STUDY ON NEWLY DEVELOPED DRILL BIT MONITORING SYSTEM FOR COMPOSITE ASSEMBLY IN AEROSPACE INDUSTRY

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ABSTRACT

Aerospace industry is the current multi- billionaire developed industry, where the demands for the air transportation has increasing significantly day by days as people nowadays required short time to travel from one place to another to do their business. Due to this reason, this industry needs reliable monitoring system to ensure aircraft can fly without facing the catastrophic failure. So, the monitoring system is used to maintain the performance of the aircraft manufacturing such as drilling process, which is one of the major machining processes in the Aerospace industry. The aim of a monitoring system for drilling process is to observe the drill wear pattern so it will not damage the workpieces in the next usage, as all products in Aerospace industry usually are the high- end product that cost a huge amount of money. Monitoring system can be used as one part of the inspection in the aerospace industry. Furthermore, this inspection process will use a digital microscope as the sensor to capture the images of the drill bit, meanwhile a computer program will be used for the inspection part. Then, the analysis will be made by using designed programming to calculate the value of the wear pattern. For this research, the study of the current manufacturing practices for drilling process in the aerospace industry by carry out case study. This research can help to test the performance and capability of the newly developed drill bit monitoring system in the Aerospace industry. Lastly, by having this research, the reliability of the newly developed monitoring system can be determined by looking at the results and suggestion, besides the suggestions will be made to improve the reliability of it

PEMBELAJARAN MENGENAI PEMBAHARUAN SISTEM PENGAWASAN BAGI MATA GERUDI UNTUK GABUNGAN KOMPOSIT DI DALAM INDUSTRI AEROANGKASA

ABSTRAK

Industri aeroangkasa merupakan suatu industri sedang membangun yang bernilai berbillion ringgit. Tuntutan untuk penggunaan pengangkutan udara yang semakin meningkat dari hari ke hari, di mana manusia memerlukan waktu perjalanan yang singkat untuk pergi dari satu tempat ke satu tempat yang lain bagi menyelesaikan urusan masing-masing. Oleh disebabkan ini, industri ini memerlukan satu sistem pengawasan yang boleh diharapkan untuk memastikan kapal terbang boleh terbang tanpa menghadapi sebarang masalah berbahaya yang boleh mengundang kerugian kepada syarikat penerbangan mahupun penumpang-penumpang.Jadi, sistem pengawasan digunakan untuk mengekalkan prestasi pembuatan penerbangan seperti sistem gerudi, yang mana merupakan antara proses pemesinan yang utama di dalam industri aeroangkasa. Tujuan sistem pengawasan ini dibangunkan untuk proses menggerudi adalah untuk pemerhatian corak kehausan mata gergaji supaya ianya tidak merosakkan kepingan kerja pada pengunaan akan datang, kerana kesemua produk industri aeroangkasa kebiasaannya mempunyai harga yang tinggi untuk dibeli semua dan dikekalkan. Sistem pengawasan yang digunakan merupakan salah satu pemeriksaan di dalam industri aeroangkasa. Proses pemeriksaan menggunakan digital mikroskop sebagai pengesan untuk menangkap gambar mata gerudi, manakala program komputer akan digunakan dalam bahagian pemeriksaan. Seterusnya, analisa akan dibuat menggunakan sistem pengkomputeran yang direka khas untuk mengira nilai corak kehausan mata gergaji bagi membolehkan

pengguna membuat keputusan sama ada mata gergaji tersebut masih boleh berfungsi ataupun tidak.Melalui kajian ini, diharapkan dapat membantu untuk menguji prestasi dan kemampuan sistem pengawasan bagi mata gerudi di dalam industri aeroangkasa. Akhir sekali, dengan mempunyai kajian ini juga, keboleh percayaan sistem pengawasan boleh ditentukan dengan melihat kembali pada keputusan dan perbincangan, disamping beberapa cadangan akan diberi untuk meningkatkan keboleh percayaan sistem ini.

DECLARATION

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

FIZAKAMAL

NUR HAFIZAH BT KAMAL AZHAR

Date: 5th June 2017

STATEMENT 1

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

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STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available to outside organizations.

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Date: 5th June 2017

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CHAPTER 1

INTRODUCTION

1.1 Brief Introduction

In recent years, drilling process is becoming the major machining processes in the Aerospace industry. It is roughly calculated that approximately 250 million twist drills are used annually by the United States industry alone. Besides, it was also estimated that drilling accounts for nearly 40% of all metal removal operations in the Aerospace industry, even 245,000 holes need to be drilled for a small jet [1]. Generally, drilling is a process of cutting the non-metallic and metallic material into the circular shape called a drill hole, where it has a high length to diameter ratio. Drilling can be performed in three different steps which are pilot holes drilling, final size drilling and reaming (provide better tolerance and surface finish). Usually, drilling by a using twist drill is the most frequently process practiced in secondary machining of the composite materials for the structural joining purpose. In order to maintain the performance of the drilling process, monitoring system is necessary because all products in Aerospace industry usually are the high- end product that cost a huge amount of money to re-purchase. The aim of a monitoring system for this industry is to observe the drill wear pattern so it will not damage the workpieces in the next usage. Wear pattern occurs because the heat distribution that are generated during cutting, the friction between drill bit and workpiece, gradient of pressure that are exerted on it, and the distribution of stress between tool and workpiece. Direct measurement of tool wear can be obtained after a certain number of drill holes and assessment tool condition can be done through vision inspection, which is drill bit monitoring system is used to detect the area of wear pattern. The inspection process will need a digital microscope as the sensor to capture the images of the drill bit whilst a computer program will be used for the inspection part.

1.2 Problem Statement

The monitoring unit for drill bit visual inspection is a need where a digital microscope will be used as the monitor, while a computer program will be used for the inspection part. Generally, this monitoring unit will help to capture images of drill bit to analyze the condition of the drill bit either it need to be changed or still can be used for the next drilling process. So, in order to know the effectiveness of this monitoring system, testing the drill bit monitoring system need to be developed by collecting the data from monitoring process which will result the value of the drill bit wear pattern. This research is conducted to processes and analyzed regarding the monitoring result. However, to conduct this research, there are several parameters that need to be fixed first in the composite drilling process in the Aerospace Industry. For an example, drill bit type, drilling setting, and material of the workpiece are considered involve in the monitoring process. The reason why these parameters need to be fixed because in the next chapter, the reliability and performance of the drill bit monitoring system can be questioned and analyzed in more details.

1.3 Objectives

I. Able to identify the type of drill bit wear type and condition by having the study of the drilling process in term of qualitative approaches on the current practice Aerospace Industry.

II. Design and conduct the experiment to test the performance and capability of the newly developed drill bit monitoring system in the Aerospace industry.

III. Able to measure the percentage of wear by using the newly developed monitoring system from the sample of the current drill bit used in current drilling process of Aerospace Industry and make the improvements based on the results and discussions.

1.4 Thesis Layout

Chapter 1: Introduction

In this chapter, the idea of the projects will be briefly explained and the basic knowledge regarding the composite drilling process in the Aerospace Industry is situated. Next, the problem statement and objectives are identified and defined based on the project current situation in real aerospace industry, besides the thesis outline also describe in this chapter to create awareness for the thesis's reader about project flows.

Chapter 2: Literature Review

This chapter has a purpose to define the key terms, terminology, definitions and equations for the thesis title. It also helps to summarize the studies of previous researches and works regarding the composite drilling process in the Aerospace Industry by stating their own project setup and analysis.

Chapter 3: Research Methodology

In this chapter, the application of the specific techniques or procedures is defined and used to identify, select, and analyze the future expected results based on the thesis problem statements. In other words, it assists the project flow to show where the case study is carried out in collaboration with the selected Aerospace Industry. The data will be collected from selected company and kept for future analyze and references.

Chapter 4: Results and Discussions

This chapter will helps with the interpretations of the findings of the study based upon the methodology that have been applied for this project. The results obtained will be analyzed and relate back to the theoretical studies to explain the reasons why at the results are obtained in certain ways after the project is carried out in the selected Aerospace industry. The results obtained from the drilling process will assist the discussions part to give out suitable future recommendations for better reliable results.

Chapter 5: Conclusions and Recommendations

In this chapter, the outcomes are concluded based on the project's objectives. The work of the projects need to be restated clearly to ensure the thesis is aligned with the project's work frames. Future work recommendations will be made in this part. The importance of the future recommendations according to the results and discussions will be used by the developer of the system to make the appropriate improvements for it, in order to establish future good image enhancements and measurement of the results.

CHAPTER 2

LITERATURE REVIEW

2.1 Drilling and Inspection of Composite

Since 1970s, composite material manufacturing and design technologies have grown up to a level where 50% of Boeing primary structure used it in 787 programs. So, machining of composites particularly drilling process is fundamental for joining the aircraft structure during assembly operations. The defects cause by drilling will impact in cost as it will damage the structure. In this scenario, tool wears play important roles to avoid any damages from occurs as it will decrease man-hour productivity but increase in economic impact [2]. Next, tool wear also consequence in the damage of the laminate called delamination that will appear during drilling process. This delamination will decrease the integrity of laminate structural which resulting deterioration performance and low tolerance. Actually, delamination is a damage which occurs in the inter-laminar regions or between drill bit and workpiece adjacent layers. It can be divided according to the area called laminate region, peel up and push out.

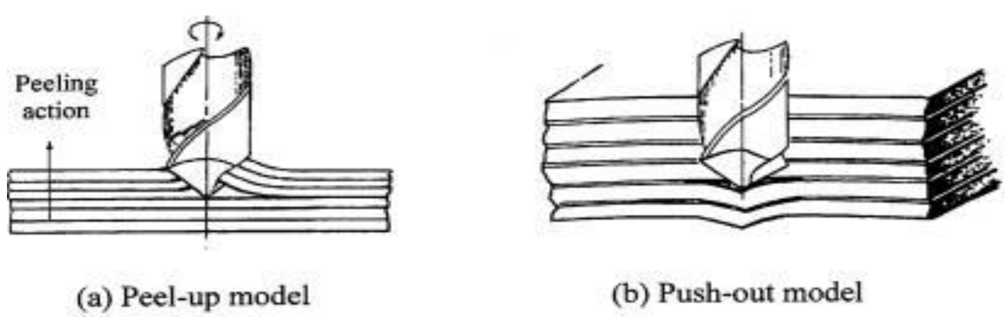

Figure 1 Peel-up and Push-out Model

The inspection is a fundamental process after drilling in aerospace industry, because it helps to maintain the quality of production before send it to the customers. Due to high cost and demands of composite materials in Aerospace industry, inspection is a must even though it is complicated as the materials is anisotropic. Inspection can be done by using tool wear monitoring methods which can be categorized into two methods; direct and indirect methods. Generally, direct methods it is directly possible to determine tool wear because measurement is not ambiguous. Example of direct monitoring methods such as visual inspection or computer vision [3]. Visual inspection is a process of evaluation and examination of the components and systems with the aid of human sensory system and help only by using the mechanical devices as a sensory input. In this direct visual inspection or can be called as NDT (Non-destructive Test), the monitoring unit for drill bit visual inspection is a need where a digital microscope will be used as the monitor, while a computer program will be used for the inspection part. Generally, this monitoring unit will help to capture images of drill bit to analyze the condition of the drill bit either it need to be changed or still can be used for the next drilling process. Figure 2 has shown the example of the NDT.

Figure 2 Example of Digital Microscope Camera for Monitoring System

Inspection process must be carried out in the environment with the sufficient light as the lighting is very vital and can substantially affects the wear percentage result. The artificial light is favorable for visual inspection where the inspector need to set the appropriate level of light level called illuminance to ensure the exposure of drill bit area of interest will have the same lighting pattern for the better image comparisons. During inspection, it is important to ensure the environment is not really noisy as it will cause the vibrations and causing the movements during image acquisition process, which will make the position of drill bit monitor under the camera system have a movement that will give contribution to variable position and dimension throughout the project.

For the test of monitoring system, several parameters is needed to ensure the results that are obtained from visual inspection reliable .Drill bit type, drilling setting, and material of the workpiece are considered involve in the monitoring process. This parameters are fixed according to availability of them in Aerospace Industry. Drill bit is used as parameters because it has tool life that corresponds to the numbers of holes can be drilled until it does not longer has a capability to drill acceptable quality of holes. Next, the drilling setting is commonly accepted as tool wear is estimated to be increased extensively with increasing of cutting speed and drilling temperature [4]. Material of work pieces is considered also in test of monitoring system as different materials will carry out different properties that might influenced the quality of drilling process. Lastly, the fixed parameters will be used in the drilling process, and the images of the drill bit will be captured under image acquisition sytems and measurement of the wear percentage that are made from measuring system will contribute to the future recommendations for the drill bit monitoring system for better improvement in developing of the NDT.

2.2 Drilling Parameters

2.2.1 Drill bit / Cutter

Generally, the drill bit is a cutting tool which is used to remove material by creating and making a circular cross-section, known as holes. Drill bits come in many shapes and sizes according to the materials it needs to drill. For the composite material, the most important type of drill is a twist drill. Common twist drills are made from HSS (High Speed Steel), but it is not really suitable for the composite drilling as it wears rapidly after making several holes. PCD (Polycrystalline diamond) and Tungsten Carbide usually used to drill composites. From previous studies, PCD show better performance when coming to the tool wear rate but it is expensive compared to the Tungsten Carbide [4].

It is important to choose the correct drill geometry as it is will influence the cutting edge that are able to endure the punishing hardness of the composite workpiece [5]. There are several characteristic of drill bit geometry:

I. **Point angle**: it is determined by the material of the workpiece as it is the angle that are formed at the tip of the drill bit. The diameter of point angle is depends on the hardness of the material of workpiece. It can also influence the holes shape and wear rate of the drilling process.

II. **Spiral**: It is the rate of twist which is helping to control the rate of chip removal during drilling. The higher the spiral, the higher the feed rate will be applied under low spindle speeds to remove large volumes of chips. Traditionally, high cutting speeds will use the low spiral because to avoid the tendency of the drill bit to clog the holes of workpiece.

III. **Length of bit:** Can control the depth of drilling, accuracy of the resultant hole, and stiffness of the bit. Deeper hole can be drilled by using the longer bit as it is more flexible. Length can be divided into 3 parts, can refer to figure 3, which are short (Screw- Machine-length), Medium (Jobber- length), and long (Taper length or Long series). Commonly, Jobber- Length widely used for the manufacturing drilling.

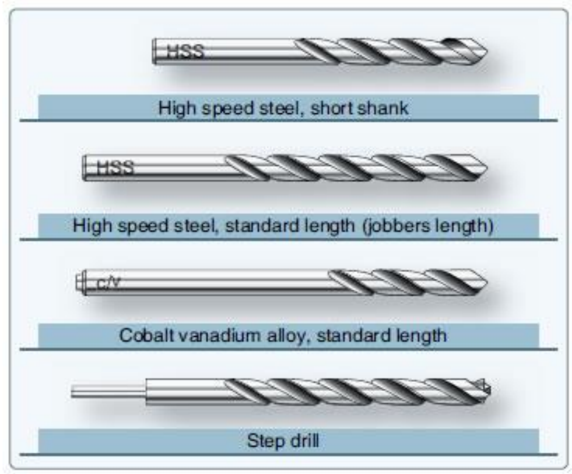

Figure 3 Drill Bit Length

IV. **Lip angle:** It determines the amount of support for the cutting edge. The drill bit can cut the work piece aggressively if the greater lip angle is used to drill compared to a bit with the smaller lip angle. This condition can result in wear, binding, and sometimes the catastrophic failure. Besides, very acute point angle has a more web surface area occur at any of time of drilling, which may need an aggressive lip angle, but for the extremely sensitive to small changes in lip angle, flat bit can be used as it had a small surface area to support the cutting edges.

V. **Flute:** It is the straight or helical grooves cut on the body of drill which provides cutting lips, allow the removal of chips, and permit cutting fluid to reach the cutting lips of drill bit. The flutes has certain length from outer corner of the cutting lips to the back end.

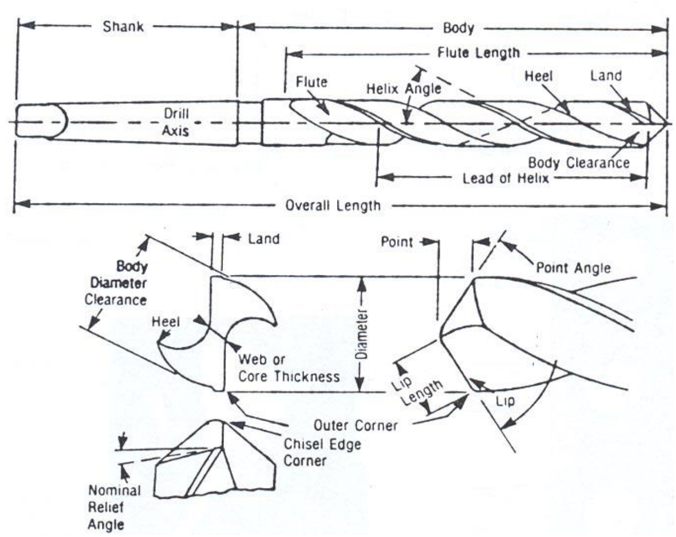

Figure 4 Drill Bit Geometry

Drill bit geometry as shown in figure 4, will affect the thrust force and torque. The higher the thrust, the higher probability of tool wear will be occurred during drilling. Thrust increase steadily until it reaches value that are corresponding to steady drilling through the thickness of the workpiece. Whilst, the torque is increasing linearly until the cutting edges of the tool is completely engaged. Proper choice of drill bit geometry will results in better drilling holes quality. The quality of the holes need to be in better condition as it can measure the success of the drilling operating and can address the strength and fatigue life of the carbon composites. Moreover, tool life can affect the acceptable number of holes that drill bit can make as the Aerospace industry need a very tight holes tolerance. Drill holes need to have a permissible variation in dimensions such as depth, width, diameter, height, and angle of holes, surface roughness and the appearance of the burrs.

2.2.2 Speed and feed rate

Speed rate is a measurement of the rate which the periphery or outside of the tools can move in relation to the drilling work. The term for this speed is usually in surface feet per minute (SFM) or revolution per minute (RPM). Below is the equation of the speed rate

$$V = \pi DN \tag{1}$$

V= peripheral velocity of the tool

D= Diameter of the tool

N = Rotational velocity of the tool

To find the N,

$$N(rpm) = 12\left[\frac{in}{ft}\right] x \frac{V[sfm]}{\pi x D\left[\frac{in}{rev}\right]} \tag{2}$$

The feed rate is a

$$f\ \left(\frac{in}{\min}\right) = N\ (rpm)\ x\ f_r\ (\frac{in}{rev}) \tag{3}$$

f_r= Feed per revolution of the drill