SURFACE ROUGHNESS IN LATHE BORING OPERATION

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ABSTRACT

Optimizing the cutting parameters is important to obtain the best surface roughness, to minimize the cost of production and to increase productivity. The main objective of the project are to study the optimum cutting parameters that are the cutting speed, feed rate and depth of cut for single tool boring process to obtain the best surface roughness. The Brinell hardness of the material tested is 151. In this study, the Design of Experiment (DOE) with Box-Behnken design is used. By using the STATISTICA software a table of run was generated based on the full factorial with three factor and three levels. Twenty seven experiments are then run according to the "Table of run" generated by the STATISTICA software and the surface roughness value is recorded. Analysis of variance (ANOVA) was used to identify the significant cutting parameters that affect the surface roughness. The ANOVA table has shown that from the 27 experiments, cutting speeds and depth of cut are significant. From the experiment, rough optimization values are obtained. The rough optimizations of cutting speeds are 110 m/min and the depths of cut are 0.278 mm gives a surface roughness value of 2.18 μm. The experiments are continued by another ten experiments to find the fine optimized cutting speed and depth of cut to obtain the best surface roughness. It was concluded that the fine optimization cutting speeds for the mild steel (AISI 1019) are 112 m/min and the depths of cut are 0.182 mm gives a surface roughness of 2.06 μm for the specific machine. The usage of a harder material which is commonly used in industry and cutting parameter such as tool nose radius and length of the boring tool is highly recommended to find the optimization parameter for the best surface roughness in the boring operation.

ABSTRAK

Mengoptimumkan parameter pemotongan adalah penting untuk mendapatkan tahap kekasaran permukaan yang terbaik, mengurangkan kos pengeluaran dan meningkatkan produktiviti. Objektif utama projek ini adalah untuk mencari parameter optimum pemotongan, iaitu kelajuan pemotongan, kadar suapan dan kedalaman pemotongan bagi proses membuat lubang untuk mendapatkan kekasaran permukaan yang terbaik. Kekerasan Brinell untuk keluli yang digunakan ialah 151. Dalam kajian ini, Rekabentuk Eksperimen menggunakan reka bentuk Box-Behnken. Dengan menggunakan perisian STATISTICA, jadual jangka dibuat berdasarkan faktorial lengkap dengan tiga faktor dan tiga peringkat. Kemudian, 27 uji kaji dijalankan berdasarkan "Jadual jangkaan" yang dihasilkan oleh perisian STATISTICA dan nilai kekasaran permukaan direkodkan. Analisis varians (ANOVA) telah digunakan untuk mengenalpasti parameter pemotongan yang penting yang memberi kesan kepada kekasaran permukaan. Jadual ANOVA telah menunjukkan bahawa daripada 27 eksperimen, kelajuan pemotongan dan kedalaman pemotongan telah memberi kesan kepada kekasaran pemotongan. Daripada eksperimen tersebut, nilai-nilai pengoptimuman peringkat pertama akan diperolehi. Pengoptimuman peringkat pertama untuk kelajuan pemotongan ialah 110 m / min dan kedalaman pemotongan ialah 0.278 mm akan memberikan nilai kekasaran permukaan sebanyak 2.18 µm. Eksperimen diteruskan dengan sepuluh ujikaji lagi untuk mencari kelajuan pemotongan dan kedalaman pemotongan yang paling optimum untuk mendapatkan kekasaran permukaan yang terbaik. Eksperimen telah dilakukan untuk mendapatkan kelajuan optimum pemotongan dan kedalaman. Kesimpulannya, pengoptimuman kelajuan pemotongan untuk keluli (AISI 1019) ialah 112 m / min dan kedalaman pemotongan ialah 0.182 mm memberikan kekasaran permukaan sebanyak 2.06 µm. Ini adalah untuk mesin yang tertentu sahaja. Penggunaan bahan yang lebih keras yang banyak digunakan di industri dan parameter pemotongan seperti jejari alat pemotong dan panjang pemotongan amat disyorkan untuk mencari parameter yang paling optimum bagi kekasaran permukaan yang terbaik dalam operasi membuat lubang.

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α	Rake angle,°
R_a	Arithmetic mean value, μm
R_q	Root-mean-square, μm
R_y	Maximum peak-to-valley roughness, μm
rms	Root-mean-square, , μm
F_t	Tangential cutting force, *N*
F_r	Radial cutting force, *N*
γ	Edge angle,°
t1	Thickness of the uncut layer, *mm*
t2	Thickness of the chips produced, *mm*
Di	Indention Diameter, *m*
F	Applied Force, kg.f
D	Indenter Diameter, m
CS	Cutting speed, m/min

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
DOE	Design of Experiments
CNC	Computer Numerical Control
HBN	Brinell Hardness

CHAPTER 1

INTRODUCTION

1.1 INRODUCTION

The conventional lathe machine has been used in the industry for many applications such as turning, boring, drilling, milling, planning shaping, broaching and sawing. For the Conventional Lathe Machine, the turnings are one basic machining operation. The boring operation also uses the conventional turning machine for machining. The boring operations are to enlarge a hole made previously by some other process such as drilling. The boring process makes the existing hole dimensionally more accurate than can be obtained by drilling alone and to improve the surface finish. After the boring operation the surface roughness are test using the Perthometer. The poor qualities of the surface finish are one of the industry critical issues due to the improper setting of cutting parameter. This may cause the industry to have losses due to rework and waste of time. In order to solve this problem, research studies on the Surface Roughness in the Lathe Boring Operation are carried out. In this research, the main objective will focus on the finding of the optimum parameter for single tool boring process for the best surface roughness on Mild steel.

1.2 PROJECT BACKGROUND

The lathe machine are a device that for rotating a hard object, originally wood, and later mostly metal, so that the object can be shaped by a stationary cutter (Bunch and Hellemans, 2004). The lathe machines are used in many applications these days. It can be used for turning, drilling, boring, reaming, facing, milling, planning, broaching, sawing and shaping. The boring operations are an operation using the lathe machine to make internal hole in the cylinder bar. Firstly, the work pieces are drilled using smaller drill bit then using a bigger drill bit. Following that, the bars are bore using the selected parameter.

Engineer tries many ways to improve the production line in order to obtain high production rate and to reduce cost. As for the boring operation, finding the optimum cutting parameter to get the best surface roughness is one of the ways to make the production rate high. Beside it can reduce the cost of the industry to do rework and to scrap the material.

Correct used of cutting parameter can produce surface roughness with high quality finish. This project focuses on the impact of the cutting parameter on the surface roughness on the Mild steel. The cutting parameter are the main key in determined the surface roughness of the material. The cutting parameter such as the cutting speed, feed rate and depth of cut might have significant influent on the resulting surface roughness. The interaction between the cutting parameter may exist and it might significantly affect the surface roughness. The impact of cutting parameter are important and yet to be investigate.

1.3 PROBLEM STATEMENT

Surface roughnesses are one of the critical issues for the lathe boring operation. The surface roughness of the product will determined the quality of it. If the surface roughness are high therefore the quality of the product are low. In the lathe boring operation, the length of the tool, tool rake angle, cutting parameter (cutting speed, feed rate, and depth of cut), type of boring bar, and tool nose radius can affect the surface roughness of the work piece. In this study, the cutting parameters chosen to be investigated are the effect of the cutting parameter on the surface roughness.

Therefore to make sure that the surface roughnesses of the product are low, the cutting parameters are control. Cutting parameter is adjusted and tunes to provide the best surface roughness. This will consumes large amount of time and effort, and still the optimal cutting conditions may not be found. These issues of optimized parameter selection are currently being studied in this study.

The surface roughness result may not be good if the cutting parameters used are unsuitable. Thus the end product may need to go through another round of boring operation. This additional process adds to the cost of production. The relationship between the surface roughness and cutting parameter are important and yet to be investigated in this study.

1.4 PROJECT OBJECTIVE

The main objectives of this project are to study the optimum parameter for single tool boring process for the best surface roughness. The cutting parameters used to investigate were:

a) Cutting speed
b) Feed rate
c) Depth of cut

1.5 SCOPE OF THE PROJECT

In order to achieve the objective of this study, the scopes are list as below:

a) The cutting parameter are cutting speed, feed rate and depth of cut.
b) Single inserted tool are used (Carbide).
c) The conventional lathe machine numbers 9 are used.
d) Mild steel with 38 mm diameter and length of 50 mm are used.
e) The Perthometer S2 are used to measure the surface roughness.
f) STATISTICA 7.1 are used to analyzed the experiment result.

1.6 SUMMARY

At the end of this research, the optimum cutting parameter for the best surface roughness could be identified.

2.2 THEORY OF METAL CUTTING

Metal cutting are one of the most significant manufacturing processes (Chen & Smith, 1997) in the area of material removal. Machining is the process of manufacturing a component by removing the unwanted material using a machine. When metal are used it are referred as metal machining or metal cutting. The metal cutting processes are when the layer of metal from the work-piece is removed (Nagendra Parashar and Mittal, 2006). The process for the metal cutting are drilling, sawing, turning, and milling.

As stated by Mohamed (2010) the theories of metal cutting are very well established. However, some aspects have gone through revision when the experimental results showed the new parameters involved in metal cutting. Many new alloys have also been developed to react to today's applications. As a result, there will be always a need for continuous research and improvement of tool materials, cutting conditions and parameters to optimize the output.

Nagendra Parashar and Mittal (2006) has stated that, in order to remove a layer of material from the work-piece, a cutting tool is needed to penetrate into the material of work-piece and move forward to chip off a layer of material from the work-piece. This required the use of force to remove the layer. The metal cuttings are illustrated in Figure 2.1. From the figure it shows that the sharp edge of the tool will be forced into the metal and this will increase the stress of the metal. The continuing of stress on the metal will first exceed the elastic limit and then the ultimate strength of the metal. This will cause shear failure and eventually a layer of metal gets separated in the form of chips.

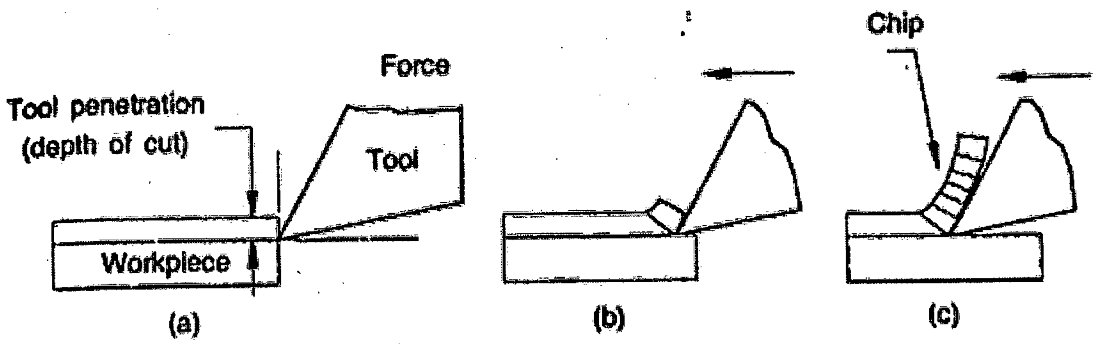

Figure 2.1: Metal cutting operation

Source: Nagendra Parashar and Mittal (2006)

The important parameters that involve in the basis of metal cutting are (Boothroyd and Knight, 1989):

a) Thickness of the uncut layer (*t1,mm*)
b) Thickness of the chips produced (*t2.mm*)
c) The inclination of the chip-tool interface with respect to the cutting velocity (the face of the tool in contact with the chip are commonly known as the rake face), i.e., The rake angle α
d) The relative velocity of the work-piece and the tool
e) To make cutting possible, a clearance angle between the job and the flank surfaces are also provided. In Figure 2.2 showed the basic machining operation and important parameter.

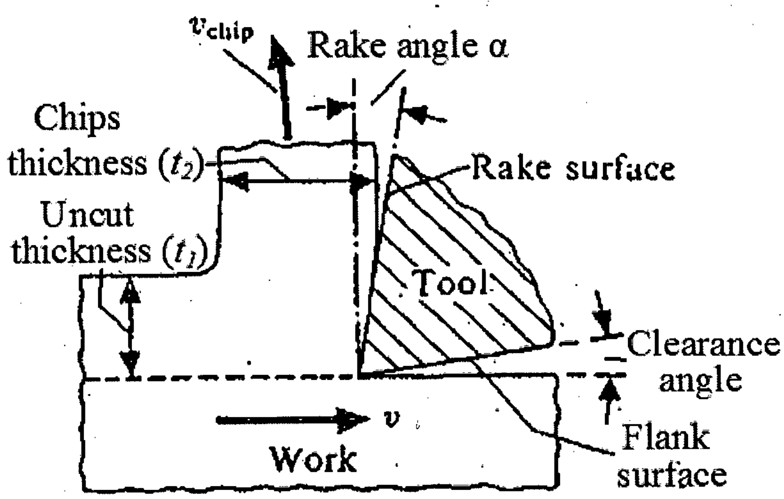

Figure 2.2: Basic machining operation and important parameter.

Source: Boothroyd and Knight (1989)

The orthogonal cuttings are when the cutting edge of the tool are perpendicular to the relative motion of the tool and work piece (Nagendra Parashar and Mittal, 2006). The orthogonal cutting operation happens on a plane and can be analyzed in a two dimensional plane (Viktor, 2010).

2.2.1 Orthogonal cutting and Oblique cutting

The book by Rao (2009) has stated that the orthogonal are a cutting process in two dimensional. The cutting processes are when the cutting edge is perpendicular to the cutting velocity, as shown in Figure 2.3 (a). As for the oblique cutting are cutting processes in three dimensional. The oblique cutting happens when the major edge of cutting are presented to the work-piece at an angle which are not perpendicular to the direction of feed motion, as shown in Figure 2.3 (b). The oblique cuttings are harder to analyzed compare to the orthogonal cutting because of its three dimensions.

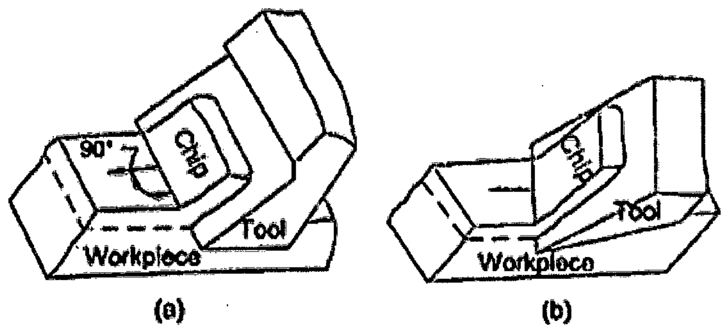

Figure 2.3: Cutting process, (a) Orthogonal cutting (b) Oblique cutting

Source: Rao (2009)

2.2.2 Metal Cutting in Turning Operation

Turnings are one of the most common of metal cutting operations. In turning, a stationary cutting tool (usually a single-point) is fed into a rotating work piece along its periphery or across its end or face for removing chip to obtain the required shape and dimension of a part (Isakov,2004). In other words, turning operation is where the excess material are from the work piece are removed to reduce its diameter (Nagendra Parashar and Mittal, 2006). The turning operation uses the lathe machine as shown in Figure 2.7. As stated by Mohamed (2010) the turning process requires a turning machine, work piece, fixture and cutting tools are required. The work piece with desired dimension are secured at the fixture, which are secure at the turning machine, and allowed it rotate at high speeds. The cutting tools used in the operation are a single-point cutting tool. The cutting tool feeds into the rotating work piece and cuts away material in the form of small chips to create the desired shape. (Noordin et al., 2007)

2.2.3 Tool Geometry

Geometry of the cutting tools effect the quality and productivity of the machining operation (Viktor, 2010). For cutting tools, geometry depends mainly on the properties of the tool material and the work material. In Figure 2.4 shows the typical throw-away insert tool. Figure 2.5 shows the typical right handed cutting tool. When the tools are in contact with the material, cutting takes place mainly over the side edge. For single point tools, the most important angles are the rake angles and the end and side relief angles (Khandey, 2009). The inclination of the side cutting edge with longitudinal axis of the shank, and the inclination of the end cutting edge with the width direction of the shank are called the side cutting edge angle and end cutting edge respectively as shown in Figure 2.6 (Juneja and Seth, 2003).

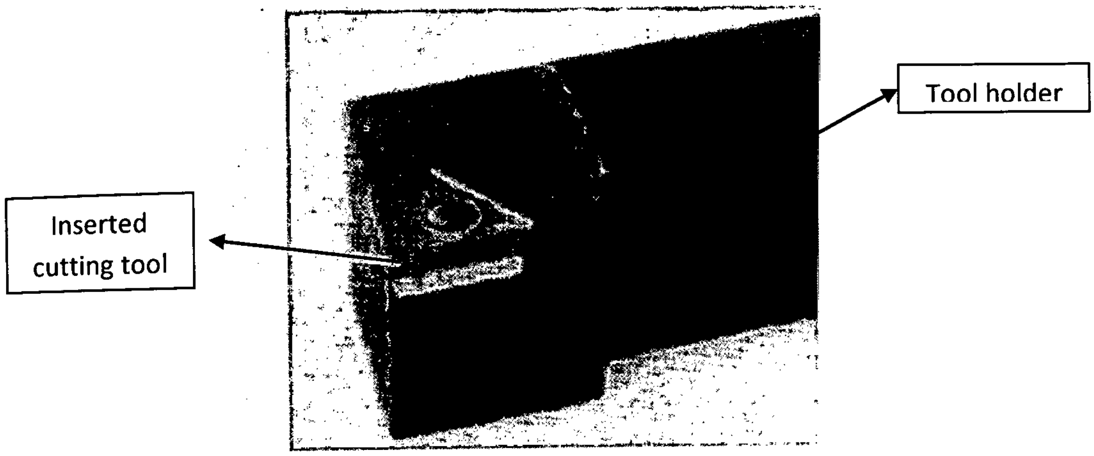

Figure 2.4: Typical throw-away insert tool

Source: El-Hofy (2007)

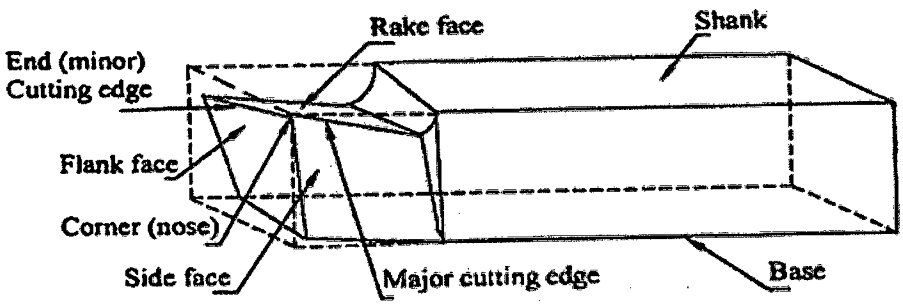

Figure 2.5: Typical right handed tool

Source: Juneja and Seth (2003)

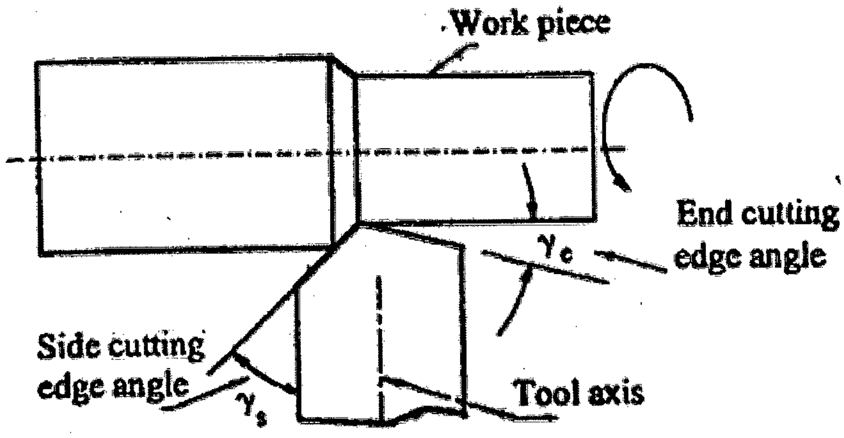

Figure 2.6: Side and End Cutting Edge Angle

Source: Juneja and Seth (2003)

2.2.4 Cutting tool material

Proper selection of tool materials, cutting parameters, tool geometry and machine tools are essential to produce high-quality products at low cost (Şeker et al., 2004). The classes of cutting tool materials currently in use for machining operation are high-speed tool steel, cobalt-base alloys, cemented carbides, ceramic, polycrystalline cubic boron nitride and polycrystalline diamond. Different machining applications require different cutting tool materials (Edalew et al., 2001).

Khandey (2009) said that the HSS tools are so named because they were developed to cut at higher speeds. Developed around 1900 HSS are the most highly alloyed tool steels. The tungsten (T series) was developed first and typically contains 12-18% tungsten, plus about 4% chromium and 1 - 5% vanadium. Most grades contain about 0.5% molybdenum and most grades contain 4 - 12% cobalt. It was soon discovered that molybdenum (smaller proportions) could be substituted for most of the tungsten resulting in a more economical formulation which had better abrasion resistance than the T series and undergoes less distortion during heat treatment. Consequently about 95% of all HSS tools are made from M series grades. These contain 5 - 10% molybdenum, 1.5 - 10% tungsten, 1 - 4% vanadium, 4% Chromium and many grades contain 5 - 10% cobalt. HSS tools are tough and suitable for interrupting cutting and are used to manufacture tools of complex shape such as drills, reamers, taps, dies and gear cutters. Tools may also be coated to improve wear resistance. HSS accounts for the largest tonnage of tool materials currently used. Typical cutting speeds: 10 - 60 m/min.

As stated by Juneja and Seth (2003), the cemented carbide is divided into two, which are the tungsten carbide and alloyed tungsten carbides. The tungsten carbide consists of powered tungsten carbide (85-95%) and cobalt (5-15%). The properties of the tool are highly depending on the content of cobalt. If the content of cobalt increases, hardness of the tools material decrease and the toughness are increased. The grain size also will affect the hardness. The finer the grain size, the greater the hardness of the tools.

Juneja and Seth (2003) also stated that the alloyed tungsten carbide has additions of carbide of titanium and niobium. Titanium carbide reduces the tendency of chips to weld to the tool. It's also decrease the process of diffusion wear of the tool and increases the hot hardness. Cemented carbide tool materials are able to retain high hardness even at temperature of 1000 °C. Other than that it can operate at a much higher cutting speed as compared to HSS.

2.3 LATHE MACHINE

The lathes are one of the most important and versatile machine tools these days. The boring operation are equivalent to turning but are performed on the internal surfaces or the work piece. Boring can be performed in many types of machine tools such as lathes, drilling machines, horizontal or vertical milling machine and machining centers. In this study the conventional lathe machine are used as shown in Figure 2.7 to carry out the boring operation. In APPENDIX A1 shows the General Characteristic of Machining Processes and Typical Dimensional Tolerances.