tool wear were presented too. This gives a whole idea on how to improve from existing design.

Meanwhile, Chapter 3 describes the method and technique used throughout the study of how fabrication of hardware is used, how the data is collected and how data is analyzed. The method used is based on the previous study.

In Chapter 4, the results were explained in two graphs where the comparison between Binarization and Sobel filtering method are made. Then, discussions on why
such graphs are obtained and which method is the most suitable to be used in this project is being presented. Finally, Chapter 5 concludes and recommend some improvements that can be done in the future.
CHAPTER 2
LITERATURE REVIEW

2.1 Drill bit

2.1.1 Drill Bit Parameter

Drill bit or cutter is a tool that is used in the making of circular cross-section which is known as holes and the process is called drilling. In the market, there is a vast option of the drill bit to choose from and it is usually depending on what material to be drilled and what are the desired outcomes; pilot hole, true hole or etc.

Since drilling is the most major machining process in the industry, apart from drilling parameters, drill bit geometry plays a vital role in making sure that hole produced is within requirement. Using worn drill bit will just damaging the workpiece material. Once the workpiece is damaged, there is nothing can be done except for pay for a replacement which will obviously lead to cost increment.

The twist drill is a rotary cutting tool that usually has two cutting edges and two flutes which are grooves formed in the body to provide cutting lips. The flutes will help in the removal of chips and allow coolant or cutting fluid to reach cutting section. Few basic features of a twist drill are point angle, main cutting edge, chisel edge, flute profile, and helix angle as shown in Figure 2.1.

![Figure 2.1 Drill bit nomenclature.](image-url)
Figure 2.2 A drill bit should have an equal angle on both sides.

Point angle is located at the tip of the twist drill and the angle is measured between the two main cutting edges. A drill bit should have the same angle for both sides as shown in Figure 2.2 and the cutting edges should be equal in length (Schneider et al., 2002).

Before the drilling process starts, point angle is used to center the twist drill in the material. Small point angle makes it easier for centering process. Besides, the small point angle also helps in reducing the risk of slipping on curved surfaces. Meanwhile, a larger point angle has a shorter tapping time. Tapping is the action that creates a thread onto the side of the hole. Centering in the material gets harder and a higher contact pressure is required.

The actual drilling process is done by the main cutting edges. A drill with long cutting edges has a higher cutting performance compared to short cutting edges, even if the differences are very small.

Chisel edge depicted in Figure 2.3 is located in the middle of the drill tip and gives no cutting effect. It connects two main cutting edges and responsible for entering the material and exerts pressure and friction on the material. These properties can lead to increase in heat generation and power consumption.
Figure 2.3 Chisel edge located on the tip of the drill bit and connecting two cutting lips.

The profile of flute responsible is to promote chip absorption and removal. The wider the groove profile, the better the chip absorption and removal. Wide groove profiles are flat while thin groove profiles are deep. The drill core thickness is determined by the depth of the groove profile. Flat groove profiles allow thick core diameter and deep groove profiles allow thin core diameters.

Helix angle is the angle between the leading edge of the land and the drill axis that decides the chip formation process. Larger helix angles contribute to the effective removal of soft, long-chipping materials. On the other hand, smaller helix angles are used for hard, short-chipping materials.

2.1.2 Drill Bit Wear

The drill bit starting to wear as soon as the cutting process begins. Therefore, it does not need to wait until a number of holes produced. Even though the drilling process is at a constant rate, wear does not progress at a constant rate too. Instead, it accelerates continuously.

Kim et al. (2002) studied the tool wear measuring technique by using a carbide-coated end mill as a tool. It is found that the wear can be categorized into two parameters; the mechanical and chemical parameters. The mechanical parameters such as abrasion
and adhesion occurred due to the thermally loaded motion acting between the tool and the workpiece. Chemical parameters such as diffusion and oxidation occurred due to rise in temperature that leads to activation of chemical responses. Oxidation exists due to the oxide between the coating layer and the workpiece. Meanwhile, adhesion is caused by excessive wear of flank face of the cutting edge. When the flank wear reaches a specified dimension, the tool is considered to end its useful life (Zhang et al., 2013).

Flank wear has been proven to have unfavorable effects on surface integrity where it hardened the surface layer due to residual stress and microstructure changes. Central wear and flank wear usually showed at the ball end mill while flank wear is displayed at flat end mill.

As for twist drill, shown in Figure 2.4, the wear starts at the sharp corner of the cutting edges and works its way along the cutting edges to the chisel edge and up the drill margins as mentioned by Schneider et al. (2002). The clearance is reduced as wear progresses while heat is generated due to the abrasion and this induces to a faster wear. The degree of wear actually indicated by the wear that occurs on the drill margins but normally, it is not as obvious as wear lands. Wear lands appear behind the cutting edges and is not the best indicator of wear.

![Figure 2.4 Type of drill wear.](image)
2.2 Point Angle Effect

2.2.1 Drilling Parameter

There are many types of the drill bit in the market nowadays and each drill has its own purpose and function. Some drill type is made specifically for its material and function such as plug cutters, masonry, augers and etc. There is a common drill bit which can be used in daily drilling and can almost drill any material which is known as twist drills. There are a variety of point angles can be found for the twist drill but the commons are 118° and 135°.

Choosing proper point angle is vital since different point angle will give a different effect on the material and affect drilling parameter. The point angle affects the feed force and drilling torque characteristics. Not only that, thrust force also is affected by point angle. Smaller point angle can reduce the thrust force at different feed rate. However, larger point angle has no major difference in the thrust force due to full diameter engagement occurred between drill tip and composite laminates.

2.2.2 Delamination

Drilling onto a composite material introduces a major concern in aerospace industries and that would be an interlaminar delamination in the composite. This failure affects the structural integrity and long-term reliability severely (Hocheng et al., 2006).

Delamination can occur at two places which are at the exit and the entrance of the holes. It is also known as push out and peel up respectively. It has been proven that point angle has great influence on the delamination factor when at a constant feed rate and cutting speed. Persson et al. (1997) studied shows that hole machining defects have significantly reduced the strength and fatigue life of composite laminates. Maoinsen et al. (2014) did an experiment to test three different point angle of drill bits which are 85°,
118° and 135°. It is found that smaller point angle shows less delamination compared to larger point angle at high feed rate. Meanwhile, larger point angle shows less delamination at lower feed rate.

### 2.3 Inspection System

#### 2.3.1 System Setup

Basically, the experiment setup depends on the wear parameter to be analyzed. Different setup is needed to assess different parameter so that the best outcome could be obtained. An experiment was done by Pfeifer et al. (1990), the camera is set to be linear to the drill bit because it was the flank wear that to be analyzed. Since flank wear occurs at cutting edge, the linear setup would be appropriate for the experiment. This study is supported by Azhar (2017) where the camera is set to be also linear with a drill bit to allow its wear to be detected and measured. On the other hand, Atli et al. (2006) mentioned that they were measuring the drill bit tip shape. Therefore, a 90° view towards the drill bit is more appropriate.

#### 2.3.2 Lighting

When capturing images, lighting is a crucial parameter as it is to provide the correct amount of illumination to the image. As mentioned by Lambrecht et al. (2011), there are five different sources of light in a common portrait studio which are the key light, fill light, rim light, backlight and kicker illustrated in Figure 2.5. Different purpose of the images may require a different source of light or maybe a combination of two or more sources.
Figure 2.5 Different sources of light in a common portrait studio.

In a tool wear monitoring system, the main requirement of the system is to provide sufficient contrast between the worn region and the background. The intensity and the angle of the illumination source should be adjusted to emphasize the tool region of interest. Besides selecting an appropriate light source, consideration must also be given to the technique which will give optimum results. There are three techniques that have been used extensively for various machine vision applications including front lighting, backlighting, and structured lighting.

The light source is needed to create a clear contrast between the tool flank and the background in the image (Zhang et al., 2013). In this study, light-emitting diode (LED) light from the charge-coupled device (CCD) camera is used to help capture the wear region. This means that the light source is facing the object. The wear area can be identified by the gray level of the image captured by using only the naked eye. The gray level is higher compared to the unworn tool area and the background to detect wear region. The change of the gray values is large at the nearby edge of the tool wear region,
Ramzi et al. (n.d) use lighting from the digital microscope and two additional LED strips to add illumination for a better image quality. There are two servo motors used to control the angle of the lighting and also a light barrier to limit the lighting from hitting the drill bit. This also supported by Atli et al. (2006), where a light source was located near the camera location pointing towards the cutting tool to provide sufficient illumination.

A number of light source also affects the quality of the image. More than one source of light also helps in terms of capturing clearer images. The different images could be observed by changing the lighting angles. The tool bit becomes shady when the light comes from left and right sides and since wear is going to be measured, it is not favorable to have an image with shade. Only the bright part could be monitored and measured but not the shady part (Kim et al., 2002).

However, there is also research regarding different lighting setup which is by using backlight effect. Backlight separates a dark subject area from a dark background by illuminating the background directly behind the subject with a small reflector. Lim et al. (2012) studied how various lighting condition affect scanned images. In one of the conditions, they applied backlight effect in scanning the tool insert and found out that the outcome images have the best contrast and uniform illumination.

This is supported by the gray level histogram plotted and is shown in Figure 2.6 (e). It shows that backlight has a peak value concentrated at a higher gray level value compare to other lighting conditions which signify good illumination condition. Therefore, in this project, backlight effect is used as lighting setup as the objective is to detect the wear edge. It is great to notice that source of light or lighting setup is depending on the type of cutting tool to be monitored and what are the desired outcomes.
Figure 2.6 Gray level histogram of scanned images: (a) open, (b) controlled black, (c) controlled white, (d) controlled gray and (e) backlight.

2.3.3 Online/Offline

There are two methods for measuring and analyzing drill bit wear which is online and offline methods. Referring to the word online, it means something that it is always
going on, always in the move and something that can be used directly. Meanwhile, offline means that the system needs to be shut down or turned off, then the tool needs to be detached from the drill gun.

As indicated by Azhar (2017), the drill bit is detached from the machine to be analyzed under the camera. García-Sanz-Calcedo et al. (2016) in their study used an online method where drilling experiments were performed on a vertical drilling machine. Tool life was estimated by monitoring signals acquired during machining. Hall current sensors were used to measure current signals from the machine.

According to Zhang et al. (2013), using an online method shows that there are two possible working principles for their measurement and monitoring design. The first mode is known as a real-time mode where the measurement and monitoring system capture and detect the tool wear during the milling operation is ongoing. The other mode is known as an in-process mode where the machine tool is stopped from operating for capturing and detecting purposes. However, they only focus on in-process mode because of a more precise measurement of tool wear can be achieved from this mode.

### 2.3.4 Wear Detection

Atli et al. (2006) mentioned that Canny edge detection is used in his experiment to detect the edges encountered in an image. This method able to detect the best edge pixel by marking the high threshold value and then continuing with neighboring locations which its gradient magnitude is above the low threshold value. Note that this method only considers neighboring pixels that are located along a line normal to the gradient magnitude direction to further speed up the process.

The author also proposed a deviation from linearity (DEFROL) metric illustrated in Figure 2.7 where each side of the tool tip was separately processed. Points were placed
at each side’s top and bottom tip and DEFROL metric counted a total number of pixels lying between these lines. Worn tool portrayed significantly higher DEFROL values than sharp tools. Supporting that, it obtains a very low value for a sharp tool every few frames and it showed that it is very easy to differentiate between worn and sharp tool using this method.

![Diagram of tool wear](image)

Figure 2.7 DEFROL method used in detecting the edges of the tool.

A $3 \times 3$ convolution-matrix can be used to manipulate the grey-scale image of the CCD-camera which is stored in the Video Random Access Memory (V-RAM) (Pfeifer et al., 1990). This operator calculates new grey-scales for every pixel with a mathematical formulation. This convolution filter is often called a Sobel filter. The result shows the boundary lines of the High-speed Steel (HSS) drill. Angle position of the cutting edge with the help of Hough-transformation. According to Kim et al. (2002), an image measuring program called ‘Image-Pro Plus’ was used in measuring the tool wear.

In the measurement and monitoring system, it is discovered that besides image processing, wear also could be detected by using sensor and it can be categorized into two; direct and indirect sensors (Kurada et al., 1997). Direct sensors are able to measure actual dimensions of the worn area or detecting the condition of tool’s cutting edge. The most common direct sensors are a proximity sensor, radioactive sensor and vision sensor. Proximity sensors are used to measure the change in the distance between the tool’s edge and the workpiece. Electric feeler micrometers and pneumatic touch probes are used to
measure the distance. Radioactive sensors detect tool wear by measuring the tool directly where a small amount of radioactive material is implanted on the flank face of the cutting tool. Vision sensors are applied directly to measure tool wear which utilizes the cutting tool itself.

Indirect sensors measure a parameter that can be correlated with tool condition and the most common indirect sensors are cutting force sensors, vibration sensors, and acoustic emission sensors. In cutting force signals, a dynamometer is attached to a tool holder to monitor the cutting force in one or two orthogonal directions. The increase in the cutting force required as a progressively wearing tool is forced through the material is indicated by the force sensor signal. When the machining process is done by using the worn tool, the fluctuation of forces on the cutting tool will increase and hence causes vibrations to occur in the system. The vibration sensors allow us to assess tool wear by monitoring the level of vibration. Last but not least, monitoring tool wears by using acoustic emission. The emission signal is normally detected by contacting a piezoelectric transducer mounted on the machine tool.
CHAPTER 3
METHODOLOGY

3.1 Overview

In the making of this project, it is consisting of two parts which are hardware setup and software development. The hardware part is more on how the setup is built, what influence it to be that shape, dimensions and some limitations. Some of the material is used from existing apparatus from another laboratory which is borrowed just for the purpose of this project. On the other hand, software part is more on how the code in MATLAB was edited to suits this project’s purpose and to obtain the desired result.

3.2 Overall Process

The project flows shown in Figure 3.1 starts with the development of the ideas by studying the previous drill bit wear system, finding the research gap and throwing some ideas on improvement process. The setup is designed based on the objective of this project. Next, the fabrication process is done based on the design earlier. All dimensions of the materials need to be accurate so that it can fit one another. Making sure that the setup can be used for the project is crucial, therefore, a testing is needed. A setup such as heights and positions need to be determined and set. Then, the setup is ready to be used. If not, the design testing procedure has to be reiterated.

In the algorithm development process, a program is created and then is used to test method functionality in inspecting and analyzing procedure. Once the result obtained is satisfied, then the overall process ends.
Figure 3.1 Overall process for this project including hardware and software setup.

As for the purpose of capturing satisfactory images, a digital microscope camera is used. This digital microscope is then connected to a computer that acts as a monitor.
3.3 Hardware

3.3.1 CAD Design

Figure 3.2 CAD design by using CATIA V5.

From developing ideas process, the design in Figure 3.2 is drawn to have a better view on how the design should be. Roughly, setup idea by Atli et al. (2006) was being used as a reference where the camera is 90° facing the drill bit. This will enable the camera to capture the drill bit tip section and eventually will support in calculating the point angle in software algorithm discuss later.

The aluminium rod that is connected to the aluminium profile is able to move front and back to alter focus length of the camera in order to obtain sharp images. Meanwhile, the slot on the Perspex enables the chuck to move left and right to make sure the drill bit is located at centre of the camera.

3.3.2 Setup Fabrication

A new setup had to be designed to properly measure the point angle. The camera and drill bit had to be aligned perfectly at the angle of 90° shown in Figure 3.3.
Figure 3.3 Proposed setup for the experiment. (a) Ring light. (b) Focused light.

The process starts with machining of aluminium profiles from various of length to 4 pieces of 190 mm and 1 piece of 210 mm. The length of the aluminium profile is influenced by the length of aluminium rod used to hold the camera. The rod used is an existing rod from a retort stand shown in Figure 3.4. Therefore, the rod is the reference length and since the aluminium profiles are longer than the rod, the profiles were designed as per the rod length. Holding the camera has already been easy as the rod came with a clamp that can fit the camera. In addition, the clamp can be manually adjusted according to the size of the camera and can be locked.

Figure 3.4 Retort stand used in the laboratory.
As for the base of the system, a Perspex block of 25×25 mm is used. Four slots of 3×3 mm are milled to lock the aluminium profiles onto the base depicted in Figure 3.5. However, an existing tool in School of Mechanical Engineering, USM could not mill the slots into a perfect rectangle shape. The slots will not be having a perfect 90º angle. Additional holes need to be drilled separately from the machine to allow edges of the aluminium profiles to fit the slots.

![Perspex base fabrication process](image)

Figure 3.5 Perspex base fabrication process; (a) cutting (b) milling.

By using a milling machine, another slot with the depth of 5 mm is milled. This slot is used to place chuck that holds the drill bit. Besides, the slot enables the chuck to move on the x-axis and enables the drill bit to be captured perfectly center.

### 3.3.3 Lighting

The source of light affected the image to be captured. It depends on the type of image that needed to be achieved. In a photography studio, they use reflectors and additional stand studio lamp to achieve perfect lighting. Good lighting will provide good,
sharp image. Without a good source of lighting, the image will become a blur and low quality.

In this project, there are two ways that were used to create backlight effect. It is known as backlight due to the source of light is coming from behind the object. The object is placed between camera and source of light. When the light source hits the object from behind, the side of the object that facing the light is brightening while on the other side becomes darken as shown in Figure 3.6. An easy example can be given is through natural phenomenon which is during eclipse where a black Moon can be seen from Earth due to the Moon is located in between the Earth and the Sun.

![Figure 3.6 Image produced with back light on.](image)

Backlight setup was introduced due to the importance of the object edge rather than the object itself. Figure 3.6 (a) shows when the light hits the object from in front or top, the object can be seen clearly and the ‘true’ shape or characteristic of the drill bit can be described in detail. However, this type of lighting setup is not favorable in this project. Moving on to Figure 3.6 (b), despite the object cannot be seen as clearly as Figure 3.6 (a), the edges of the object can be seen distinctly. This method can help to achieve this project’s objective as the edges will be used in measuring the point angle.
One way of creating backlight effect is by using a reflector. As can be seen from the Figure 3.7, a white cardboard is used to reflect the light from a 45° mini torchlight. Besides functioning as a reflector, the white cardboard also helps in diffracting the light so that uniform amount of light hits the drill bit. This helps a lot in terms of enhancing and getting sharp edges since every single light particle reaches the object.

This method can be done under room light condition because the mini torch light acts as a focused light and with the help of white reflector, it is capable of creating excellent backlight effect.

Figure 3.7 Backlight effect using a reflector and a torchlight (focused light setup).

Figure 3.8 Image captured using focused light setup.
Another method to create backlight effect for this project is by using direct light from behind the object, which is the ring light as the source as illustrated in Figure 3.9. White papers were used to diffract the light from the source to allow an equal amount of light to hit the object. Just on top of the ring light, behind the white paper, there is a black matte paper that functions as a light shield. The light that passes through the white paper is well distributed that it can reach the drill bit from the top causing blur edges. This is when the light shield comes in, to ensure the light only passes through the white paper
and only hits the drill bit from the back. Therefore, sharp edges can be seen from the front shown in Figure 3.11.

![Figure 3.11 (a) Without the presence of white paper (b) With the presence of white paper.](image)

3.4 **Measuring Angle of Intersection**

MATLAB software has various functions such as processing images and edges detection. In this project, the program code was inspired by Math Work title ‘Measuring Angle of Intersection’ where the outline of the code was taken as reference. The algorithm flowchart is shown in Figure 3.12.
Figure 3.12 Flow chart for measuring the angle of intersection method.

### 3.4.1 Binarization

From the example given shown in Figure 3.13, MATLAB was going to calculate angle and point of intersection between two beams.
According to MATLAB, it is a common task in machine vision applications where measurement is done hands-free by using only image acquisition and image procession technique.

The same method used in this project where the image was captured by the digital microscope and stored in a MATLAB folder. Image processing begins after the image is imported into the MATLAB program. Note that the image must be in Portable Network Graphics (PNG) or Joint Photographic Experts Group (JPEG) format, then only MATLAB could read the file.

Next, from the normal colored image that has been imported previously, few lines of code are written to allow the image to be converted into a binary image which is represented by black and white pixels shown in Figure 3.14. This is to allow MATLAB to detect an object of interest and to ease next process. Conversion of the binary image is another feasible way to reduce the information set from the greyscale images. An image having greyscale pixels are transformed into black value if they are under a pre-defined threshold, while others are transformed to white pixels (Pfeifer et al., 1990).

![Binarized image of a drill bit.](image)

Figure 3.14 Binarized image of a drill bit.

Once the image is converted to a binary image, a region of interest need to be specified. By means, the area needs to be extracted by cropping the image. An image
might have more than one angle or point of intersection. Therefore, to avoid MATLAB from confusing which angle to measure and to make it easier to extract the edges, this process needs to be done.

Figure 3.15 Cropped image to ease point location tracing process.

After cropping the binary image shown in Figure 3.15, a single point of the boundary is used as a starting point location for boundary tracing process. Since it is going to measure an angle, two boundary lines are needed. However, the point still starts from that single point mentioned previously and, in this case, there were two starting points shown in Figure 3.16. The accuracy of the angle and point of intersection calculations can be maximized by extracting as many points that lie on the boundary line. To calculate the angle, a dot product is introduced.

Figure 3.16 Two boundary lines needed and detected to measure the angle of intersection.
Proceed to the next step, finding the point of intersection. This point is computed based on the boundary lines that have been plotted before. Finally, all values will be plotted on the image and the program ends as depicted in Figure 3.17.

![Figure 3.17 Angle of intersection between two boundary lines is calculated.](image)

3.4.2 Sobel Filter

Sobel filtering is a method where the ‘Sobel’ routine detects the edge lines from an image. Measuring the angle of intersection by using Sobel filtering method is almost similar to binarization method. The outline, the way MATLAB measure and calculate the angle of intersection and the outcome result are about the same. The difference is only during image processing procedure. In Sobel filtering, after the image is binarized, the only edge of the drill bit is detected and transformed into white pixels shown in Figure 3.18. Compared to binarization, the whole drill bit is being transformed to white pixels.
Figure 3.18 Only the edges of the drill bit is being transformed to white pixels.

Next, the image is cropped as shown in Figure 3.19 to ease in finding the starting point location for the boundary lines. In addition, the image needs to be cropped to avoid MATLAB from detecting other inappropriate point location.

Figure 3.19 Cropped image of Sobel filtering method to ease tracing boundary process.
Figure 3.20 Two boundary lines needed and detected to measure the angle of intersection.

Figure 3.21 Angle of intersection between two boundary lines is calculated.
3.5 Data Collection

3.5.1 Gathering Information

In the aircraft assembly line, there are few drill bits with small differences such as point thinning, but still, produce the same size of the hole. According to the technicians from Spirit AeroSystems Sdn. Bhd., the difference is due to a different manufacturer or a different batch of produce.

Table 3.1 Parameters for twist drill used in this project.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drill Bit</td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Carbide</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>100</td>
</tr>
<tr>
<td>Diameter</td>
<td>pilot - 4.88/0.193 inch</td>
</tr>
<tr>
<td>Speed (rpm)</td>
<td>2800</td>
</tr>
<tr>
<td>Feed rate (mm/rev)</td>
<td>0.1</td>
</tr>
<tr>
<td>Workpiece</td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Carbon Fiber</td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>3.91</td>
</tr>
<tr>
<td>Hole depth (mm)</td>
<td>3.91</td>
</tr>
<tr>
<td>Hole size (mm)</td>
<td>3.91</td>
</tr>
<tr>
<td>Type of panel</td>
<td>Fixed Leading Edge (FLE-inboard)</td>
</tr>
</tbody>
</table>

There is a total of four maximum number of holes drill bits used for this experiment which are 80, 364, 613 and 3000. Since the drill bits used in aircraft assembly line are high cost, these were the only drill bits that were given by Spirit AeroSystems Sdn. Bhd. for research purposes. Drill bit with a maximum number of 80 drilled holes was made as reference drill bit since it has the lowest number of drilled holes. Usually, the drill bit can drill holes up to 7000 holes before it becomes wear.

3.5.2 Capturing Images

A digital microscope is used as a camera during this project. Keeping in mind that all images need to be constant because, in MATLAB program, size of the cropped
image had been determined from the first trial. It would be waste of time to alter the size and coordinate to crop the image every time a new image is captured.

To ease the process of capturing constant images, a new software was introduced. It is known as Drill Bit Monitoring System (DBMS) where this software provides reference line and is linked to the digital microscope. The movement of the drill bit on the system can be monitored from the computer by using the software, either it was too left or too right, it needs to be adjusted until the cutting lips are placed within the reference lines.

To determine whether at what angle is the desired angle, the drill bit is rotated until the point a and the neighboring edges fit into the reference line as shown in Figure 3.22.

![Figure 3.22 Drill bit is fit perfectly within the reference line.](image)

In Figure 3.23 (a), part of the right side of the drill bit can already be seen. Satisfying image will only consist of one sideline, instead of two referring to Figure 3.23.
(b). The image shows that the drill bit is already over-rotated to the left. In spite, the drill in Figure 3.23 (a) shows only one sideline on the right side, the drill bit is under-rotated because the left side of the drill bit can be seen. In this matter, a reflection of light helps in term of appearing the side that should not be captured by the system.

It is not necessary to capture in an exact way, as long as the image captured lies within the limit of crop image mentioned previously, the image is possible to be processed.

![Figure 3.23 (a) Drill bit is over-rotated to the left. (b) The drill bit is under-rotated to the left.](image)

3.5.3 Measuring Point Angle

Point angle is measured between the cutting lips. When the observer is looking from the front view, he or she might be confused as there are two edges symmetrically both right and left side; a total of four edges all together depicted in Figure 3.24.
Figure 3.24 Side 1 and 2 positions on the drill bit.

Figure 3.25 Top view of drill bit tip.

Figure 3.25 shows clearly on how to understand Figure 3.26. In the aerospace industry, the drill bit used is not as same as conventional twist drill bit and the production is limited. This is the reason why the cost of the drill bit is expensive besides the material is designed specifically for aircraft composites.
In Figure 3.27, it can be observed that the cutting lips are approximately only half of the length for one side. Referring back to the meaning of point angle, it is the included angle between two cutting lips. Therefore, the cutting lips lie on the region a and d.
3.6 Data Analysis

For each drill bit, 10 images were captured for face one and another 10 for face two. This was to test the capability of the system and to prove that images taken were constant.

Therefore, for each image to be processed, it needs to go through MATLAB program. In step one, the image needs to be imported into the program. Noted that this image is in true color version. Then, it needs to be converted into a grayscale image in step two. A grayscale image is an image where the only intensity of light is displayed. For this step, subroutine ‘rgb2gray’ was used where Red, Green, and Blue (RGB) represents a 3-D numeric array of the true color image.

Proceed to step three, the grayscale image was converted to a binary image by using ‘im2bw’ routine. If the luminance of the image is greater than 0.5, the routine will replace all pixels in the grayscale image with white (1) and if other than that, replace with black (0). To successfully run this method, the object that was being focused on must be in white.

For binarization method, step four was all about complementing the image as the purpose is previously mentioned. However, for Sobel filtering method, from the binary image in the previous step, it will come out with the outline of the drill bit.

Step five is all about cropping the image to limit the region of interest and to ease the next step. In this step, there are four values that need to be input as coordinates to determine the area to be cropped. Each pixel comes with one coordinate. Hence, it was a smooth process to determine the limit for cropping area.

There were two boundaries used in data analysis process which were on right and left of the image and were created in step 6. First, initial point to start each boundary needs to be defined in terms of pixel values. All subsequent points will be extracted by
using ‘bwtraceboudaries’ routine and the points need to be maximized in order to obtain the highest accuracy of angle and point of intersection. Not only that, all points extracted will then become lines and ‘polyfit’ routine will help to create fit lines to the boundaries.

Step seven allows MATLAB to create vectors for the lines based on the line equation created in the previous step. These vectors will be used in the calculation of angle and point of intersection together with a length of vectors.

Once vectors and its length were obtained, angle for each image can be calculated using this formula. The final step was the calculating point of intersection between the two vectors. To calculate the point, both line Eq. (3.1), Eq. (3.2), and Eq. (3.3) need to be solved together.

\[
\cos \theta = \frac{\vec{u} \cdot \vec{v}}{\|\vec{u}\| \|\vec{v}\|} \quad (3.1)
\]

\[
y = m_1x + c_1 \quad (3.2)
\]

\[
y = m_2x + c_2 \quad (3.3)
\]

Eq. (3.4) to Eq. (3.6) is used to calculate mean and standard deviation to check data consistency.

\[
\mu = \frac{x_1 + x_2 + x_2 + \ldots + x_n}{n} \quad (3.4)
\]

\[
\sigma^2 = \frac{1}{N} \sum_{i=1}^{N} (x_i - \mu)^2 \quad (3.5)
\]

\[
\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (x_i - \mu)^2} \quad (3.6)
\]
CHAPTER 4
RESULTS AND DISCUSSION

4.1 Overview

Table 4.1 and 4.2 shows the mean value that has been calculated from sets of data, each with ten iterations for each drill bit and each side acquired during data collection. Constant variable in both the tables above is a source of light while the manipulative variable is the method of analyzing the data.

From the first column, it can be seen that there are two methods being applied in this project to analyze the data which are the binarization method and the Sobel filtering method. For each method, there are four different drill bits, each with a different maximum number of drilled holes. In the third and fourth column of the tables, there is the mean value of point angle calculated for side 1 and 2 respectively.

Table 4.1 Mean data from 10 iterations of each maximum number of drilled holes (drill) by using focused light.

<table>
<thead>
<tr>
<th>Method</th>
<th>Drill</th>
<th>Side 1 (°)</th>
<th>Side 2 (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binarization</td>
<td>80</td>
<td>135.232</td>
<td>135.271</td>
</tr>
<tr>
<td></td>
<td>364</td>
<td>134.091</td>
<td>134.062</td>
</tr>
<tr>
<td></td>
<td>613</td>
<td>133.267</td>
<td>133.468</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td>134.463</td>
<td>134.647</td>
</tr>
<tr>
<td>Sobel Filtering</td>
<td>80</td>
<td>135.052</td>
<td>135.072</td>
</tr>
<tr>
<td></td>
<td>364</td>
<td>133.840</td>
<td>133.825</td>
</tr>
<tr>
<td></td>
<td>613</td>
<td>132.722</td>
<td>132.886</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td>134.267</td>
<td>134.363</td>
</tr>
</tbody>
</table>
Table 4.2 Mean data from 10 iterations of each maximum number of drilled holes (drill) by using a ring light.

<table>
<thead>
<tr>
<th>Method</th>
<th>Drill</th>
<th>Side 1 (°)</th>
<th>Side 2 (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binarization</td>
<td>80</td>
<td>134.903</td>
<td>134.873</td>
</tr>
<tr>
<td></td>
<td>364</td>
<td>134.156</td>
<td>134.006</td>
</tr>
<tr>
<td></td>
<td>613</td>
<td>133.421</td>
<td>133.584</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td>134.324</td>
<td>134.416</td>
</tr>
<tr>
<td>Sobel Filtering</td>
<td>80</td>
<td>134.977</td>
<td>134.912</td>
</tr>
<tr>
<td></td>
<td>364</td>
<td>134.167</td>
<td>134.037</td>
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<tr>
<td></td>
<td>613</td>
<td>133.230</td>
<td>133.210</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td>134.212</td>
<td>134.232</td>
</tr>
</tbody>
</table>

4.2 Focused Light

From the graph in Figure 4.1, it is clear that there are two trends of the line which can automatically divide into two sections. The first section is between a maximum number of drilled holes of 80 until 613 and the second section is from 613 until 3000 maximum number of drilled holes.

Figure 4.1 Point angle vs maximum number of drilled holes by using focused light for a different method.
Generally, in the first phase, all four lines dropped dramatically from approximately slightly above 135.0° to the range of 132.7° to 133.5°. From 80 drilled holes to 364 drilled holes, it can be observed that all four lines are parallel to each other. This is supported by calculating the gradient for each line and it is proven by the value of -0.004.

Meanwhile, from 364 drilled holes to 613 drilled holes, there are four different gradients shown in the graph. The steepest gradient is shown by Sobel filtering side 1, followed by Sobel filtering side 2, Binarization side 1 and lastly Binarization Side 2.

There is a very small difference between the gradient of Sobel filtering side 1 and side 2 which is 0.0007. Whilst, for the gradient of Binarization side 1 and side 2, the difference is 0.0009. The difference value between those two comparisons which is 0.0002 shows the difference in steepness of slopes trend that can be seen in Figure 4.1.

Moving on the second phase, the slope of the gradients increase from the range between 132.7° until 133.5° to range between 134.3° to 134.6°.

Focusing on Binarization method point angles, at 80 maximum number of drilled holes, point angle value for side 1 and side 2 are almost similar which are at 135.232° and 135.271°. When drill bit with 364 drilled holes being analyzed, it is also found out that both sides mean value of point angle is about the same.

At side 1, the point angle is 134.091° and at side 2, the point angle is 134.062°. However, when 613 and 3000 drill bits being analyzed for both sides using the Binarization method, they showed quite a difference. For drill bit with 613 drilled holes, point angle for side 1 is 133.267° while point angle for side 2 is 133.468°.

As for drill bit with 3000 drilled holes, point angle for side 1 is 134.463° and point angle for side 2 is 134.647°. The difference between side 1 and side 2 for 613 and 3000
drill bits are 0.20 and 0.19 respectively. Compared to the difference between 80 and 364 drill bits, the values are only 0.04 and 0.03.

Focusing on Sobel filtering method, at 80 and 364 maximum number of drilled holes, point angle value for side 1 and side 2 are quite constant. For drill bit with 80 drilled holes, after analyzing its side 1 and 2, the point angles obtained are 135.052° and 135.072° respectively. For drill bit with 364 drilled holes, the point angle is 134.840° for side 1 and 134.825° for side 2.

On the other hand, when drill bits with 613 and 3000 drilled holes being analyzed for both sides using the Sobel filtering method, they showed quite a difference. For drill bit with 613 drilled holes, point angle for side 1 is 133.722° while point angle for side 2 is 133.886°. As for drill bit with 3000 drilled holes, point angle for side 1 is 134.267° and point angle for side 2 is 134.363°. The difference between side 1 and side 2 for 613 and 3000 drill bits are 0.16 and 0.10 respectively. Compared to the difference between 80 and 364 drill bits, the values are both 0.02.

4.3 Ring Light

As illustrated in Figure 4.2, the graph pattern is similar as in Figure 4.1. The only difference between these two figures is the source of light. Despite the source of light is different, the outcome result trends are the same, where from 80 drilled holes drill bit to 613 drilled holes drill bit, the inspection system detected a noticeably fall of point angle. In spite of the point, the angle should decrease more after 613 drilled holes, it shows a sudden increase for 3000 drilled holes.
When drill bit with 80 maximum number of drilled holes being analyzed, it can be seen from Figure 4.2 that all four mean values lie on approximately at the same point angle value which is 134.9°. Concentrating on the drill bit with 364 drilled holes, points for Binarization and Sobel filtering for side 1 shows almost the same point angle value which is 134.156° and 134.167° respectively. The difference between those two point angles is only 0.01.

On the other hand, those two methods for side 2 are also roughly identical. For Binarization method, the point angle is 134.006° and as for Sobel filtering method, the point angle is 134.037°. The difference between these points is only 0.03. This explains why both points for side 1 and both points for side 2 lie almost on top one another.

Next, analyzing drill bit with 613 drilled holes, for Binarization method, it can be observed that it is a little different in value for side 1 and 2. Side 1 point angle is 133.421°, while side 2 point angle is 133.584°, makes it a little higher than side 1 with a difference.
of 0.16. For Sobel filtering method, both side 1 and 2 appear to lie on practically the same point angle value which is 133.230° and 133.210° where the difference is only 0.02.

As for the second phase of the graph which is from drill bit with 613 drilled holes to 3000 drilled holes, the point angle increases gradually. All the points focus on the range of point angle 134.0° to 134.5°.

4.4 Wear Pattern

It is obtained that at drill bit with 80 drilled holes, the point angle data for focused light is marginally more than 135° which is the point angle of this drill bit originally, is because of the production has a tolerance of ±5 (Champion Cutting Tool Corporation, n.d; Greenfield Industries, n.d).

![Point Angle VS Maximum Number of Drilled Holes](image)

**Figure 4.3 Division of section A and section B.**

As can be seen in Figure 4.1 and Figure 4.2, the trend of the graphs is the same, where at section A, the graph drops significantly while at section B, the graph rises steadily. Both figures prove that as the max number of drilled holes increase, the point angle will decrease.
Ramirez et al. (2014) discovered that after 42 holes being drilled, the tool used in his project already wear and abraded. The decreases in point angle are due to wear that occurs on the drill bit geometry, starting from the sharp corner of the cutting lips and continues along the cutting lips to the chisel edge. The drill wear begins as soon as drilling process started and it does not progress at a constant rate, instead, it accelerates non-stop (Schneider et al., 2002). Therefore, the system has proved that it is capable of detecting a difference in point angle.

At section B, the point angle increases instead of decreases maybe due to a different drill bit used for each number of drilled holes. Each drill bit may bring different characteristic due to a different batch of production, different company producing the drill bit and etc. In the normal case, the point angle would decrease as the wear increases but in this matter, perhaps it is because of the drill bit used to drill 3000 holes, only drills test piece instead of actual workpiece. In the factory, window cut outs which are also composites, are used as test piece for variety of purposes. This test piece thickness is assumed to be thinner than actual workpiece. Therefore, a strong reason why the error occurs perhaps can be found if the same drill bit that is used to drill 80 maximum drilled holes, drill until 3000 holes and making sure the same workpiece being drilled is vital

The similarity of both sides is important because the point angle between side 1 and side 2 should be the same. Even if the wear occurs on only one side of cutting lip, the same point angle should be obtained when analyzing either side.

In terms of lighting, during image capturing process, there is slightly different where when adjusting the drill bit to be within the reference line for focused light, the light is turned off until before the image capturing process. When adjusting the drill bit to be facing correct angle towards the camera, external lighting hits the drill bit and hence being reflected. This may disturb the human eye in judging the drill bit to be not under-
rotated nor over-rotated to the left. This also contributes to why the point angle of the drill bit with 80 drilled holes is slightly above 135°.

When using ring light as a source of light, the light is turned on during the adjustment process. This helps a lot in determining whether the drill bit is over or under rotated to the left as the drill bit is now dark shaded, being separated from the background and if one of the issues mentioned occurs, the reflection of light can be seen. This has been the benchmark on how to determine the correct angle to be analyzed.

Despite the difference in the source of light setup, both Binarization and Sobel filtering methods show constant value as can be proved from the trend of the graph.
4.5 Data Consistency

Referring Table 4.3, the standard deviation value is quite vary compared to every drill bit for each side 1 and side 2. The range value is between 0.1 to 0.7. The same range noticed in Table 4.4 where the standard deviation range is also in between 0.1 to 0.7. Comparing this two tables which represent by a different method but the similar source of light, both methods are giving approximately constant data.

From Table 4.5, it shows that all standard deviation value is below 0.1. The highest value would be 0.14 which is value for drill bit with 613 maximum number of drilled holes, side 2. The lowest value is from data of side 2, a drill bit with 364 maximum drilled holes. As seen in Table 4.6, all standard deviation value is less than 0.1.

Since all standard deviation value is less than 1.0, it can be concluded that the data given by Binarization and Sobel filtering method by using both light setups are consistent. Standard deviation calculation is done to prove that all the data in one set are close to each other for every iteration. It does not use to prove whether the set of data is good or bad.
Table 4.3 Point angle for side 1 and side 2 for each drill bit by using Binarization method with focused light.

<table>
<thead>
<tr>
<th>No. of iteration</th>
<th>Side 1 (°)</th>
<th>Side 2 (°)</th>
<th>Side 1 (°)</th>
<th>Side 2 (°)</th>
<th>Side 1 (°)</th>
<th>Side 2 (°)</th>
<th>Side 1 (°)</th>
<th>Side 2 (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>135.087</td>
<td>135.057</td>
<td>134.66</td>
<td>134.604</td>
<td>131.864</td>
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Table 4.4 Point angle for side 1 and side 2 for each drill bit by using Sobel filter method with focused light.

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Table 4.5 Point angle for side 1 and side 2 for each drill bit by using Binarization method with ring light.

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Table 4.6 Point angle for side 1 and side 2 for each drill bit by using Sobel filter method with ring light.

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5.1 Conclusions

This research investigates on designing inspection system of drill bit point angle, a method to inspect and to measure the point angle. The system built is a closed setup where the camera can move in two axes while the drill bit can move in one axis. The distance between the camera and the drill bit is fixed to 40 mm. There are four different point angle of the same drill bit type used for this research which is $80^\circ$, $364^\circ$, $613$ and $3000^\circ$. All drill bits are given by Spirit AeroSystems Malaysia Sdn. Bhd. for the purpose of solving the problem that they are facing, to determine the tool life of the drill bit.

This study is to provide the company with preliminary inspection of drill bit point angle to determine whether the tool can still be used or has ended its life. Drill Bit Monitoring System (DBMS) provides reference line to enable the images of the drill bit to be captured constantly. In MATLAB software, measuring the angle of intersection program is used to measure and analyze the point angle. However, after that, the source of light has changed and improved in its setup gives us an alternative to measuring the point angle.

In measuring intersection angle, when the true color image is converted to a binary image, the object pixels will transform into black while the background into white pixels. Because the boundary detects edge white pixels, the binary image needs to be complimented. Now, the object is in white pixels and the background portrays by black pixels.

Another method used is by using Sobel filter routine. The outline of the program is more likely similar to measuring intersection angle method. However, in this method,
Sobel filter is introduced after the image with greyscale pixels transformed into a binary image. It is found out that with Sobel filter, the edges are clearer compared to measuring the angle of intersection method. The image only illustrates the edges as white pixels compared to the other method that the whole object is in white pixels.

In term of lighting, backlight effect is implemented in this study as to obtain an image with sharp edges outline. There were also two techniques used which are focused on light and ring light. Focused light can create backlight effect under room light condition even without any cover to prevent reflection. The focused light is powerful enough to reflect and diffract light making the object’s outline edges clear and sharp.

With ring light as a source, white paper is used to diffract the light from the source to obtain uniform light. This uniform light will then hit the object from behind. But there is a consequence where a light shield is needed. It is found out that the light diffracted hits the object not only from behind but from the top too. This results in the reflection that will reduce the sharpness of the edges in the image. Both light setups are able to give satisfactory results nonetheless. It is just to study whether these two light setups will give different results.

During data collection, each drill bit was repeated for 10 iterations for side 1 and another ten iterations for side 2. This is to test the capability of the system to capture the image constantly. In addition, human’s eye also plays a huge role in the inspection process. Human’s judgment is needed to make sure the correct angle is facing the camera by making sure the point on the left side of the drill bit fit perfectly within the reference line. To conclude, a more flexible yet accurate system can be done in the future. Assuming this research is a preliminary study in designing an inspection system.
5.2 Recommendations

Some of the future work recommendations that require further investigation in improving in research work are listed:

i. The use of an automatic rotary table to rotate the drill bill precisely to avoid parallax error or over and under-rotate problem.

ii. The use of a motor in adjusting the camera automatically in x and z-axes. This is to enable the camera to achieve its optimum focal length.

iii. A camera casing or proper holder need to be used to avoid shaking or swaying if the camera is disturbed.

iv. A proper source of light can be used to produce a uniform backlight effect even without a light distributor (paper).
REFERENCES


Binarization method by using focused light

80 Side 1
Sobel filtering method by using focused light

80 Side 1
Binarization method by using ring light

80 Side 1
3000 Side 2
Sobel filtering method by using ring light

80 Side 1