INVESTIGATION ON THE EFFECT OF DRY TURNING ON AISI 305 STEEL WITH CERAMIC INSERTS BY ANALYSIS OF WORKPIECE SURFACE PROFILE

By:

NURNADIA AZWA BT MOHAMAD

(Matrix no.: 125425)

Supervisor:

Prof. Mani Maran Ratnam

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DECLARATION

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LIST OF ABBREVIATIONS

SEM	Scanning Electron Microscope
ACF	Autocorrelation Function
DSLR	Digital Single Lens Reflex
rpm	Revolution per minute

ABSTRAK

Penyelidikan ini mempersembahkan pemesinan beralih kering untuk melihat profil bahan kerja AISI 305 dengan menggunakan seramik sebagai alat pemotong. Pemesinan dilakukan sebanyak lima kali sepanjang percubaan menggunakan spesimen yang sama dan memasukkan pemotong. Imej seramik akan ditangkap sebelum pemesinan dan selepas setiap laluan pemesinan di bawah Mikroskop Pengimbasan Elektron (SEM) untuk memerhatikan prestasi semasa operasi pemesinan. Imej benda kerja ditangkap dengan menggunakan resolusi tinggi kamera DSLR dengan pembantu cahaya latar untuk mendapatkan profil bahan kerja yang berkualiti tinggi. Penataan latar belakang yang sesuai adalah penting untuk mendapatkan kualiti pemprosesan imej yang baik. Imej bahan kerja akan diekstrak ke dalam pengaturcaraan simulasi untuk mendapatkan profil autokorelasi. Dari profil fungsi autokorelasi, profil permukaan akan diperhatikan untuk mengesan alat haus beransur-ansur. Profil permukaan bahan kerja diperiksa menggunakan kaedah pengukuran dan penglihatan untuk mengesahkan profil. Kaedah penglihatan adalah kaedah pengukuran yang paling tepat berbanding dengan pengukuran kerana beberapa had peralatan.

ABSTRACT

This research presents the dry turning machining to observe the workpiece profile of the AISI 305 by adopting ceramic insert as a cutting tool. The machining was conducted fifth passes throughout the experiment using same specimen and cutting insert. The image of ceramic insert before machining and after every each pass of machining were captured under Scanning Electron Microscope (SEM) to observe the performance during machining operation. The image of workpiece is captured by using high resolution of DSLR camera with assistant of backlighting to obtain high quality of workpiece profile. Appropriate setting of backlighting is significant to obtain a good quality of image processing. The image of the workpiece will be extracted into simulation programming to obtain the autocorrelation profile. From the autocorrelation function profile, the surface profile will be observed to detect the gradual wear of tool. The workpiece surface profile is examined using stylus and vision method to verify the profile. Vision method is the most accurate measurement method compared to stylus due to some limitations of the equipment.

CHAPTER 1

1.0 INTRODUCTION

1.1 Introduction

Turning operation is a fundamental of manufacturing process of removing unwanted material from the outer diameter of the cylindrical specimen. Machining works in the event of parts rotated while the cutting tool moves parallel with the rotational axis. Turning also can machine the internal diameter of specimen which called as boring. This process is done to produce a smooth hole from the inner of cylindrical form. For this experiment, the dry turning operation is employed to observe the surface of the material.

Austenitic stainless steel is one of the difficult-to-cut material [1]. It is extremely used in industrial application such as chemical manufacturing, food processing mechanism and machinery parts due to the excellent in work hardening, low heat conductivity, mechanical strength and high corrosion resistance [2]. Besides, austenitic stainless steel has high built-up edge formation which leads to the arising in temperature and cutting force during machining. Furthermore, arising of temperature can be a root cause in poor surface finish of the material and trigger on tool wear as all the parameters such as cutting speed, feed rate and depth of cut give higher response on the surface roughness [3-5].

Additionally, the experiment was conducted by adopting alumina-based ceramic insert as cutting tool. Recently, ceramic has gained a high attention due to the low thermal conductivity, low density and low dielectric constant. Although Al_2O_3-based ceramics resulted in high hardness, shock resistance, chemical stability and fracture strength, the previous studies shown the ceramic tool failure still arise for continuous machining. The life of cutting tool can be gradual wear leading to tool failure or premature edge failure due to chipping. After machining, the configuration of cutting insert is observed under Scanning Electron Microscope (SEM). Moreover, an application of chipped tool during continuous machining will possess to the degradation of the surface quality and uneven workpiece profile. Therefore, the workpiece surface will be analysed using autocorrelation function to detect the tool wear after machining.

The project focuses on dry cutting effect in turning of AISI 305 steel with application of ceramic insert to observe the performance of cutting tool by analysed using autocorrelation function. Comparison between vision method and stylus method are made to verify the surface profile of the workpiece.

1.2 Project Background

The purpose of machining is to produce a part in a specific dimension. The workpiece profile is obtained by using autocorrelation function. Autocorrelation was done by comparing the workpiece profile with shifted the image by a lag distance. The detection of tool wear will cause the peak of autocorrelation function of the workpiece profile decreased rapidly as the lag distance increased at different rotational angle.

Recently, machine vision is an accurate direct method in detecting a tool wear by using DSLR camera with macro lens to capture the image of workpiece surface after machining. Hence, to obtain the surface profile image, the machining process needs to be free from disturbances such as contaminant, vibration and noise to get a constant profile. Nevertheless, the machining operation tends to produce noise and vibration which cause uneven profile.

One of the most important parts in machine vision component is illumination. The appropriate selection of light source depends on the amount of light, required stand-off distance and ambient issues involved. In monitoring the wear cutting tool, the main requirement system is to provide sufficient contrast between the worn region and the background. The intensity and the angle of illumination source should be focus on the tool region of interest.

1.3 Problem Statement

Autocorrelation function is used to detect the presence of random profile by comparing the workpiece profile with replicate itself by a lag of distance which gives more information in studies. Although, the ACF analysis has been applied in chipping and fracture of tool performance in previous research, there has yet focused on surface profile analysis caused by gradual wear due to the continuous machining.

1.4 Research Objectives

The objectives of this project are as follows:

- To investigate on the effect of dry turning on AISI 305 steel with ceramic insert using autocorrelation function.
- To verify the workpiece surface profile by comparison between vision and stylus method.

1.5 Scope of Research

To achieve the project objectives, the dry turning is operated on AISI 305 steel using conventional lathe machine. The machined workpiece surface will be captured under high-resolution DSLR camera with well backlighting. The surface workpiece surface profile will be extracted using subpixel edge detection. Next, the profile will be imported into MATLAB to process the ACF graph. The ACF works by comparing the workpiece profile with shifted the image by a lag distance to observe the gradual wear of tool and then correlated with the best ACF profile to analyse the deviation between the profiles.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter will provide the review from previous research that is related to final year project. From the previous researches, the investigation on surface roughness in dry turning involved various type of materials, cutting insert, experiment design and other method have gained great attention.

2.2 Material of specimen

The material used in this experiment is AISI 305 steel which one of the difficult-to-cut material in machining. In previous research, the current grade machinability of steel (AISI 304) is low compared most other grades of steel due to high mechanical strength, low conductivity and high work hardening [9]. Thus, austenitic stainless steel gained more interest in industrial application by a reason of resistance to the corrosion

2.3 Cutting insert

In 2006, Kumar et al. [10,11] mentioned that the alumina-based ceramic tool acquired high abrasion resistance and hot hardness. Therefore, it become an attractive alternative of carbide tool insert in steel machining, Besides, ceramic insert also is more stable compared to high-speed steels and carbides which less prone to chip stuck on the insert during machining and low tendency for built-up edge to form. Hence, it resulted in good surface finish and high dimensional accuracy of the machining.

From the previous year's work [1], the dry machining of AISI 304 Austenitic Stainless Steel was carried out using AlTiCrN Coated Insert Produced by HPPMS Technique. The effects on the surface finish, cutting force, wear of tool, chip thickness and the tool life were examined during the machining operation.

The experimental on the ceramic material was observed to predict the hardness of the material. The experiment works by addition of whiskers and micron particles with different dimension and scale of raw material. As the result, the experimental of hardness material with addition whiskers and micron particles possess to good agreement of theoretical value. Meanwhile, the experimental of hardness material by addition of nanoparticles give higher value compared to theoretical counterpart. [12].

2.4 Surface roughness

Product that have good surface finish will gain more profit in manufacturing production. However, higher surface roughness is required compared to fine surface finish in experimentation to visualize the detection randomness of surface profile easily. In 2013, Swapnagandha et al. found that increases in feed rate will causes more friction exists between cutting tool interface with workpiece surface, thus leading to the increasing of the surface roughness.

Autocorrelation or serial correlation is the correlation of a signal with a delayed copy of itself as a function of delay. The analysis of autocorrelation is a mathematical tool for finding repeating patterns [6,7]. The purpose of ACF is to detect non-randomness in workpiece surface and to identify an appropriate time series model if the surface of the parts are not random [8]. Therefore, even the gradual wear of tool is used for continuous machining, the autocorrelation graph will show regularities profile because the cutting tool is not fully damage.

CHAPTER 3

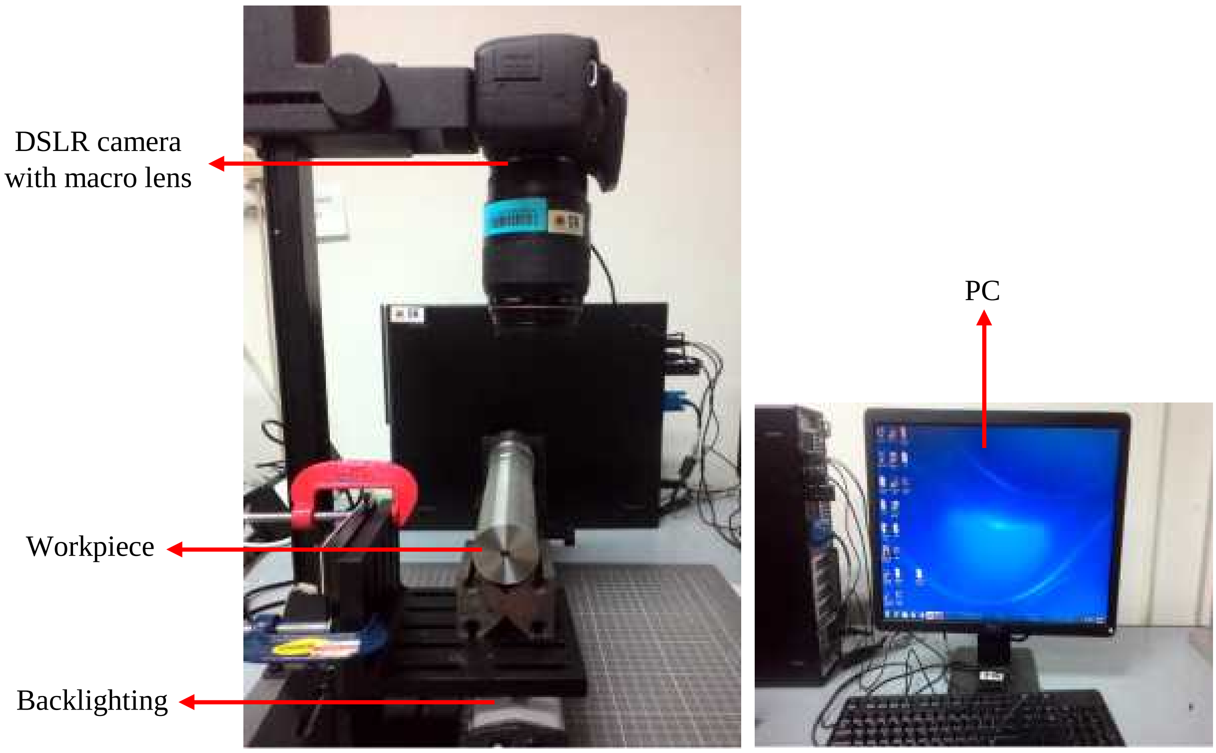
3.0 METHODOLOGY

3.1 Introduction

This chapter will explain in detail the step to set up the experiment from turning operation until observation of workpiece surface profile by using ACF graph. The overall project flow is described in detail in this section.

3.2 Project Methodology Flow

The turning operation was conducted by using 45 mm diameter AISI 305 stainless steel workpiece of length 200 mm. The machining was done on a Pinocho S90 conventional lathe machine by using aluminium ceramic insert cutting tool from Sandvik Coromant Ltd., Sweden. The image resolution and focal length for this experiment is 5184 × 3456 pixels and 100 mm by using high resolution DSLR camera and image processing was done using computer in the Metrology and Precision lab. The illuminance is important in capturing the image of workpiece profile to obtain high quality image processing. The photograph of experimental set up is shown in Figure 3.1 (a) and (b). The assistant of the backlighting is an effective way to get a good image. The illumination of the backlighting must be controlled appropriately to ensure the image is not over lighting and not too dark which will possess to bad image quality.



(a) b)

Figure 3.1 Experiment set up (a) DSLR camera with backlighting (b) Computer workstation

3.3 Selection of cutting tool

The cutting tool used is ceramic material with rhombus shape by Sandvik Coromant Ltd., Sweden. A ceramic insert was mounted on a Sandvik tool holder with cutting tool edge angle 80º. Before carrying out dry turning, the image of ceramic insert was captured under Scanning Electron Microscope (SEM), Hitachi TM1000 SEM as shown in Figure 3.2. Besides, the observation on the cutting tool after each pass of machining also required to detect the wear of insert.

Figure 3.2 Scanning Electron Microscope (SEM), Hitachi TM1000

3.4 Selection of work material

The workpiece material evaluated in this study is AISI 305 Stainless Steel. Figure 3.3 shows the image of workpiece.

Figure 3.3 Image of workpiece

3.5 Dry Machining

The performance of ceramic insert was evaluated in dry turning which no lubricant are used as a future green machining. Dry turning operation test was performed on a Pinocho S90 conventional lathe machine to study the effect of dry turning by adopting ceramic as cutting tool. Before starts machining according the desired parameter, one pass of straight turning with application of lubricant is required to clean the surface of material to obtain a smooth surface using carbide insert. Figure 3.4 shows the image of wet straight turning passes. The purpose of applying lubricant is to remove burr, chip, contamination, maximize the cutting tool life and to obtain a fine surface finish.

Figure 3.4 Image of wet straight turning

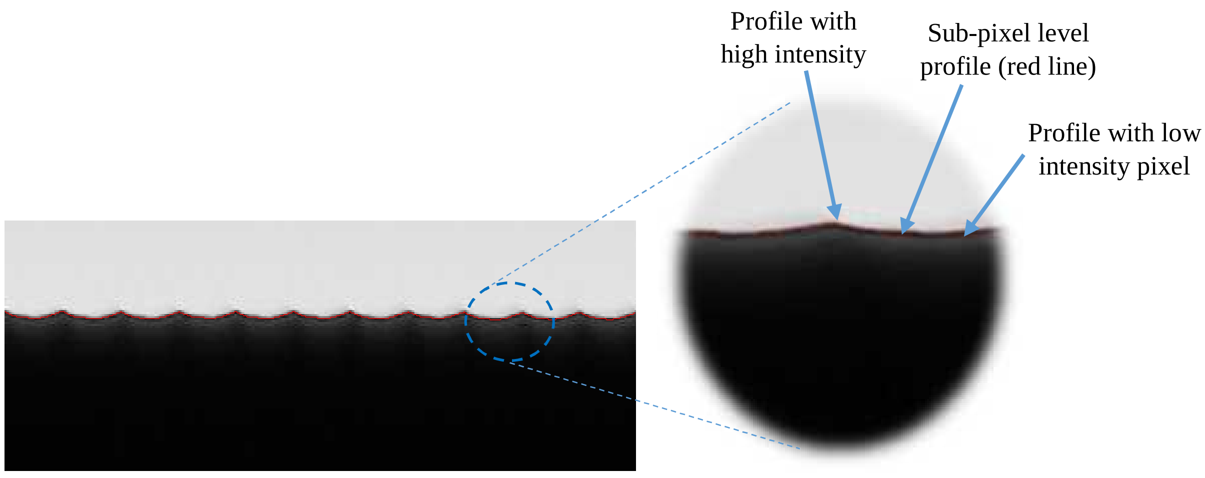
The image of machine set up is shown in Figure 3.5 (a) and (b). The experimented works consisted of fifth passes using same cutting tool, specimen and parameter which is cutting speed, 1400 rpm, feed rate, 0.4 mm/rev and the depth of cut is 1 mm. The continuous machining was done to observe the tool failure in machining.

(a)

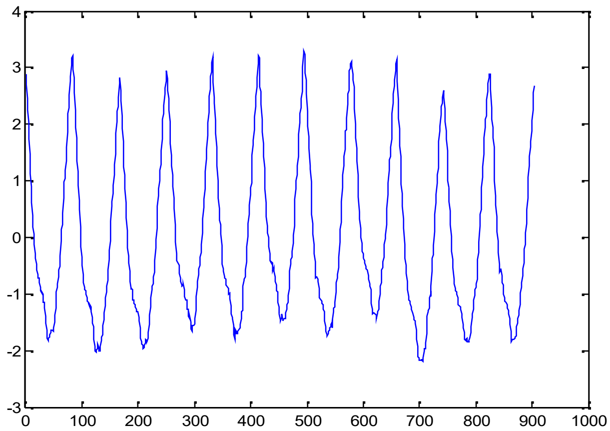
(b)

Figure 3.5 Image of machine set up (a) Pinocho S90 conventional lathe machine b) Close view of conventional lathe machine

After machining the specimen, the image of workpiece profile was obtained from DSLR camera by capturing the image of the workpiece with 4 mm length at the beginning, middle and at the end of the workpiece. The captured profile image was extracted into the Mat lab programming to observe the autocorrelation function. The extracted result was obtained in Figure 3.6 (a), (b), (c) and (d).



a)



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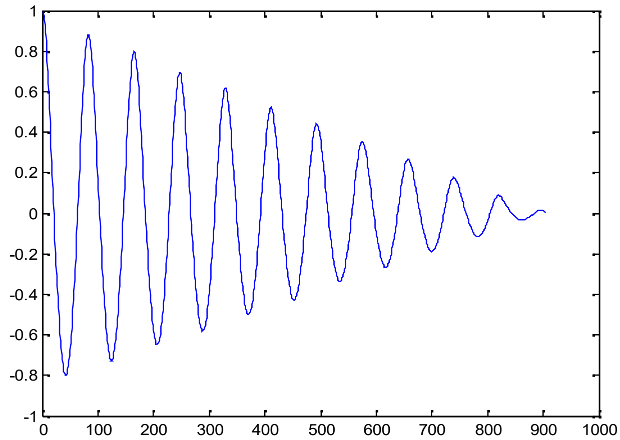

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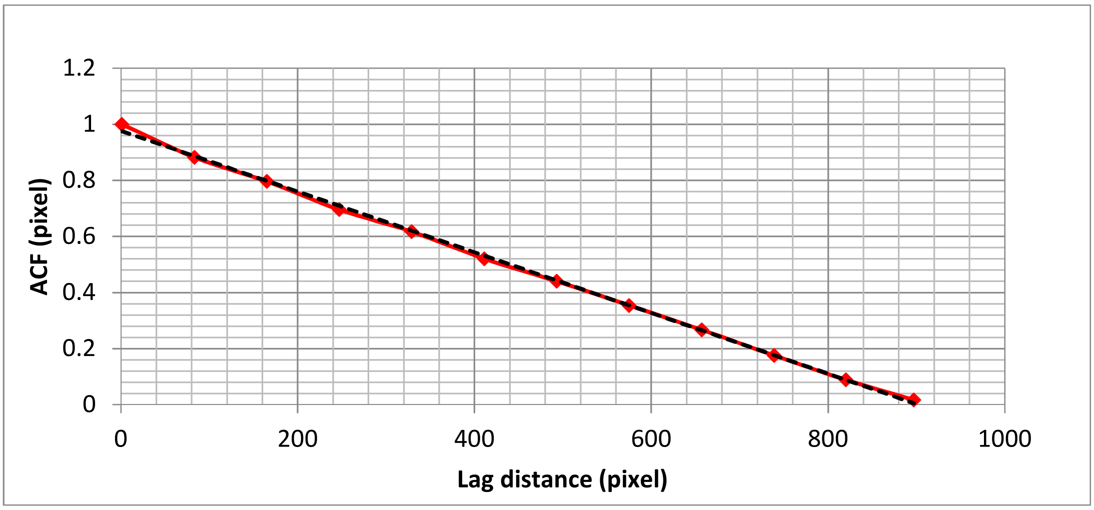


d)

Figure 3.6 Result of extracted profile from simulation a) Image after binarize b) Extracted profile c) ACF profile d) ACF graph

3.6 Comparison between Machine Vision methods with Stylus method

The profile of machined workpiece was compared by using machine vision and stylus method. Stylus method is measured using SURFCOM-130A Surface and Roughness Tester machine. Practically, machine vision method is the most accurate measurement compared to stylus method because the stylus have edge radius, thus it cannot measured the workpiece surface accurately. The Standard Operation Procedure (SOP) was listed in Figure 3.7. The image of Surface and Roughness Tester machine as shown in Figure 3.8 (a), (b), and (c)

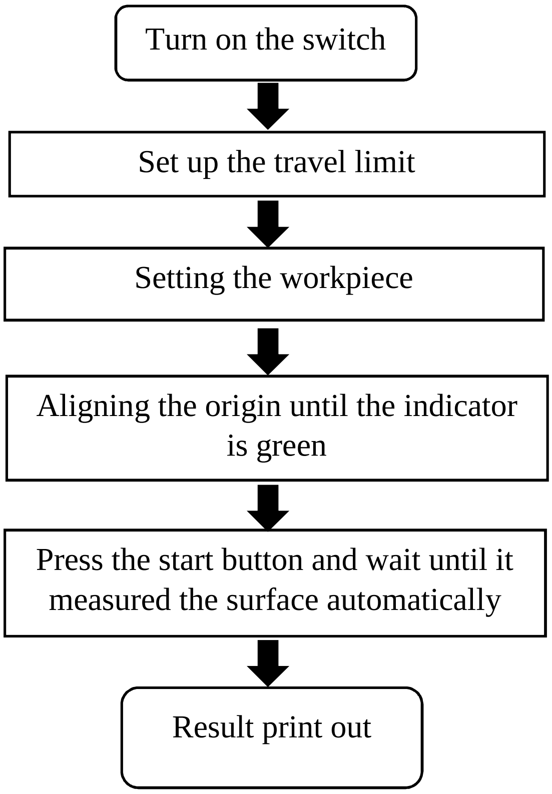


Figure 3.7 Standard Operation Procedure (SOP)

(a)

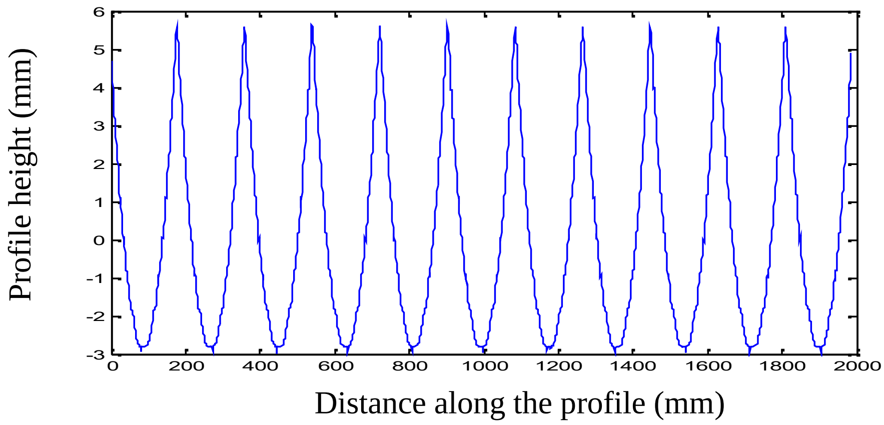
(b) (c)

Figure 3.8 (a) Image of SURFCOM-130A (b) Data Processor (c) Image of measured workpiece

3.7 Theoretical Analysis

Figure 3.9 (a), (b), (c) and (d) show the theoretical surface profile analysis. The workpiece profile was designated from SolidWorks 2014x64 edition software to represent the theoretical profile of a machined surface. In theory, the peaks of ACF profile will decreases uniformly and linearly as lag distance increases due to the periodic workpiece surface profile.

(a)



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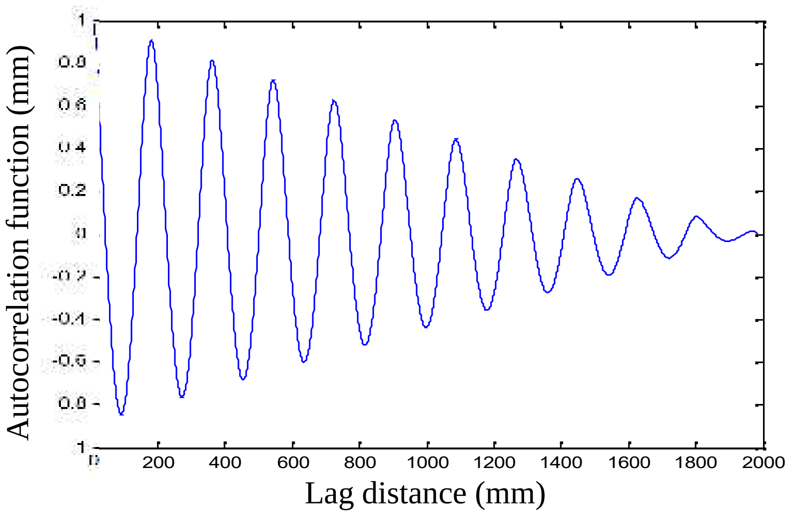
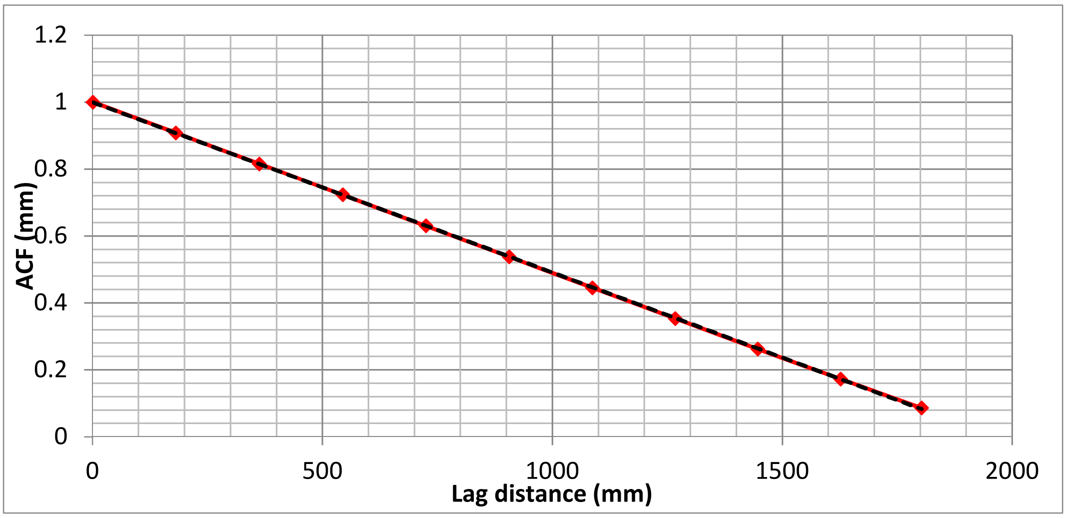


(c)



(d)

Figure 3.9 Theoretical surface profile analysis (a) Image after binarize (b) Extracted profile (c) ACF profile (d) ACF graph

Based on the Figure 3.9 (a), the image of workpiece was captured under DSLR camera before extracted the image into the MATLAB programming. The presence of noise, vibration and contamination will lead to low image quality.

CHAPTER 4

4.0 RESULT AND DISCUSSION

4.1 Introduction

The machining was done to fifth passes to detect the wear of ceramic insert using constant parameters. Additionally, the performance of cutting tool was analysed by observing the workpiece profile at the beginning, middle and the end of the workpiece surface with different rotational angles.

4.2 Surface roughness

The experiment was done using cutting speed, 1400 rpm with feed rate, 0.3 mm/rev and depth of cut is 1 mm. The reason used for high cutting speed is to obtain a faster wear of cutting tool after a few passes. Same goes to depth of cut, which feeds 1 mm diameter of the workpiece material is to access a tool failure. Besides, the higher feed rate per revolution is adopted to get more helical configuration of workpiece profile like the screw thread, thus the surface profile of workpiece will simply be examined. Figure 4.1 (a) and (b) shown the image of workpiece surface. Figure (a) is the image of the workpiece surface after undergo first machining, figure (b) is the surface image of forth passes and figure (c) is image of workpiece after fifth passes. Based on the figure below, figure (a) posses to fine surface profile which indicated the cutting tool is new compared to figure (b), the surface image is slowly damage after a few passes of machining which demonstrate that the tool starts to wear gradually. For the figure (c), the surface profile is slightly missing due to the tool wear.

(a)

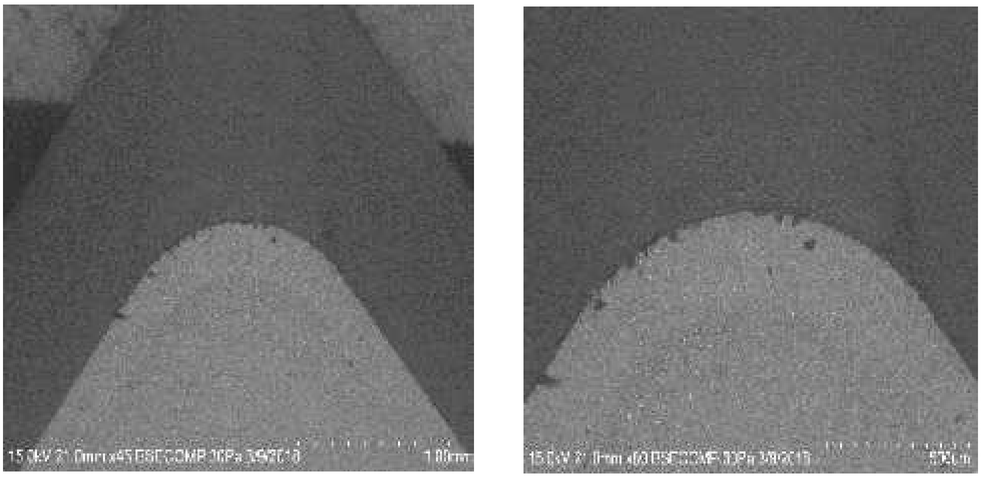
(b)

(c)

Figure 4.1 Workpiece surface profile (a) After first machining (b) After forth machining (c) After fifth machining

4.3 Condition of ceramic insert

After gone through few passes of machining, the performance of cutting insert was analysed under Scanning Electron Microscope (SEM). The image of insert is captured before machining and after each passes of the machining. Figure 4.2 (a) and (b) shown the photo of ceramic insert before machining.



(a) (b)

Figure 4.2 (a) Image of new ceramic insert before machining (b) Close-up view of insert

Figure 4.3 (a), (b), (c) and (d) show the close view of ceramic insert and their corresponding extracted sub-pixel profile. At the first passes, the image of insert did not show any differences between due to the high hardness of ceramic cutting tool, plus the insert is still new. Hence, the extracted graph shows a periodic pattern of profile. Based on figure (b), the image of insert closed to the image of insert at the first passes which mean the insert was still not wear. Besides, the figure (c) shows that the insert slightly differs from the previous image. It indicates that the cutting tool starts to wear. Meanwhile, at the fifth machining, the image of ceramic insert having a large gradual wear at the cutting edge, thus the extracted profile show ununiformed profile pattern.

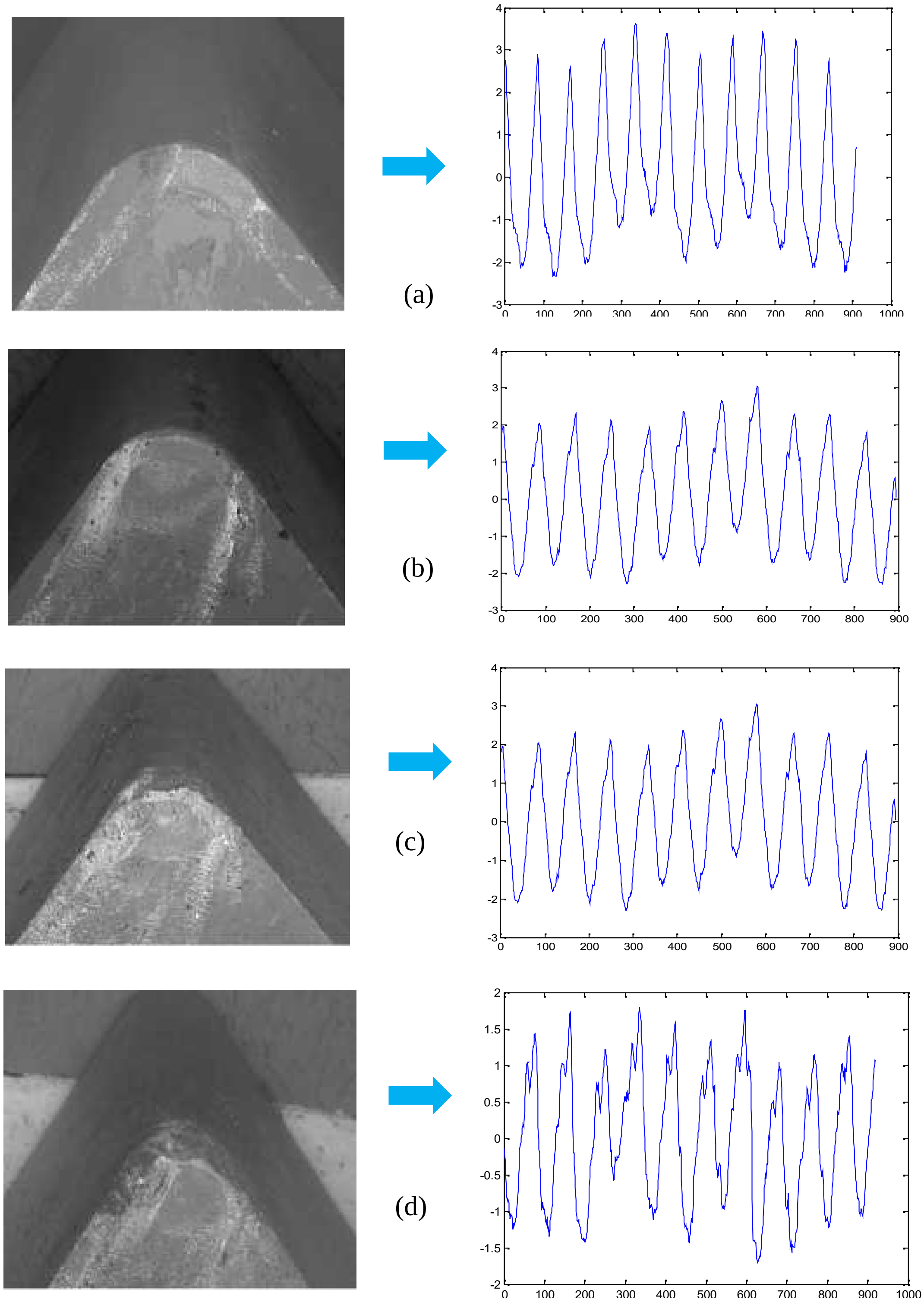


Figure 4.3 The close view of ceramic insert and their corresponding extracted sub-pixel profile (a) First machining (b) Second machining (c) Third machining (d) Fifth machining

4.4 Surface profile at different rotational angles

The surface of the workpiece was observed in every section of rotational angles start from 0º, 90º, 180º and 270º. Figure 4.4 below show the extracted and ACF profile from simulation at the first machining of middle of the workpiece surface.

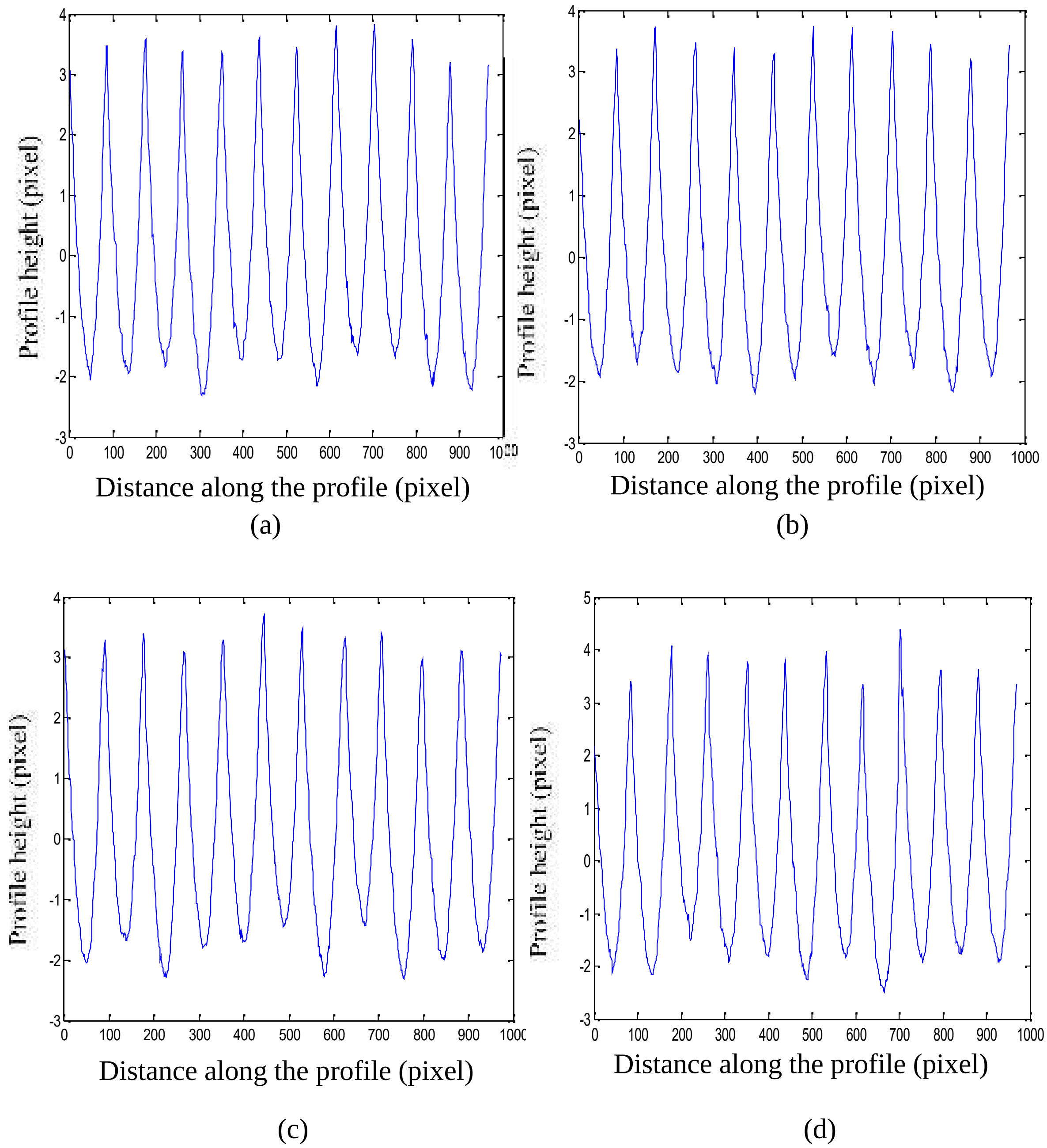
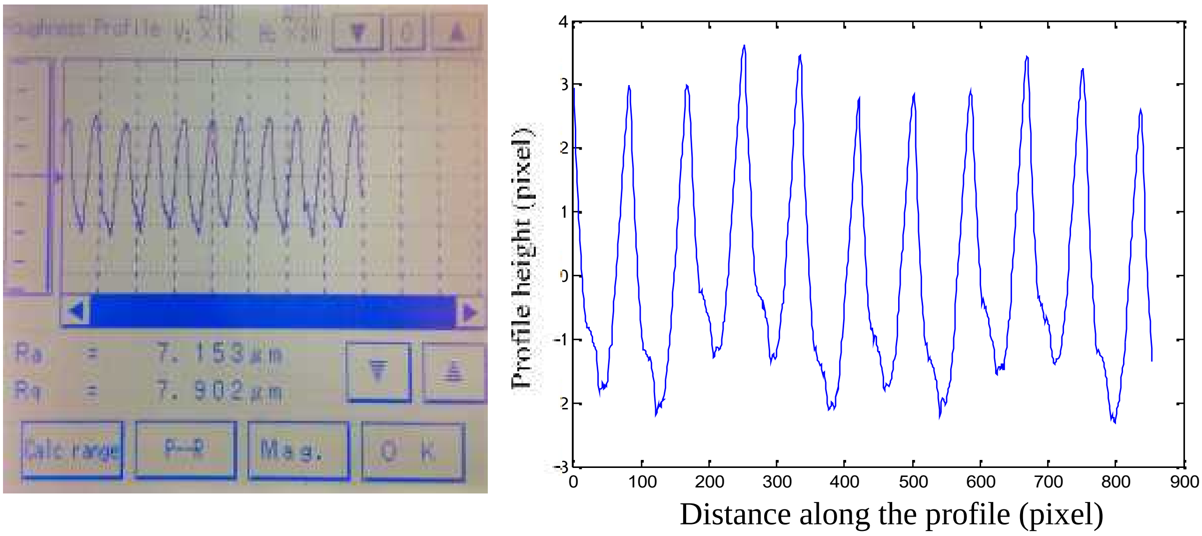


Figure 4.4 Extracted image profile at different rotational angles (a) 0º (b) 90º (c) 180º (d) 270º

From the Figure 4.4 (a), (b), (c) and (d), the extracted image profile in each of the rotational angles demonstrate same profile at the first machining operation. It presents that the cutting tool is new and give fine surface finish in the workpiece. If the cutting tool gradually wears, the image of the extracted profile is not same in each of the angles due to the uneven surface of cutting insert will give the unsmooth surface profile.

4.5 Surface verification using Stylus and Vision method

A measurement of the workpiece profile will be verified using stylus and vision method. Basically, the stylus method works by travelling along the workpiece surface. The image of the workpiece surface measurement as shown in Figure 4.5.



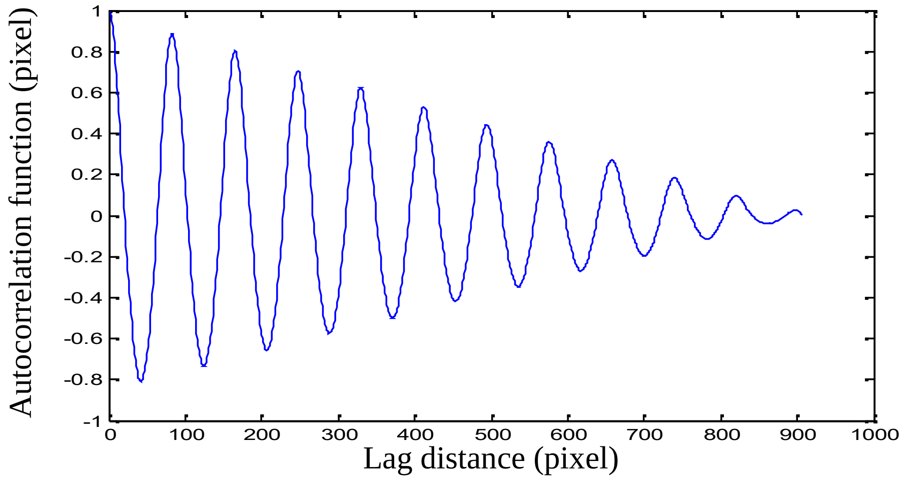
(a) (b)

Figure 4.5 (a) Stylus method (b) Vision method

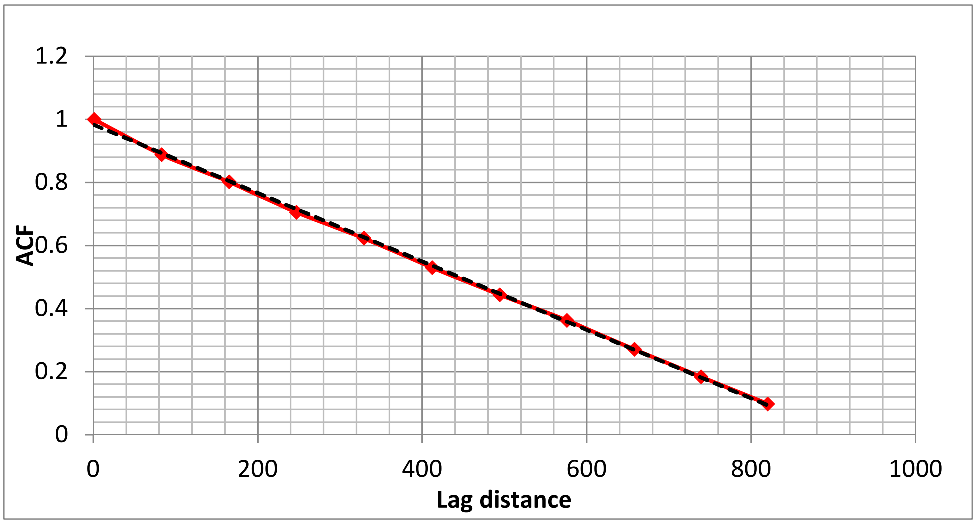
According to the Figure 4.5 (a) and (b), the image of the surface workpiece roughness is almost equivalent to each other. Practically, the vision method is the most accurate method in measuring the surface roughness profile compared to stylus because a stylus have edge of radius, thus it cannot measured an accurate workpiece profile.

4.6 Autocorrelation function analysis

Based on the theoretical analysis, the ACF profile will show a periodic pattern profile if the cutting the tool is new. ACF works by shifting the image of itself by a certain lag of distance. The image of ACF profile and ACF plotted graph is shown in Figure 4.6 (a) and (b).



(a)



(b)

Figure 4.6 Profile of 90º at the beginning of workpiece (a) ACF profile (b) ACF graph

From Figure 4.6 (a) and (b), the peaks of autocorrelation function is decreased uniformly and linearly as the lag distance increased which means the same image was shifted itself at certain lag of distance. Besides, from the ACF graph, it shows a linear pattern of surface profile which indicates the new of cutting tool gives fine surface finish of the workpiece. Therefore, the hypothesis of this experiment was achieved.