

**PENILAIAN KEKASARAN PADA PERMUKAAN
YANG DIMESIN MENGGUNAKAN LASER**

*(ASSESSMENT OF ROUGHNESS OF MACHINED
SURFACES USING LASER)*

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(Rq Average)

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ABSTRAK

Laporan ini merupakan suatu pendekatan penilaian mengenai hasil keputusan eksperimen bagi mengukur kekasaran pada permukaan specimen yang dimesin dengan menggunakan laser dan ini adalah jenis pengukuran kaedah tanpa sentuh. Terdapat 2 spesimen yang digunakan dalam ujian ini iaitu keluli lembut dan aluminium. Biasanya, kekasaran permukaan diukur dalam *purata tinggi kekasaran (Ra)* dan *punca min kuasa dua (Rq)* dalam ujian pengukuran kaedah sentuh. Akan tetapi bagi pengukuran kaedah tanpa sentuh, parameter yang digunakan ialah purata piksel dan sisihan piawai pada garisan profail. Tujuan laporan ini ialah membandingkan keputusan bagi kedua-dua kaedah yang digunakan. Kemudian pemerhatian dilakukan ke atas graf yang dibangunkan bagi melihat sebarang kecenderungan atau corak tertentu yang terhasil. Bagi tujuan tersebut, eksperimen pengukuran kekasaran menggunakan kaedah sentuh dijalankan terlebih dahulu diikuti dengan kaedah tanpa sentuh menggunakan specimen-specimen yang sama. Specimen-specimen ini dimesin pada beberapa parameter yang berbeza bagi melihat kesannya terhadap kekasaran permukaan. Kerja ini juga melibatkan penggunaan beberapa program tertentu seperti DT-Acquire 2 bagi mengambil imej yang dirakam dan Matrox Inspector 2.1 yang banyak digunakan dalam pemprosesan imej.

ABSTRACT

This report is an assessment approach, which presents the experimental results to measure roughness of machined surface using a laser which is a non-contact method measurement. There are two specimens has been tested which is mild steel and aluminum. Usually, surface roughness is measured in *average height of roughness* (Ra) and *root-mean-square* (Rq) for non-contact method measurement. But in non-contact method, the parameters used are *average pixels* and *standard deviation* of the profile line. The objectives of this report are to compare the results of the two different methods. Then observing the graph line whether it has some trend or pattern. In order to do this, the contact method is been carry out followed by thee non-contact experiment by using the same specimens. The specimens are machined in some different parameter to see the effect to its surface roughness. This work also presents the use of some programs such as DT-Acquire 2 for image grabbing and Matrox 2.1 which is to do some image processing.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Every material has a surface roughness. Even it is through the machining process such as milling, grinding etc. the material still having roughness of its surface. The important of accurate measurement of surface roughness in engineering applications is always emphasized. In recent years many techniques for measuring the surface roughness have been developed. The roughness of the surface can be determined by using some related methods.

The measurement of surface roughness is defined by a collection of international standards. These standards cover characteristics of the measurement equipment as well as defining the mathematical definition of the many parameters used today. The purpose of a parameter is to generate a number that can characterize a certain aspect of the surface, removing the need for subjective assessment. However it is impossible to completely characterize a surface with a single parameter. Therefore combinations of parameters are normally used.

Normally, we use contact method to measure surface roughness using several parameters like average height, root-mean-square height, maximum peak to-valley roughness and ten point average height. Most of the reported works employ techniques that evaluate surface roughness. However, with the demand on the quality and the miniaturization in the precision industry, accurate multi-parameter evaluation is often required.

For example, the design and manufacture of engine cylinders for vehicles are never complete without measurement and specification of key parameters such as the surface roughness. While using this method, it is not suitable for on line measured especially during machining. So it has problem for contact method. In this case, we will develop an optical technique for measuring the surface roughness of a specimen by using an integrated set-up. The method is based on laser scattering.

Scattering experiment can provide a wealth of detailed information about the structural and dynamical properties of matter. Light scattering, in particular has important applications in particles and can describe about the characteristic of surface roughness.

1.2 OBJECTIVES

The objectives of this project are;

- a. To study about surface roughness and the effects to measurement
- b. To prepare machined specimens with some different parameter of speed machining
- c. To measure surface roughness using contact method measurement.
- d. To develop non-contact using laser scattering and image process.
- e. To get several parameters of image scattered through image processing by using a suitable program or software.
- f. To compare results between contact and non-contact method

1.3 SCOPE OF WORKS

Before doing these experiments, the planning and preparation of works should be done first to make sure everything is under requirement to achieve the objectives. The planning is such as the preparation of specimen. There are 2 types of specimen that will be used which are mild steel and aluminum. In the first session, the specimens go to milling process to make some machined surfaces. The machining speed is setup into 5 different speed where the ranges from 310 to 1140 revolution per minute (rpm). A test in contact method will be done with those specimens. Then an investigation the parameter of the machine to see whether there are any effect to the specimens. After that, the second step is to develop the experiment setup for non-contact method. The parameters taken for this method are average pixel and standard deviation of the line profile. The graph of parameters measurement will be discussed.

Lastly, all the data and results of these 2 methods will be observed for the comparison. The observation should be in many aspects to know especially the suitable machining parameters for some materials.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Roughness is a surface condition that generally results from a particular production process or material. Roughness exist on almost all natural particle surfaces including brass, aluminum or mild steel bar even it looks smooth with usual eyes . It is measured using several parameters such as average height, root-mean-square height, maximum peak to-valley roughness and ten point average height.

There are two basic methods to measure the roughness of a surface, contact and non-contact method. Contact method is based on the principle of profile meter. The main disadvantage of these devices is the contact with the surface, which could scratch the surface and the device could give inaccurate readings of the roughness measurement.

2.2 THEORY

Measured Surface

A measured surface is a representation of the real surface obtained with some measuring instrument. This distinction is made because no measurement will give the exact real surface. Later portions of this project describe will two different types of measuring methods.

Surface Roughness Texture

Surface texture is the combination of fairly short wavelength deviations of a surface from the nominal surface. Texture includes roughness, waviness, and lay, that is, all of the deviations that are shorter in wavelength than form error deviations.

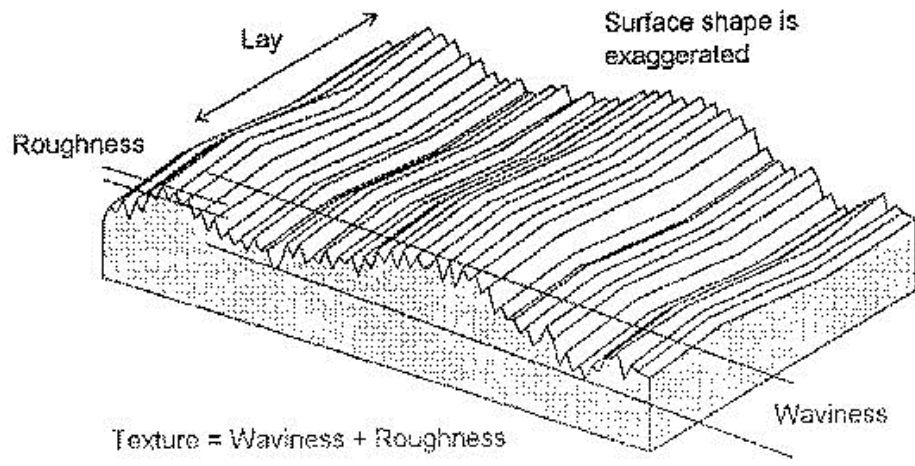


Figure 2.1 Surface texture includes roughness and waviness
 (Taken from surfaces info-www.predev.com)

There are two major methods of surface roughness measurement which are:

1. Contact method measurement
2. Non-contact method measurement

2.2.1 Contact Method

The average height of roughness (R_a) is defined as the average of the absolute values of the deviations of the height from the centerline along a specified sampling length:

Average height of roughness (R_a)

$$R_a = \frac{y_a + y_b + y_c + \dots + y_n}{n}$$

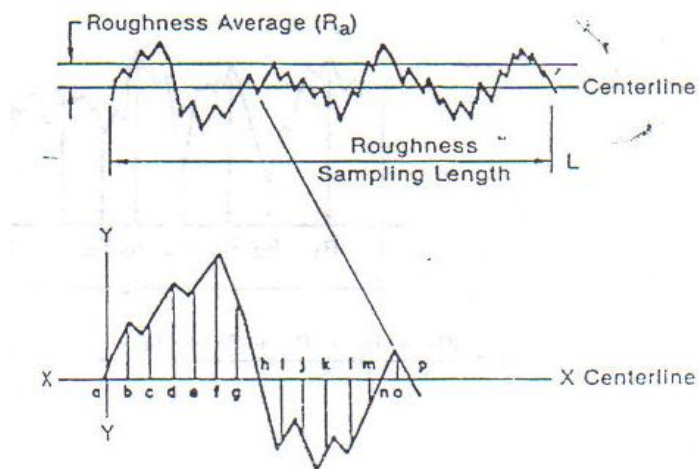


Figure 2.2 Calculating R_a value from profile graph

The root-mean-square roughness R_A or R_q is defined as the root-mean-square of the absolute values of the deviations of the height measured from the centerline along a specified sampling length:

Root-mean-square (RMS)

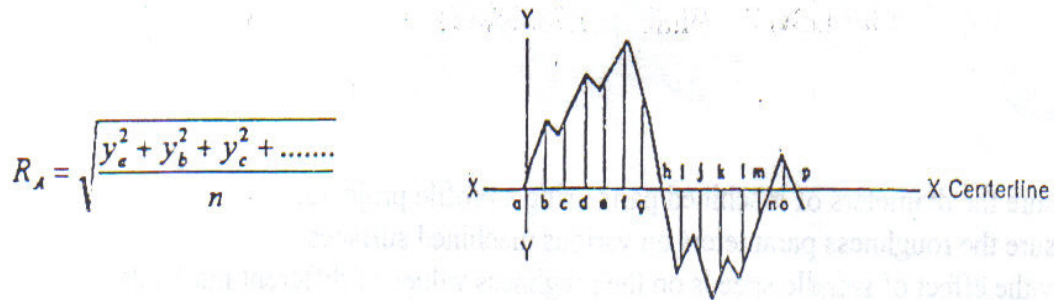


Figure 2.3 Calculating R_q value from profile graph

The present experiment consists of two simple principles, which are used to measure roughness. Realization of the contact method is could scratch the surface and does not require any high precision and sophisticated mechanical and optical applications. While the laser scattering allows use of a computer that fast and easy measurements.

2.2.2 Non-Contact Method

LASER stands for Light Amplitude Stimulation Emission Radiation. Lasers work as a result of resonant effects. The output of a laser is a coherent electromagnetic field. In a coherent beam of electromagnetic energy, all the waves have the same frequency and phase.

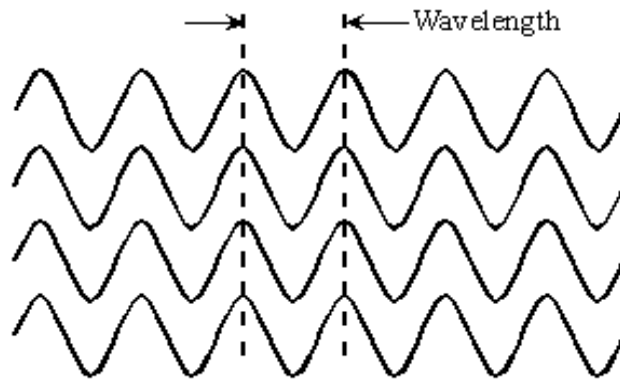


Figure 2.4 Coherent electromagnetic waves have identical frequency and align in phase
(Taken from Melle Griot articles-www.mellegriot.com)

In a basic laser, a chamber called a cavity is designed to internally reflect infrared (IR), visible-light, or ultraviolet (UV) waves so they reinforce each other. At each end of the cavity, there is a mirror. One mirror is totally reflective, allowing none of the energy to pass through; the other mirror is partially reflective, allowing approximately 5 percent of the energy to pass through. Energy is introduced into the cavity from an external source; this is called pumping.

In terms of optical design, meeting these somewhat conflicting goals translates into devising systems that have a minimum number of components, elements made of readily worked glass types, and low sensitivity to alignment errors. The number of elements in the systems described here was minimized by choosing the simplest lens form that could correct the aberrations that are significant in the intended application.

The Laser Advantages

There are several advantages and also some good reasons to use a laser for this method:

- **Small size and weight:** A typical laser measures less than one millimeter across and weighs a fraction of a gram, making it ideal for use in portable electronic equipment.
- **Low current, voltage, and power requirements:** Most lasers require only a few milliwatts of power at 3 to 12 volts DC and several milliamperes. Therefore, they can operate using small battery power supplies.
- **Low intensity:** A laser cannot be used for spectacular purposes such as burning holes in metal, bringing down satellites, or blinding aircraft pilots. Nevertheless, its coherent output results in high efficiency and ease of modulation for communications and control applications.
- **Wide-angle beam:** A laser produces an adjustable focal beam so that it is easy to meet ray of light requirement.

For this project, laser scattered concept is applied to this method where a laser pointer and CCD camera is used for tracking. It is known that the unique properties of laser radiation result in the grain structure called speckles. It is the angular distribution for the intensity of light reflected for rough surfaces. The features of these speckles depend on the characteristics of the rough surfaces.

The speckle images recorded with the camera will be downloaded to the computer and it analyses the images for measurements using certain software for example Matrox Inspector. The measurements are including with some parameters of surface roughness (i.e. the mean square deviation of the profile, σ) and some features of these images (the mean area S under the curve of light intensity for one line of the image or its contrast C).

CHAPTER 3 METHODOLOGY

3.1 PREPARING SPECIMEN

All the specimens came in a long bar. So it has to be cut into a small piece to make it easy to handle the specimens. The specimens were prepared in dimension of (70 x 40 x 10) mm. They were cut by using a hydraulic shear cutter machine. The size of the specimen were not had the standard reference and the example as shown in figure 3.1.

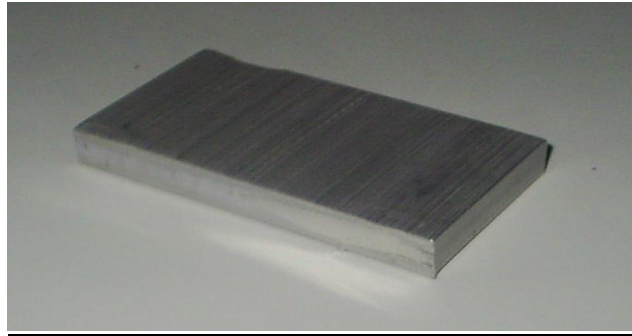


Figure 3.1 Size of aluminum specimen

Theory of Machining Specimen

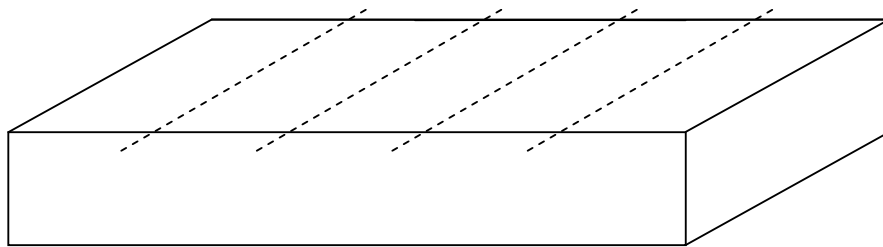


Figure 3.2 The machining process of specimen setup

The specimen were divided into 5 sections as shown in figure 3.2. Then it went into milling process. The RPM from theory will be use as a reference, and then it will be higher value to the right side of specimen and lower value to the left side of specimen. This machining is not using water or coolant during the process. All the parameters of machining were fixed except the RPM value.

$$\text{RPM} = \frac{\text{CS}}{\text{TcD}}$$

$$\text{CS} = \text{RPM} (\text{CPT}) \text{T}$$

where;

RPM = revolution per minute of spindle speed

CS = cutting speed

Tc = types of tools

D = diameter of tool



Figure 3.3 Milling Machine

There were 5 different values of RPM; 320, 410, 600, 865 and 1140.

3.2 CONTACT METHOD MEASUREMENT

3.2.1 Introduction

Roughness is a surface condition that generally results from a particular production process or material. Roughness exist on almost all natural particle surfaces including brass, aluminum or mild steel bar even it looks smooth with normal eyes of view. It is measured using several parameters such as average height, root-mean-square height, maximum peak to-valley roughness and ten point average height.

3.2.2 Objectives

The main objectives of this experiment are to measure the surface roughness of the machine specimens using contact method and to evaluate graphs from that data. In order to do this, the specimen should first be machined with different parameters using milling method. So that, the machining process also apart from the objectives.

3.2.3 Equipments

There are several tools and equipments be using to do the experiment. Such as first and most important equipments are specimens which are for this case will be using mild steel and aluminum. For machining process we use a milling machine by using several different parameters that will be discuss clearly in procedure steps. The other important apparatus are Roughness Tester (Mitutoyo Surftest SV400) and Profile Projector (Mitutoyo). The functions of these apparatus are to measure the surface roughness and display the certain value related in surface roughness contact method. Generally, the lists of equipments are as below:

- i. Specimens (mild steel and aluminum)
- ii. Milling machine.
- iii. Oil cleaner (WD-40 Spray)
- iv. Roughness Tester (Mitutoyo Surftest SV400)
- v. Profile Projector (Mitutoyo)

3.2.4 Procedures

1. Milling Process

Milling machine is set-up to meet requirements as below:

a. *Mild Steel.*

Tool: High speed steel shank End Mill C974 10.00

Depth: 0.2 mm

Feed rate: 65 mm/min

b. Aluminum

Tool: High speed steel shank End Mill C974 10.00

Depth: 0.3 mm

Feed rate: 65 mm/min

RPM: 320, 410, 600, 865 and 1140

*note: This 5 values of RPM are for every specimen.



Figure 3.4 Example of Mitutoyo Surtest

2. Cleaning Method

After the specimens were machined, cleaning method were applied where by using air gun to remove any chip and waste materials from specimens. This ensures that there were no chips or any waste material sticking on the specimen surface. However, the surface of specimens cannot be touched by anything because it may effect to the data taken during the surface test.

3 Surface Tests

Immediately after the cleaning, the specimens were subjected to a surface roughness test by using the Roughness Tester (Mitutoyo Surftest SV400) and Profile Projector (Mitutoyo). The specimen is placed on the bar-holder provided on the Mitutoyo Surftest machine.

The height of the stylus is adjusted until it just touché the specimen surface. A length of 2.5 mm on the roughness is selected. While the specimen measurement start, the value of average height of roughness (Ra) and root-mean-square roughness (Rq) will be recorded.

Using the profile projector, three measurements are taken on each step for every section on both specimens. The average of Ra and Rq are being calculated for every different RPM and these values will be recorded in a data table.

Every value and parameters will be record in a reading table so that it is easy to read and manipulate the data. From this table there are 2 graphs to be plot for every specimen namely Ra (average) vs. Machining speed (RPM) and Rq vs. Machining speed (RPM).

5. Protection

Specimen protection especially mild steel is very important. This is to make sure the machined surface is out of any rust and small particles sticking in the surface because the specimen will be use in non-contact method measurement afterward. To do that the mild steel was spray with anti rust spray (WD-40) and placed in a plastic case or any other case to avoid specimens exposing to the air.

3.2.5 Results

Specimen: Mild Steel
 Depth: 0.2 mm
 Tools: End Mill 974 10.00
 Feed Rate: 65 mm/min

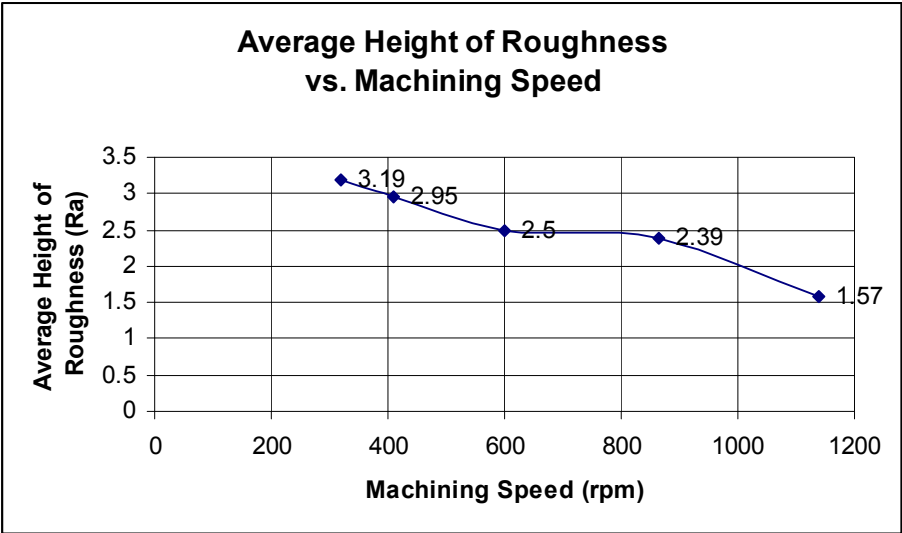
Table 3.1 Data of Ra and Rq for different machining speed for mild steel

Readings	320 RPM		410 RPM		600 RPM		865 RPM		1140 RPM	
	Ra (μm)	Rq (μm)	Ra (μm)	Rq (μm)	Ra (μm)	Rq (μm)	Ra (μm)	Rq (μm)	Ra (μm)	Rq (μm)
1	3.12	3.73	2.92	3.56	2.60	3.21	2.56	3.20	1.73	2.17
2	3.24	3.82	3.07	3.80	2.38	2.92	2.27	2.80	1.55	2.10
3	3.22	4.04	2.86	3.89	2.52	3.09	2.33	2.46	1.43	1.80
Average	3.19	3.86	2.95	3.75	2.50	3.07	2.39	2.82	1.57	2.02

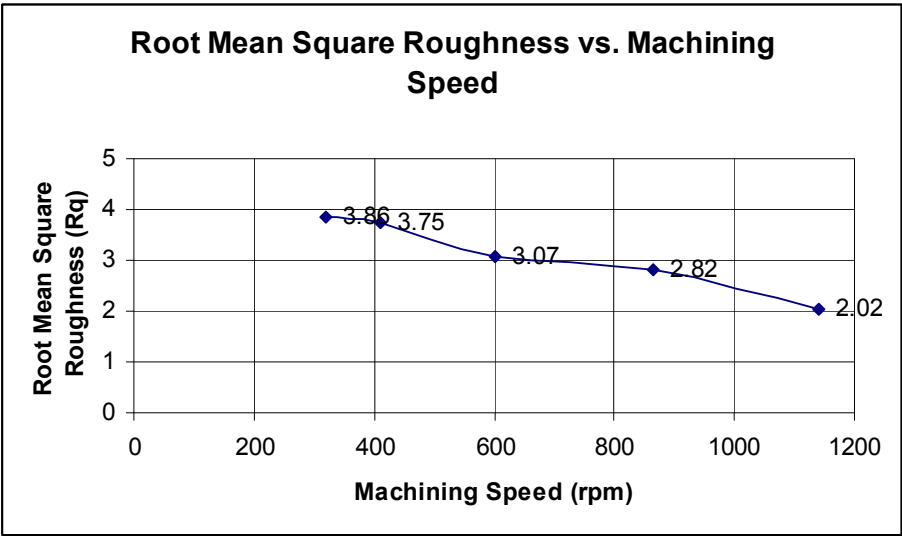
Specimen: Aluminum
 Depth: 0.3 mm
 Tools: End Mill 974 10.00
 Feed Rate: 65 mm/min

Table 3.2 Data of Ra and Rq for different machining speed for aluminum

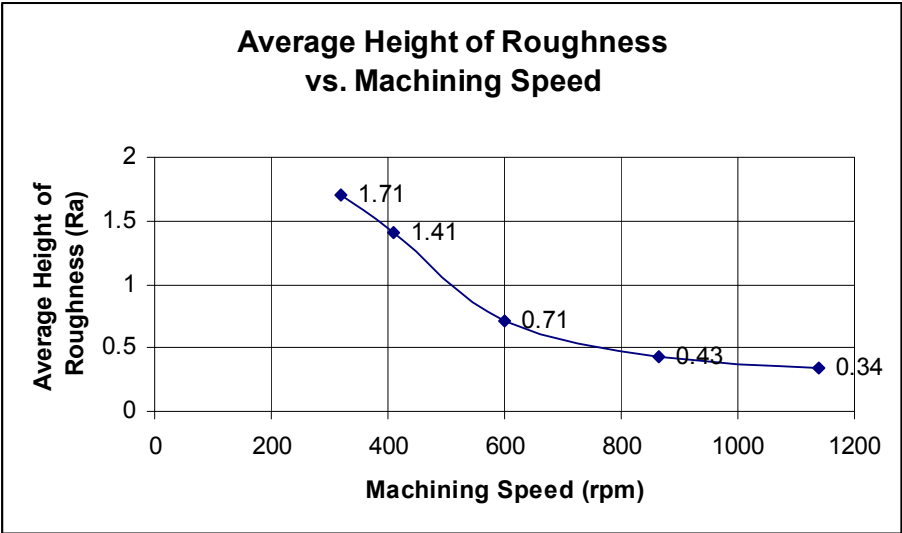
Readings	320 RPM		410 RPM		600 RPM		865 RPM		1140 RPM	
	Ra (μm)	Rq (μm)	Ra (μm)	Rq (μm)	Ra (μm)	Rq (μm)	Ra (μm)	Rq (μm)	Ra (μm)	Rq (μm)
1	1.71	2.27	1.46	1.76	0.72	0.85	0.40	0.53	0.35	0.44
2	1.68	2.13	1.35	1.60	0.70	0.83	0.45	0.59	0.31	0.40
3	1.75	2.38	1.42	1.67	0.71	0.86	0.44	0.58	0.37	0.48



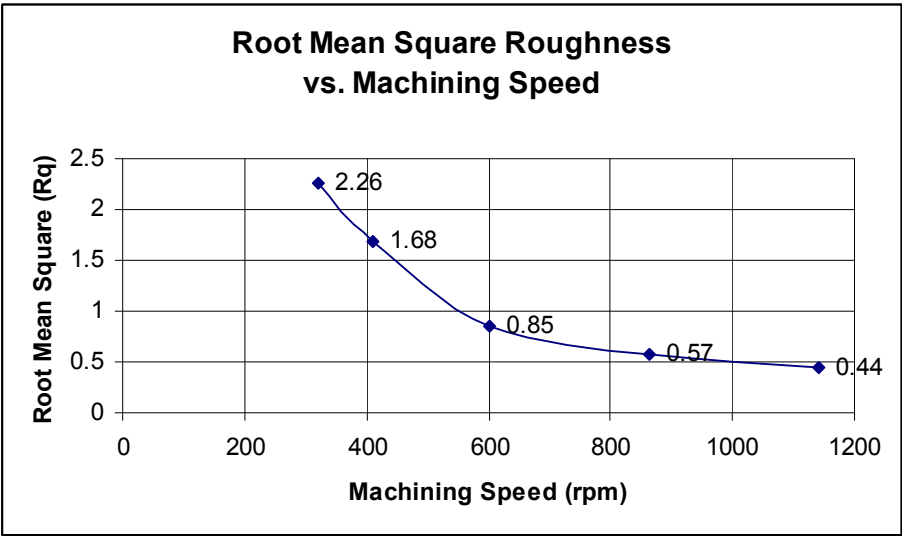
Graph 3.1 Average of Ra value versus machining speed for mild steel



Graph 3.2 Average of Rq value versus machining speed for mild steel



Graph 3.3 Average of Ra value versus machining speed for aluminum



Graph 3.4 Average of Rq value versus machining speed for aluminum

3.2.6 Discussions

In machining process, all the basis parameters were fixed except the RPM. This was to make an observation of effect to specimen surface when RPM was different. Even though the depth was fixed but the value of depth for mild steel and aluminum were different which is 0.2 mm and 0.3 mm. Actually this was because mild steel is harder than aluminum and to avoid from tool damage.

From the graph generally, we can see that the Ra and Rq is decrease when the RPM increasing. For mild steel, the line was decrease linearly but not at the middle of it. There were some ranges of RPM where the Ra and Rq of mild steel are almost constant. But for aluminum the line of graph decrease linearly and drastically from the beginning and became slowly in the end.

From the data, there are some value are not uniform with others. For example was the value of Ra and Rq but this is maybe because of some factors like old equipment, no coolant while doing the machining etc. we take the average of those values to make it easy when comparing.

3.2.7 Conclusions

As a conclusion, we can say that the behavior of specimens is influence the tool will be chooses and limit some parameter such as depth feed rate etc. We also can see that the different of RPM will take effect to the Ra and Rq. So to get a low Ra and Rq, we must increase the RPM.

3.3 NON-CONTACT METHOD MEASUREMENT

3.3.1 Objectives

The main objective of this experiment is to measure the surface roughness of the machined specimens using non-contact method which is by using a laser and camera to catch the scattering images. After some image processing, all the data is collected to develop the graphs.

3.3.2 Equipments

- Laser pointer
- CCD camera
- Machined specimen
- Computer for analyzing



Figure 3.5 (a) Laser pointer



Figure 3.5 (b) CCD camera

3.3.3 Procedures

For this experiment, laser scattered concept is applied to this method where a laser pointer and CCD camera is used for tracking. It is known that the unique properties of laser radiation result in the grain structure called speckles. It is the angular distribution for the intensity of light reflected for rough surfaces. The features of these speckles depend on the characteristics of the rough surfaces.

The speckle images are recorded with the camera to be downloaded to the computer and it analyses the images for measurements using certain software. There are 3 main softwares used for this experiment. The first is DT-Acquire 2 which is for grabbing the scattered image to the computer while the second is called Matrox Inspector 2.1. This software is used for image processing and to get data. From the data, graph is developing to be evaluated using Microsoft Excel.

When coherent light illuminates a rough surface, the diffracted waves from each point of the surface mutually interfere to form a pattern which appears as a grain pattern of bright and dark regions. The spatial statistical properties of this speckle image can be related to the surface characteristics. The degree of correlation of two speckle patterns produced from the same surface by two different illumination beams can be used as a roughness parameter.

The following figure 3.6 shows the experiment setup. A rough surface is illuminated by a monochromatic plane wave with an angle of incidence with respect to the normal to the surface, multiscattering and shadowing effects are neglected. The photosensor of a CCD camera placed in the focal plane of a Fourier lens is used for recording speckle patterns. All the devices in experiment set-up were fixed in place except the specimen to change the different machined surfaces. So that all the images captured can be analyze in a same location.

After catching this image, some processing steps have been done to get the data of the surfaces using a Matrox Inspector 2.1 program. In order to that, the first is to place the line profile position first to the wanted image. After this step, the data for position and pixel can be shown automatically.

Then all data collected were copied to the Microsoft Excel. From this, the value of average pixel and standard deviation were calculated using basic function from the software. Also from this data, graph was developed for every section. There are two location line profiles for every different machining specimen. Lastly, the value of average pixel and standard deviation were fill in the table including the average of it.

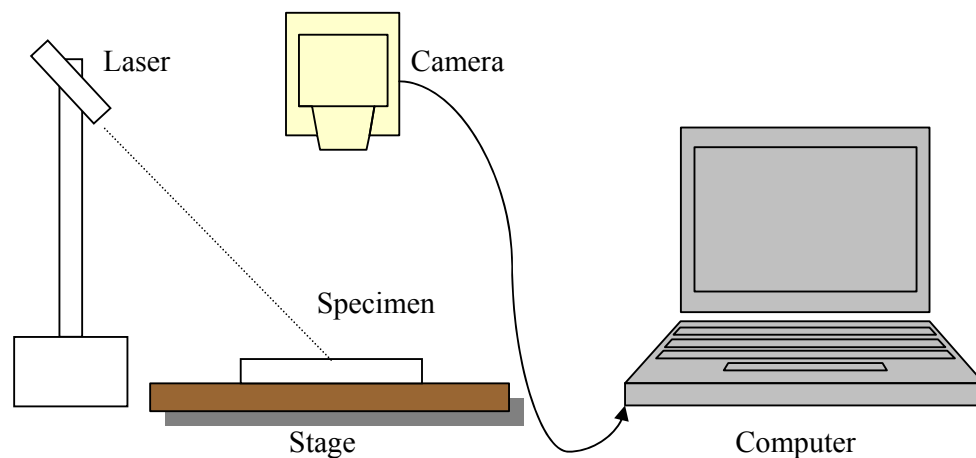


Figure 3.6 Experimental setup

3.3.4 Results

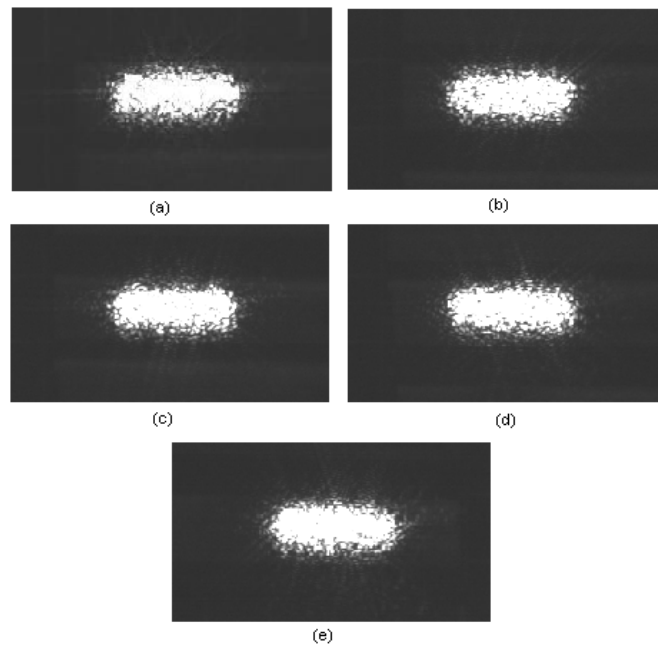


Figure 3.7 The images of mild steel machined surface using laser (a) 320 rpm, (b) 410 rpm, (c) 600 rpm, (d) 865 rpm and (e) 1140 rpm.

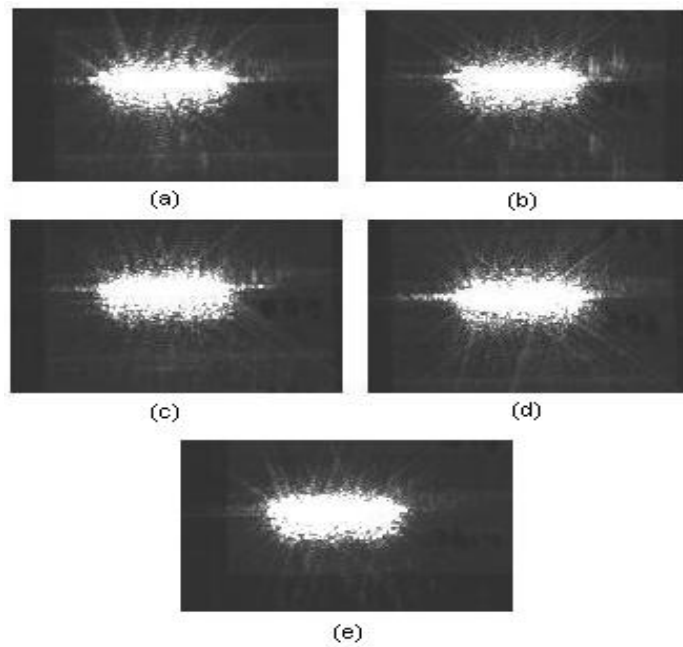


Figure 3.8 The images of aluminum machined surface using laser (a) 320 rpm, (b) 410 rpm, (c) 600 rpm, (d) 865 rpm and (e) 1140 rpm.

Centre Point

In order to make a profile line, centre point should be determined first. Centre point is a centre intensity of the image and will be used as a base line for every line profile has been made on the image. Firstly, one of the images selected had been changed into a threshold image like in figure 3.9. Then 2 profile line which were horizontal and vertical placed in approximately centre of the image. From the data, we could determine the centre point of the image for every specimen.

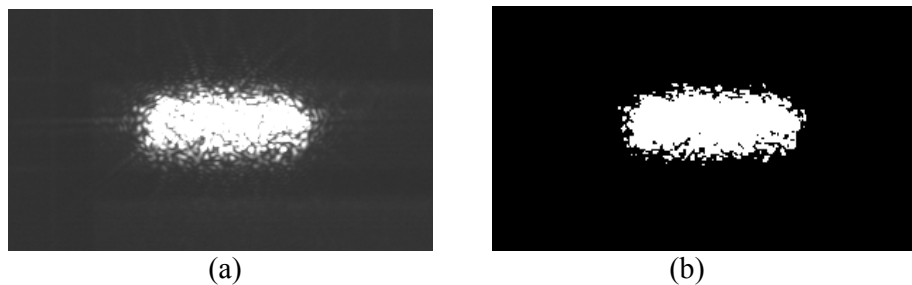
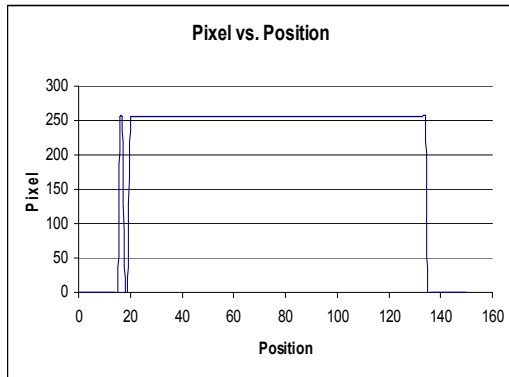


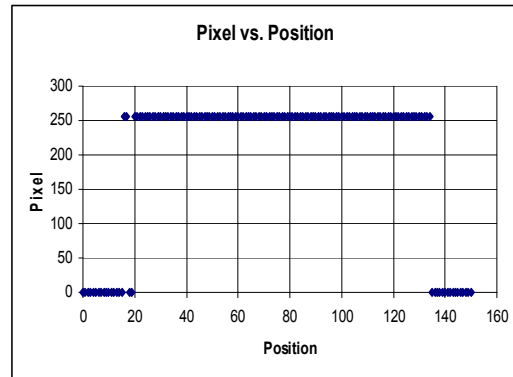
Figure 3.9 The image was switched into a threshold
(a) Initial image (b) Threshold image.

After this step, the three location line profiles were building from this centre point horizontally. These lines should be different location so that we could see the effect of this location clearly what happened when the line got far distance from the centre line. The following graphs show what were the lines looks like in two types which were line and scatter form. This was easy to trace the highest intensity area (256 pixels) and from that we could find the centre for every axis.

Actually the centre line for the X-axis not effect while doing the three line profile because the lines were horizontal so the value of X-axis remain the same. However the centre of X-axis and Y-axis was to find the centre point of the image. While the location for the three lines can be determined by any point suitable and the point selected was explained in the graphs 3.5 and 3.6 for X-axis and Y-axis location



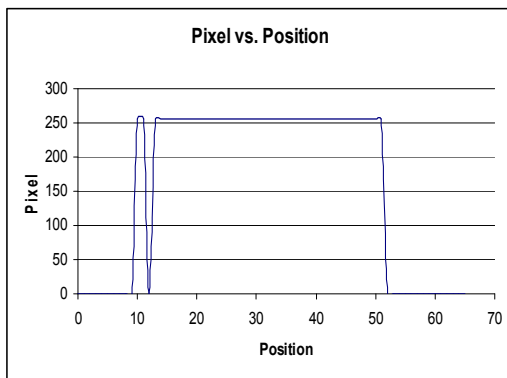
(a) Line Graph



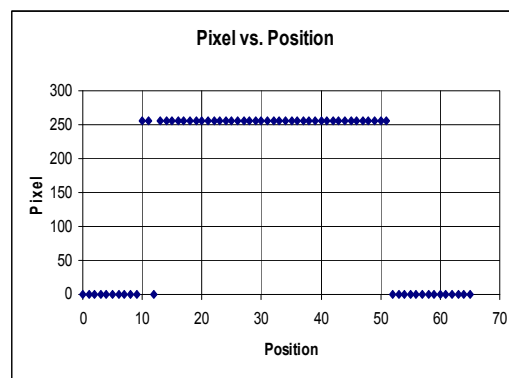
(b) Scatter Graph

Graph 3.5 Graph for mild steel with X-axis

The line was taken from 80,70 to 230,70 and the centre point was 155,70



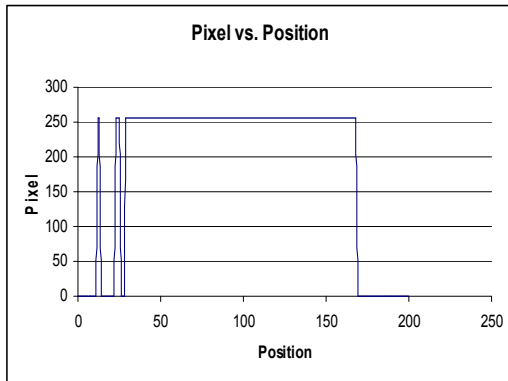
(a) Line Graph



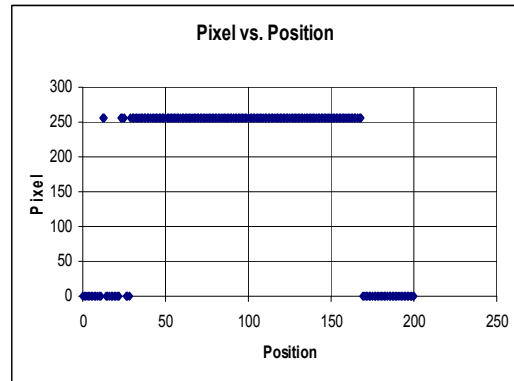
(b) Scatter Graph

Graph 3.6 Graph for mild steel with Y-axis

The line was taken from 150,40 to 150,105 and the centre point was 150,71. So the centre point for this image was 155,71



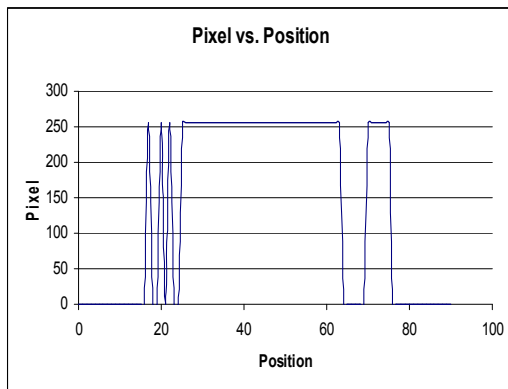
(a) Line Graph



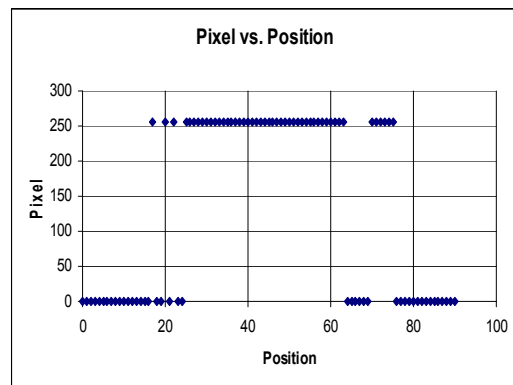
(b) Scatter Graph

Graph 3.7 Graph for aluminum with X-axis

The line was taken from 40,65-240,65 and the centre point was 130,65



(a) Line Graph



(b) Scatter Graph

Graph 3.8 Graph for aluminum with Y-axis

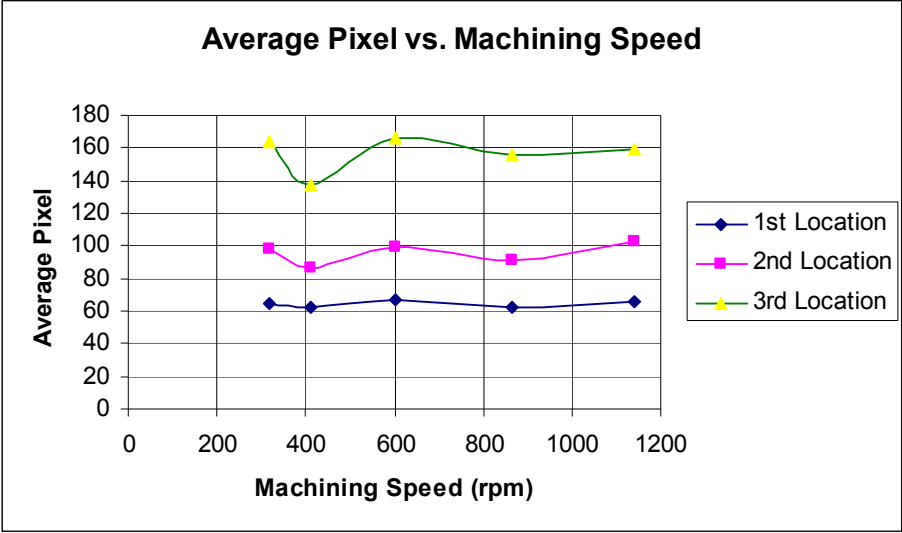
The line was taken from 145,20-145,110 and the centre point was 145,66. So the centre point image for this image was 130,66

Table 3.3 Average pixel and standard deviation for mild steel specimen

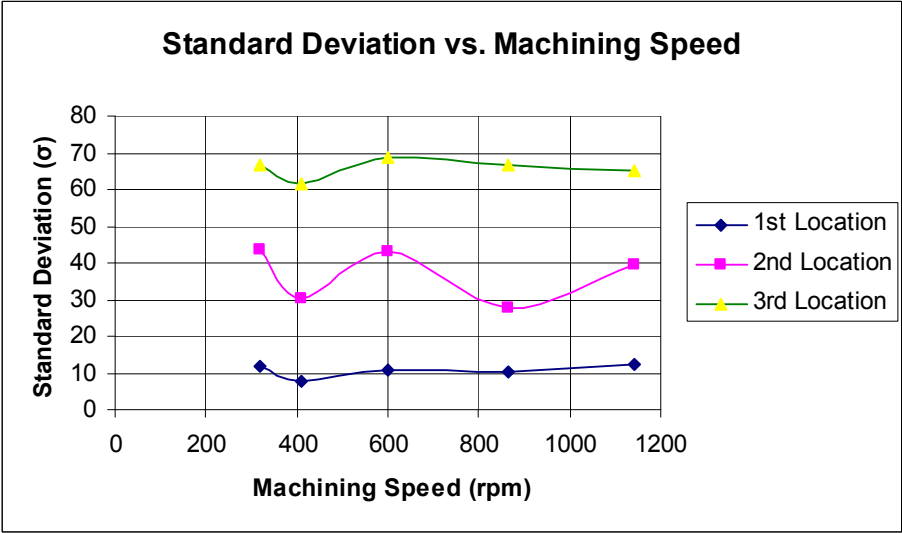
Line Profile	Machining Speed, rpm	Average Pixel	Standard Deviation. σ
1st Location 90,45 to 210,45	320	65.1734	11.7981
	410	62.7851	7.8414
	600	67.1157	10.6319
	865	62.4711	10.4148
	1140	65.4215	12.1777
2nd Location 90,50 to 210,50	320	97.8265	43.7145
	410	86.9752	30.4837
	600	98.8926	43.2627
	865	90.8099	27.7457
	1140	102.6116	39.3259
3 rd Location 90,55 to 210,55	320	164.3471	66.4242
	410	137.4545	61.5015
	600	166.6033	68.5971
	865	156.2975	66.4147
	1140	158.7603	65.3787

Table 3.4 Average pixel and standard deviation for aluminum specimen

Line Profile	Machining Speed, rpm	Average Pixel	Standard Deviation. σ
1st Location 80,35 to 200,35	320	82.1240	18.4949
	410	81.9835	15.3357
	600	82.9752	18.6483
	865	76.5703	13.7585
	1140	77.2562	14.6222
2nd Location 80,40 to 200,40	320	100.4711	37.3392
	410	103.1736	33.9285
	600	104.1405	42.4383
	865	85.7025	18.8426
	1140	88.9669	17.7721
3 rd Location 80,45 to 200,45	320	124.3884	43.7703
	410	140.1736	41.6769
	600	163.1074	60.0262
	865	111.5041	37.0246
	1140	124.9421	41.7212



Graph 3.9 Average pixels versus machining speed for mild steel



Graph 3.10 Standard deviation versus machining speed for mild steel