MODELING AND SIMULATION OF WIRE ELECTRICAL DISCHARGE MACHINE PROCESS IN MACHINING ALUMINUM ALLOY T6 6061

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ABSTARCT

This research is specially focused on finding of the constraint parameters on Wire Electrical Discharge Machine (WEDM) in machining process. The objectives of this study are to design and develop a mathematical model in WEDM parameters. The idea of this project came when WEDM is advance machine and their cutting parameters are hard to find in surface roughness cutting material. Surface roughness is the one parts of the important variable in material and quality product design. Aluminum Alloy T6 6061 was selected as the material base on their properties and useable in productions. Mathematical models that proposed by using multiple linear regression were come out with the equations that can be calculated manually by other researcher who want to find fit parameters base on their surface predicted. Two models were discussed and finally the goodness-to-fit model was selected base on the method and tests by using STATISTICA software. Simulation by using software and hand are nearly to the experimental result and that proved the experiments were success and achieves their objectives.

ABSTRAK

Penyelidikan ini adalah memfokuskan kepada pencarian parameter-parameter yang terbaik dalam proses pemotongan Mesin Wayar Elektrikal Discaj atau dikenali "wire cut". Objektif kajian ini adalah untuk menerbitkan suatu model matematik dalam faktor-faktor pemotongan WEDM. Idea projek ini telah bermula apabila WEDM adalah mesin yang canggih dan factor-faktor untuk memotong permukaan bahan sangat sukar ditentukan. Struktur permukaan adalah sesuatu yg penting dalam menentukan kualiti produk. Aloi aluminium 6061 T6 telah dipersetujui sebagai bahan kajian berdasarkan sifat dan penggunaannya dalam industri. Model matematik yang telah diterbitkan menggunakan kaedah 'Multiple Linear Regressions' dimana persamaan tersebut boleh dikira dengan mudah oleh pengkaji yang mahu mencari permukaan bahan yang dipotong seperti yang dimahukan.Dua model telah dipiih dan yang terbaik daripadanya telah diuji berdasarkan kaedah dan ujian daripada perisian Statistica. Simulasi daripada perisian tersebut dan kaedah kira matematik biasa telah menunjukkan eksperimen yang dijalankan telah berjaya dan mencapai objektif kajian.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Wire electrical discharge machining (WEDM) is a specialized thermal machining process capable of accurately machining parts with varying hardness or complex shapes, which have sharp edges that are very difficult to be machined by the main stream machining processes. This practical technology of the WEDM process is based on the conventional EDM sparking phenomenon utilizing the widely accepted non-contact technique of material removal. Since the introduction of the process, WEDM has evolved from a simple means of making tools and dies to the best alternative of producing micro-scale parts with the highest degree of dimensional accuracy and surface finish quality.

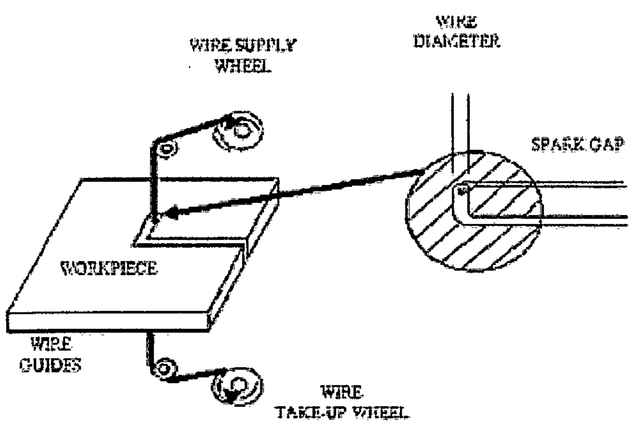


Figure1.1: Wire EDM process

Source from: M.S. Hewidy, T.A. El-Taweel and M.F. El-Safty (2005)

Scott et al. (1991) presented a formulation and solution for the multi-objective optimization problem for the selection of the best control settings parameters for the wire electrical discharge machining process. It was found that discharge current, pulse duration and pulse frequency were the main significant control factors for both the metal removal rate (MRR) and surface finish, while wire speed, wire tension and dielectric flow rate were relatively significant. Liao, Yan, Chang (2000) utilized a neural network to model the WEDM process to assess the optimal cutting parameters using an adjustable objective function.

Wire electrical discharge machining (WEDM) allowed success in the production of newer materials, especially for high accuracy cutting materials. Using WEDM technology, complicated cuts can be made through difficult-to-machine electrically conductive components. Therefore, materials with high hardness, brittleness, strength and electrical insulation, which are difficult-to-cut, can be machined. The high degree of the obtainable accuracy and the fine surface quality make WEDM valuable.

The process of wire electrical discharge machining offers many advantages which are unattainable using other methods. Over the last fifteen years, wire EDM technology has developed into a standard and popular machining technology. In many operations formerly performed by conventional manufacturing processes, the process of wire EDM is regularly less expensive, infinitely more accurate, and considerably time-saving.

1.2 Background

In this study, the effect of the cutting parameters on surface roughness on material was experimentally and theoretically investigated in wire electrical discharge machining (WEDM). The experiments were conducted using different cutting parameters of pulse duration, open circuit voltage, peak current and wire diameter. Brass wire of (0.15, 0.25 mm) diameters and Aluminum Alloy T6061 of (20.00) mm thickness were used as tool and work piece materials in the experiments. It is found that different values of parameters give the different result for surface roughness. The variation of surface roughness with machining parameters is modeled mathematically by using mathematical models. The level of importance of the machining parameters on the surface roughness is determined by using mathematical modeling.

1.3 Problem Statement

The objective of the mathematical models is to achieve higher machining productivity with a desired accuracy and surface finish. However, the selection of cutting parameters for obtaining higher cutting efficiency or accuracy in WEDM is still not fully solved, even with the most up-to-date CNC WEDM machine. This is mainly due to the nature of the complicated stochastic process mechanisms in wire-EDM. As a result, the relationships between the cutting parameters and the process performance are hard to model accurately.

1.4 Objectives of the Study

The objectives of this thesis are as follows:-

1. To study the influence of wire electrical discharge machining (WEDM) cutting parameters on the surface quality machined Aluminum Alloy 6061 T6. Surface quality in terms of surface roughness of the selected material.
2. To develop mathematical models for the prediction of surface roughness in terms of the selected cutting parameters for the Aluminum Alloy 6061 T6.

1.5 Scope and Limitation

1. This experiment just using the wire electrical discharge machining (WEDM) in Universiti Malaysia Pahang (UMP). The model is AQ535L and using SODICK Controller.
2. The parameters of the WEDM were selected such as peak current, pulse duration, servo voltage, and wire diameter.
3. The mathematical model developed can be used to predict the surface roughness based on adjustable parameters.
4. The material is limited to Aluminum Alloy 6061 T6 and their characteristic is checked.

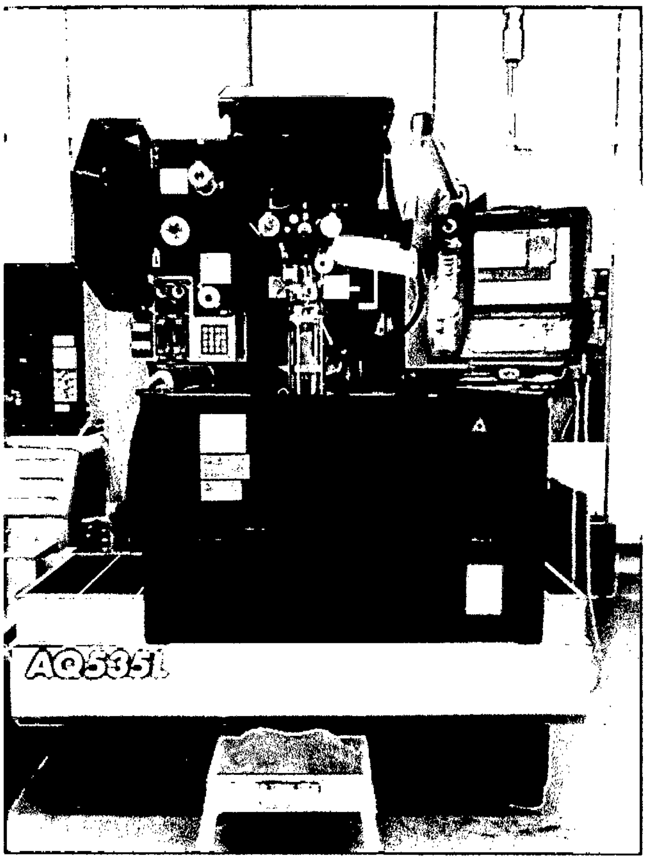


Figure 1.2: Wire-EDM in FKM lab (UMP)

1.6 Organization of the Thesis

This thesis consists o five chapters. Chapter 1 that has you read is the introduction about this study. Chapter 2 is the review of literature which discusses methods and findings previously done by other people which are related to the study. Chapter 3 is methodology which explains the approaches and methods used in performing the thesis. Chapter 4 is the chapter which reports the outcomes or results and discussion from the project and chapter 5 consists of the recommendation and conclusion.

CHAPTER 2

LITERATURE REVIEW

This chapter will show the researches that have done by others people who have the same goals as my final year project. The literature reviews all what they have found and the result just be my guide.

1.1 Introduction Wire EDM

Wire electrical discharge machining (WEDM) is a non-traditional thermal machining process of machining hard material with complex shapes accurately. It is erodes materials from the workpiece by discrete sparks immersed in a liquid dielectric medium between the workpiece and the electrode (wire) Gabor Erdos (2004). The application of WEDM base on EDM sparking phenomenon utilizing non-contact technique of material removal with a difference that spark is generated at wire and workpiece gap. Figure 2.1 show the cutting process.

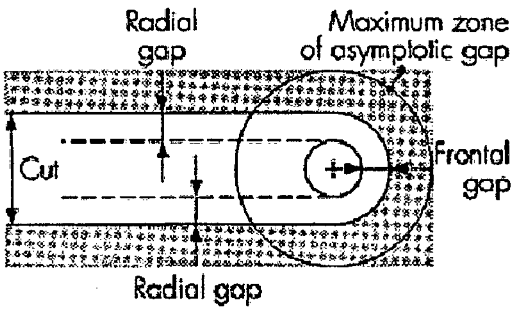


Figure 2.1:"Range of Action" of the wire

Source from: Gabor Erdos (2004)

2.2 Wire-EDM Technology

This logical dimension is depending on the chosen technology, which is finally machine dependent. Since the logical diameter of the tool is technology and machine dependent, therefore the offset paths of the final part can only be determined if the selected technology and machine is known. Furthermore there is no "analytical approach" to determine the logical radius of the wire Gabor Erdos (2004). It is determined based on experiments. Beside the logical diameter of the wire, there are many factors that determine the offset. In wire EDM there are basically three type of working mode:

- Roughing
- Finishing
- Surface finishing

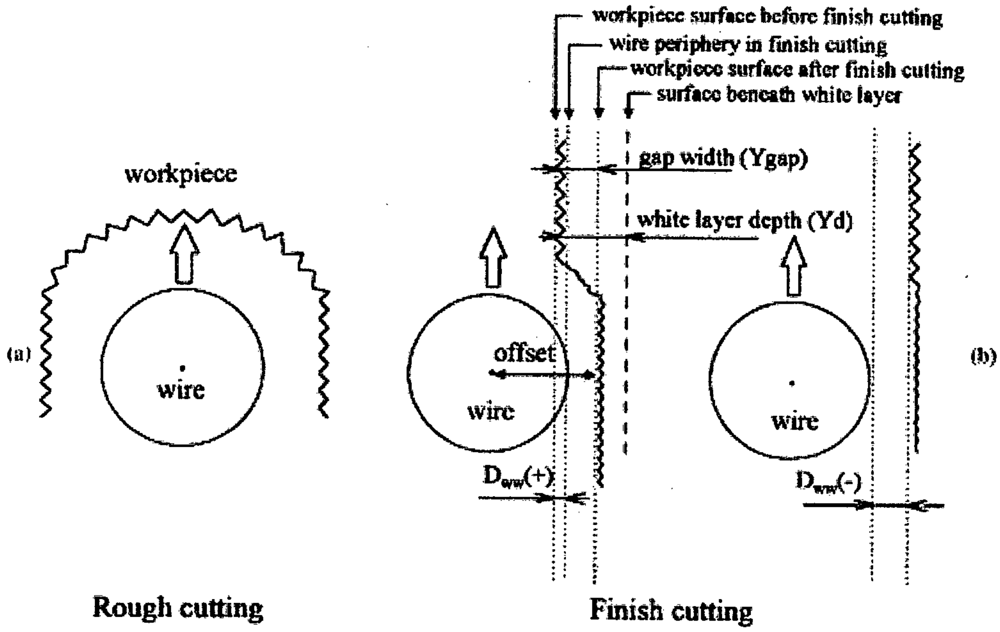


Figure 2.2: A schematic plan view of (a) a rough (b) finish, cutting of WEDM
Source from: J. T. Huang, Y. S. Liao and W. J. Hsue (1999)

The number of working modes required to manufacture the same part on deferent machines is also machine dependent. The same part might require 1 roughing 2 finishing and 3 surfaces finishing on one machine and 1 roughing 3 finishing 1 surface finishing working step on another machine. The technological parameters- which are principally the settings of the generator- used for these manufacturing steps are also different and proprietary to the machine builders. This implies that it is rather difficult to define global working steps like in milling, because the definition of the technology of these working steps varies from machine to machine.

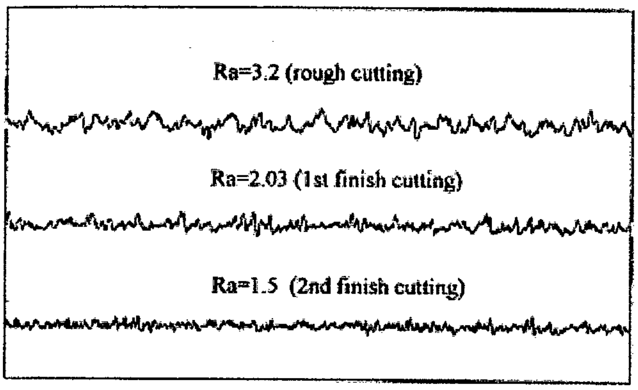


Figure 2.3: Surface roughness profiles
Source from: J. T. Huang, Y. S. Liao and W. J. Hsue (1999)

2.3 Effect of Working Parameters by Modeling

Adjustable parameters such as peak current, voltage, pulse on-stop, dielectric fluid pressure were effects of the cutting material such as surface roughness, MRR and surface finish.

Two models were designed by Spedding and Wang with (1997) input parameters of the pulse width, the time between the successive pulses and the wire mechanical tension, whilst cutting speed, surface roughness and surface waviness were the responses. It was concluded that both models provide accurate results for the process. W.J. Hsue, Y.S. Liao and S.S. Lu (1999), developed a model to estimate the MRR in the corner cutting. They showed a good agreement between the computed MRR and the measured sparking frequency of the process.

Liao et al. (1997) proposed a methodology to determine the optimal working parameters. The significant factors affecting the machining performance such as

MRR, gap width, surface roughness, sparking frequency, average gap voltage and ratio of normal sparks to total sparks were determined. They concluded that the machining models are appropriate and the derived machining parameters satisfy the real requirements in practice. Moreover, Y.S. Liao and J.C. Woo (1997) developed a pulse discrimination system to study the effect of various machining conditions on the behaviors of pulse trains in the process. An approximation method for estimating the variation of the average gap width was also submitted.

Literature lacks much to say about the use of WEDM for machining Inconel 601 material, so the need has been felt towards the highlighting of this process with the goal of achieving mathematical models to enhance the process performance M.S Hewidy (2005).

The effect of the cutting parameters on size of erosion craters (diameter and depth) on wire electrode was experimentally and theoretically investigated N.Tosun et al (2003). The experiments were conducted under the different cutting parameters of pulse duration, open circuit voltage, wire speed and dielectric flushing pressure. Brass wire of 0.25 mm diameter and AISI 4140 steel of 0.28 mm thickness were used as tool and workpiece materials in the experiments. It is found that increasing the pulse duration, open circuit voltage, and wire speed increases the crater size, whereas increasing the dielectric flushing pressure decreases the crater size. The variation of wire crater size with machining parameters is modeled mathematically by using a power function. The level of importance of the machining parameters on the wire crater size is determined by using analysis of variance (ANOVA).

2.3.1 Effect of Working Parameters on the Volumetric Metal Removal Rate

Metal removal rate in WEDM process is an important factor because of its vital effect on the industrial economy. Fig. 2.5 and Fig. 2.6 present the effect of peak current on the volumetric metal removal rate at various duty factors, wire tension and flushing water pressure, respectively. From these figures, it can be seen that an increase in the peak current leads to the increase of the volumetric metal removal rate. This increase is, however, diminished after 7 A. This result has been attributed to the increase in peak current which leads to the increase in the rate of the heat energy and hence in the rate of melting and evaporation. Increase in peak current higher over a certain limit, leads to arcing which decreases discharge number and the machining efficiency, and subsequently decreases in VMRR. The increasing of the water pressure decreases the tendency for arcing, and increases the metal removal rate.

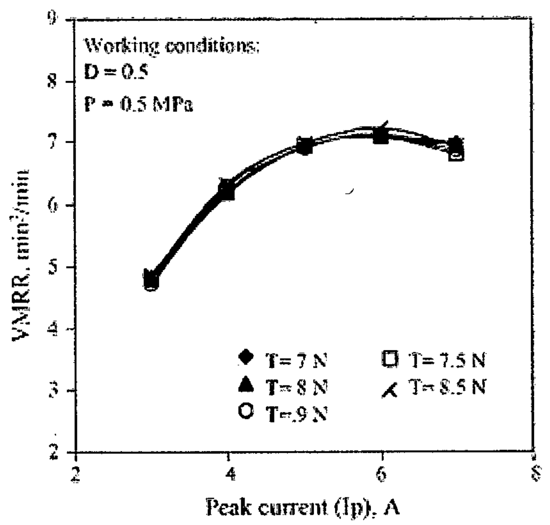


Figure 2.4: Effect of the peak current on the metal removal rate at different wire tensions.

Source from: M.S. Hewidy, T.A. El-Taweel and M.F. El-Safty (2005)

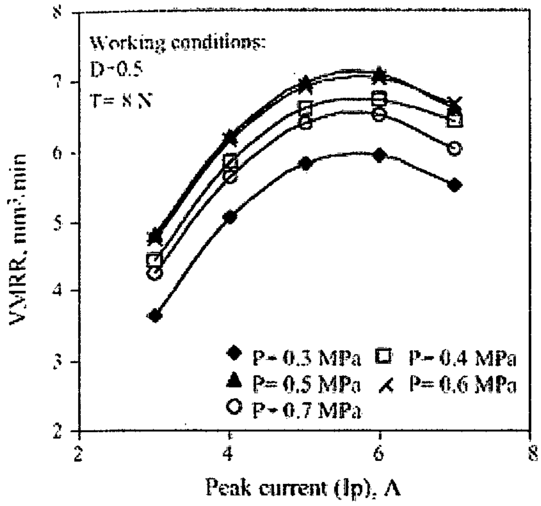


Figure 2.5: Effect of peak current on the metal removal rate at the different water pressures. M.S Hewidy (2005).

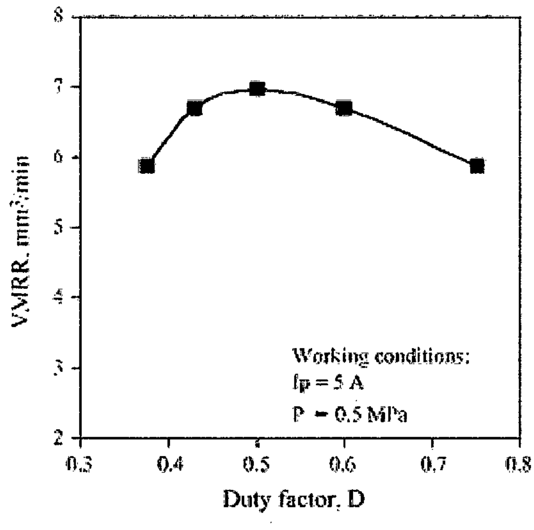


Figure 2.6: Effect of duty factor on the metal removal rate at different wire tensions. M.S Hewidy (2005).

Figure 2.7 show the effect of the duty factor on the volumetric metal removal rate at various wire tension. In these figure, it is clear that the volumetric metal removal rate generally increases with the increase of the duty factor up to 0.5 and then decreases with a further increase in the duty factor. The increase in the duty factor means applying the same heating temperature for longer time. This will cause an increase in the evaporation rate and gas bubbles number, which explode with high ejecting force when the discharge ceases causing removal of bigger volume of the molten metal. Increasing of MRR is continued with the increase of the ejecting force until reaching a situation in which the ejecting force will have no more increase in VMRR since the molten metal decreases. This explains the reasons for the increase in the VMRR with duty factor to a certain extent and then it decreases.

2.3.2 Effect of Working Parameters on the Wear Ratio

The wear ratio in WEDM is the work piece volumetric metal removal rate, expressed as a percentage of the wire material removal rate. Figure 2.8, show linear relationships between the peak current and the wear ratio at various duty factors. It can be seen that the wear ratio generally increases with an increase in the peak current. Machining at higher values of peak current leads to generation of higher heat energy, which is subjected to both of the electrodes. The motion of the wire dissipates the effects of heat energy on the wire surface, but the work piece VMRR increases the wear ratio. Furthermore, the increase of the water pressure increases the wear ratio due to the increase of VMRR, as discussed above.

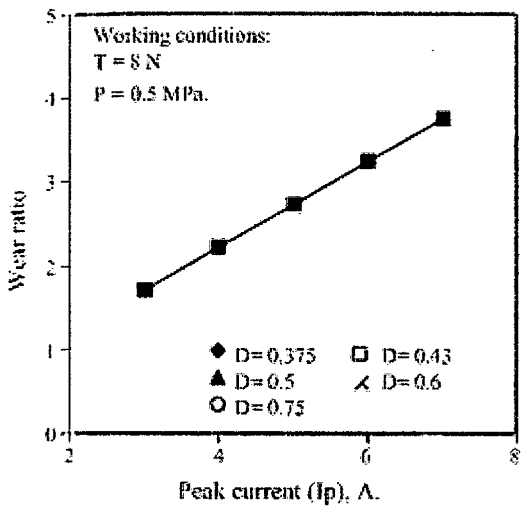
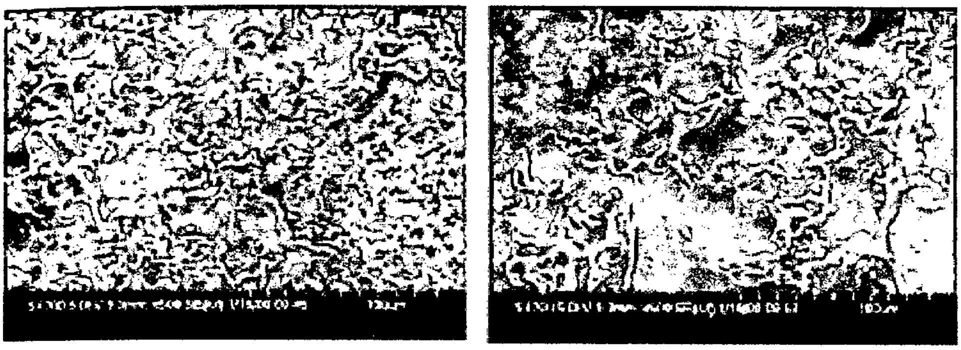


Figure 2.7: Effect of the peak current on the wear ratio at different duty factors. M.S Hewidy (2005).

2.3.3 Effect of Working Parameters on the Surface Roughness

Figure 2.8 show the effect of peak current on the surface roughness of the WEDM components at different duty factors, wire tension and flushing water pressure, respectively. It is clear that surface roughness slightly increases with the increase of peak current value up to a certain limit (Ip = 5 A) and then vigorously increases with any increase of peak current. It is believed that the increase in peak current causes an increase in discharge heat energy at the point where the discharge takes place. At this point, a pool of molten metal is formed and is overheated. The overheated molten metal evaporates forming gas bubbles that explode when the discharge ceases, taking molten metal material away. The result is the formation of crater. Successive discharges that have a random nature will result in the formation of overlapped crater, pockmarks and chimneys. The figure below is shows the SEM micrograph of WEDM machined surface at two different peak current (4 and 7 A).

From figure 2.8, it is clear that the diameter and the depth of the crater depend on the discharge heat energy or in other words, on the peak current value.



Ip = 4 A Ip = 7 A

Figure 2.8: SEM micrograph of WEDM machined surface under two different peak current. M.S Hewidy (2005). (D = 0.5, T= 8 N, P= 0.5 MPa)

2.4 Conclusion on Working Parameters

Base on the experiment and investigation that was done by researcher such as Speeding and Wang (1997), Liao and Woo (1997), it was found that both of them had discovered the effects that occurs in WEDM process base on the working parameters such as peak current, voltage, wire tension etc to the surface roughness and the cutting process. They have done their modeling to estimate the surface integrity and finishing cutting. From the article review, M.S Hewidy (2005) also stated that not only high peak current that will make the cutting process perfect. The higher peak current the higher surface roughness, wear ratio and metal removal rate. It is different from the process wire-EDM to make the surface of work-piece smooth.