JURNAL TEKNIK MESIN DAN MEKATRONIKA
Journal of Mechanical Engineering and Mechatronics
ISSN: 2527-6212, Vol. 8 No. 2, pp. 72 - 86

Study of Peak Current Wire-cut EDM on Surface Morphology With CAD/CAM Integration in The Manufacturing of Chain Components

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Abstrak.

Pada zaman yang semakin modern ini, ilmu pengetahuan dan teknologi (IPTEK) semakin berkembang pesat, salah satunya yaitu kemajuan pada sektor industri manufaktur untuk memproduksi suatu produk. Proses pemesinan yang sering digunakan saat ini adalah Wire Electrical Discharge Machining (WEDM). Mesin ini mulai banyak digunakan karena mampu memotong benda kerja dengan cepat, efesiensi yang bagus, dan dengan dimensi yang akurat. Penelitian ini bertujuan untuk mempelajari pengaruh variasi penggunaan parameter peak current pada proses pemotongan WEDM dengan menggunakan integrasi antara sofware CAD/CAM untuk membuat program dalam pembuatan komponen rantai. Kemudian dalam proses pemotongan material akan diberikan perlakuan variasi peak current untuk mengetahui surface morphologynya. Sofware yang digunakan untuk CAD yaitu Autodesk Inventor Profesional 2015 dan CAM nya menggunakan aplikasi Mastercam X4. Sedangkan variasi peak current menggunakan 8, 10, 12 A. Hasilnya menunjukkan bahwa integrasi sofware antara Autodesk Inventor Profesional 2015, kemudian hasil gambar dieksport pada aplikasi Mastercam X4 dan dapat dijalankan pada mesin WEDM. Selain itu gambar morfologi permukaan yang didapatkan, menunjukkan perbedaan yang mencolok dengan variasi peak current yang berbeda. Pada peak current yang tinggi 10 dan 12A jumlah crater yang dihasilkan lebih besar jika dibandingkan dengan crater pada peak current yang rendah 8A. Disamping itu debris yang dihasilkan pada morfologi permukaan dengan peak current yang lebih tinggi memiliki ukuran yang lebih besar dengan jumlah yang lebih banyak.

Kata kunci: *Wire-cut EDM,* Kuat Arus, Analisis *Surface Morphology, Integrasi Sofware CAD/CAM*

Abstract.

In this increasingly modern era, science and technology (IPTEK) is growing rapidly, one of which is progress in the manufacturing industry sector to produce a product. The machining process that is often used today is Wire Electrical Discharge Machining (WEDM). This machine began to be widely used because it is able to cut workpieces quickly, with good efficiency, and with accurate dimensions. This study aims to study the effect of variations in the use of peak current parameters in the WEDM cutting process by using integration between CAD/CAM software to create programs for manufacturing chain components. Then in the process of cutting the material will be given a variation of peak current treatment to determine the surface morphology. The software used for CAD is Autodesk Inventor Profesional 2015 and the CAM uses the Mastercam X4 application. While the peak current variations use 8, 10, 12 A. The results show that software integration is between Autodesk Inventor Profesional 2015, then the image results are exported to the Mastercam X4 application and can be run on WEDM machines. In addition, the surface morphology images obtained show striking differences with different peak current variations. At high peak currents of 10 and 12A the number of craters produced is larger than the craters at a low peak current of 8A. Besides that, the debris produced on the surface morphology with a higher peak current has a larger size with a greater amount.

Keywords: *Wire-cut EDM, Peak Current, Surface Morphology Analysis, CAD/CAM Software Integration*

Introduction

Along with the development of science and technology, the manufacturing industry sector continues to experience very rapid progress. Industrial development continues to be carried out in order to improve the quality of the products produced and increase efficiency in the process. One of the machining processes that is often used today is Wire Electrical Discharge Machining (WEDM). The WEDM machining process is a material cutting process with the help of erosion which occurs due to a number of electrical sparks in the gap between the cutting media and the material until the material is cut [1]. WEDM is also one of the non-conventional machining processes that runs with a computer numerically controlled (CNC) system [2]. The material removal process carried out by WEDM uses an electrical system, including materials that have high hardness, because they use electricity, so the material cut on WEDM must be conductive [3]. The cutting tool media used in WEDM is a small wire made of brass, copper, and molybdenum measuring 0.05-0.3 mm, which is installed between machine holders to cut materials with high precision [4]. During the WEDM process the material is eroded in front of the wire and there is no direct contact between the material and the wire through the dielectric fluid to eliminate mechanical stress during machining [5].

WEDM has an advantage compared to other conventional machines in terms of cutting, namely it can work on machine components that require complex profiles and complex shapes [6]. Can cut materials with a high level of hardness [7]. Can produce excellent material cuts with high and thin precision because there is no direct contact between the cutting tool and the workpiece, cleaner cuts, and high efficiency [8].

One of the workpieces that can be processed using a WEDM machine is stainless steel material. This material has a high hardness in which there is a mixture of iron, carbon and chromium [9]. One of the chain products is made of stainless steel material because of its high strength. In this study, we tried to analyze this material for the manufacture of chain component products at UPT Logam dan Perekayasaan Sidoarjo, this chain product was ordered by one of the customers who used services at UPT Logam dan Perekayasaan Sidoarjo. Making products with complex shapes and high hardness is usually very difficult to work with conventional machines, so WEDM is very suitable in terms of its advantages for cutting workpieces.

In the WEDM machining process, parameter optimization is always a topic that must be paid attention to. WEDM parameters continue to be a problem because it has to find the right parameters to produce the most accurate cuts [10]. Parameters that can affect WEDM results are usually the spark gap voltage, discharge current, and pulse duration [11]. Peak Current, pulse duration, wire tension [12].

All of these parameters will largely affect the performance of the WEDM machining process, the selection and use of the right parameters will play an important role in machining wire, the dimensional accuracy of the final workpiece and surface quality, the selection of parameters that are not optimal will cause dimensional inaccuracies, poor workpiece quality, rough workpiece surfaces, and cause wire damage in the WEDM machining process [13,14,15,3].

Discharge current is a parameter that needs attention because it relates to the amount of electric current flowing in the WEDM process. The greater the electric current that is flowing, the greater the electrical energy released from the wire to the workpiece, so that the area of the workpiece that is eroded will be greater, which will cause the MRR value and surface roughness to be high [16,17]. The increase in the value of surface roughness is closely related to the surface morphology of the workpiece produced, so that the analysis of the surface morphology of the workpiece is important for research.

Surface morphology is the result of the surface of the workpiece after machining to see the shape quality of the workpiece, and is used to predict the value of the surface roughness of the workpiece cut. By analyzing the surface morphology we can find out the existence of cracks and also deep craters on the surface of the workpiece as in the study [18]. So that the results of the analysis can be correlated with the surface roughness value of the workpiece or MRR before testing.

Based on the explanation above, this study tries to analyze the effect of discharge current with various variations on the results of the workpiece surface morphology with microstructural and macrostructural images. In the process later, programming on the WEDM machine is carried out by integrating CAD and CAM applications to design drawings according to the product chain components to be worked on, then simulating them in a real form on the WEDM machine.

Materials and Methods

Researh Materials and Tools

In making this chain component, the material used is stainless steel, the material is rectangular in shape with dimensions of 41 mm x 13 mm x 10 mm which will then be processed with a WEDM machine to form a chain component. The following is an explanation related to stainless steel material in detail in Table 1 and Table 2.

Table 1. Chemical Compotition of Stainless Steel [9]

Element	C	Si	Mn	Cr	Mo	Cu	Ni	Co	P	S	N
Component (%)	0,017	0,41	1,80	18,08	0,57	0,56	8,02	0,113	0,031	0,026	0,087

Table 2. Properties of Stainless Steel [20]

Properties	Value
Yield point [MPa]	332
Tensile strength [MPa]	673
Modulus of elasticity [GPa]	165
Strength at break [MPa]	586
Elongation at break [mm]	35,5

As for the tools used in making chain components using the WEDM machine, they will be explained as follows:

a. Computer equipped with Autodesk Inventor Professional 2015 CAD software and Mastercam X4 CAM software used to create programs.
b. Cutting wire with a diameter of 0.25 mm is used as a cutting medium for WEDM machines. In this cutting the wire used must also be able to conduct electric current as an electrode for the erosion process.
c. Dielectric fluid.
d. The dial up and hammer are used to measure the straightness of the workpiece in the chuck.
e. Clamp clamps are used to clamp the workpiece.
f. L size 6 wrench is used to lock the workpiece on the clamping chuck.
g. Calipers are used to measure the yield of the workpiece according to the cutting dimensions.
h. Scissors are used to cut wire on WEDM machines.

i. The WEDM machine used in the manufacture of this chain component is the Chmer type GX 360 L wire-cut machine. The following are the machine components and specifications of the Chmer type GX 360 L wire-cut machine used to make chain components in this study will be shown in Fig 1. and Table 3.

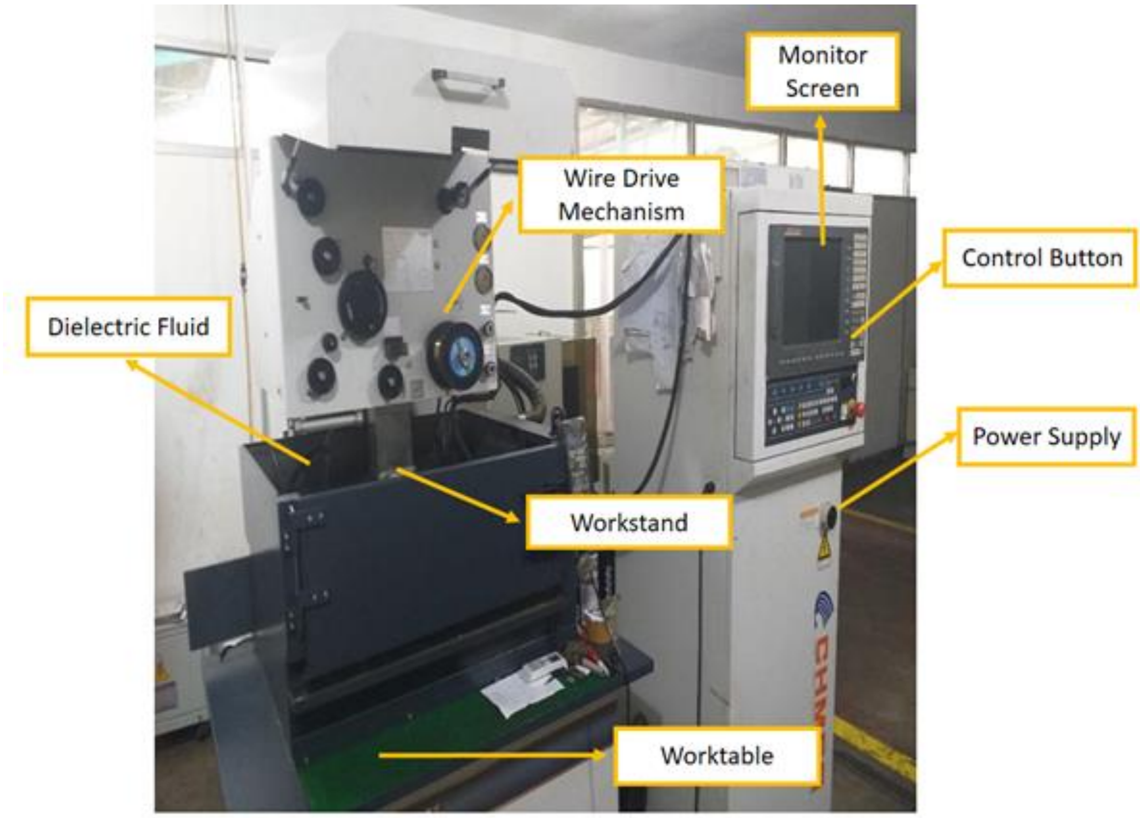


Fig 1. Wire-cut Chmer type GX 360 L

Table 3. Specifications for the Wire-cut Chmer type GX 360 L

Machine	Chmer type GX 360 L
Control	Chmer EDM 5 Axis *Wire Cutting Controller*
Machine Size	
Machine Dimensions	1260 x 2300 x 2100 mm
Machine Weight	2500 kg
Workpiece Size	
Long	745 mm
Wide	560 mm
Tall	215 mm
Max. X,Y Feed rates	800 mm/min
Max. Wirefeed rate	300 mm/sec
Maximum Workmanship	
Object Length	360 mm
Object Width	250 mm
U and V axes	60 mm
object thickness	220 mm
Tilt angle	14.5°
Object Weight	300 kg
Another	
Water Tank Capacity	340 L

Researh Methods and Steps

In this study, an experimental method was used by analyzing the effect of variations in peak current on the WEDM machining process, namely 8, 10, and 12 A in the manufacture of chain components. Later, the results of the workpiece will be observed in micro and macro structures to see the surface morphology. All results will then be analyzed using detailed descriptions of the phenomena that occur and supported by supporting images from several previous studies to make it easier for readers to understand in this article.

In addition, the manufacture of chain components will use the exploratory method to create programs according to the desired working drawings using the help of some CAD/CAM software which will then be run on a wire-cut machine WEDM brand namely Chmer type GX 360 L. This exploration will provide success in data collection using drawing design creation through integration of CAD/CAM software.

This research begins by searching for literature reviews to strengthen theory, then designing a chain component image in the Autodesk Inventor Professional 2015 application, then the resulting images are exported to the Mastercam X4 application to create programs and tools that will be prepared so that they can be simulated. Furthermore, the results of the program will be entered into the machine to be executed. In the process, treatment is given to variations in peak current which include 8, 10, and 12 A, and the machine is run until the chain components are successfully made. The results of the chain components will later be photographed using an optical microscope to analyze the surface morphology. Fig 2. will explain the flowchart diagram in this study.

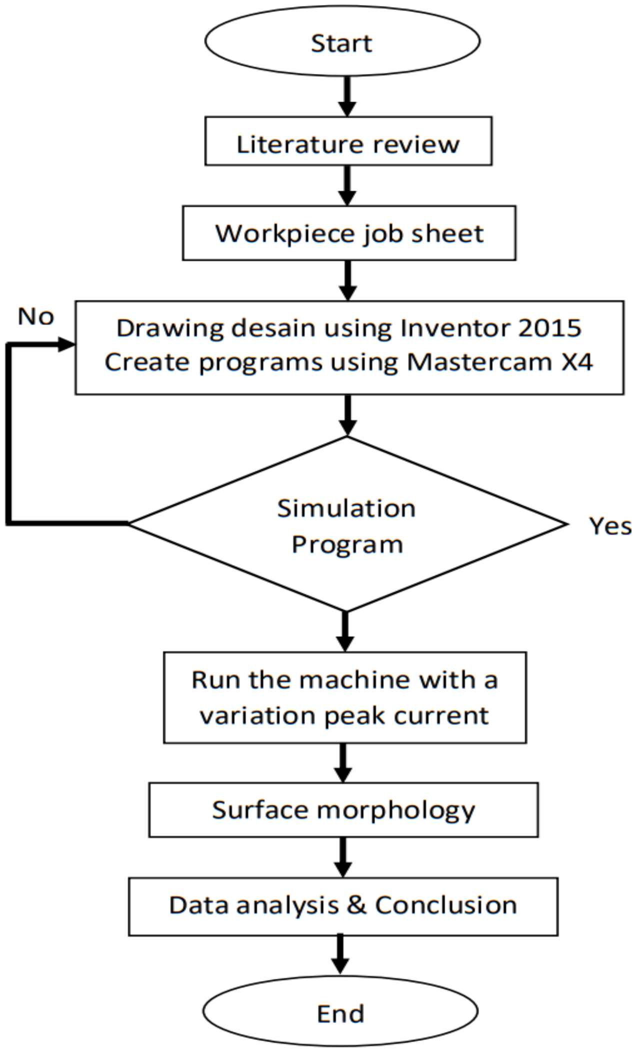


Fig 2. Research Flowchart

Integration Program of CAD/CAM in CNC Wire-cut EDM

In making chain components using the WEDM engine, the first thing that must be done is to make the program first to run the machine, the program is created using the integration between the sofware Autodesk Inventor Profesional 2015 application to design chain drawings and sofware Mastercam X4 to simulate the program.

The chain is part of a machine that functions to transmit the motion energy generated by the machine itself. Fig 3. will show the design of the chain components that will be worked on in this study using the WEDM machine.

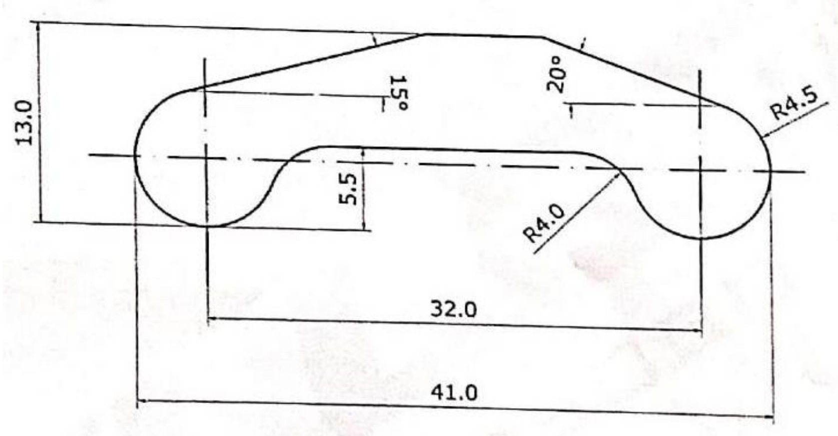


Fig 3. Workpiece Job Sheet Chain Components

From the picture above, it is possible to do a drawing design first with the CAD process using the Inventor 2015 application, all dimensions in the drawing design process are adjusted to the jobsheet image above. Start by designing a 2D image then saving which is then ready to be exported to the sofware Mastercam X4 software. Fig 4. shows the process of designing a chain component image using the sofware Autodesk Inventor Profesional 2015.

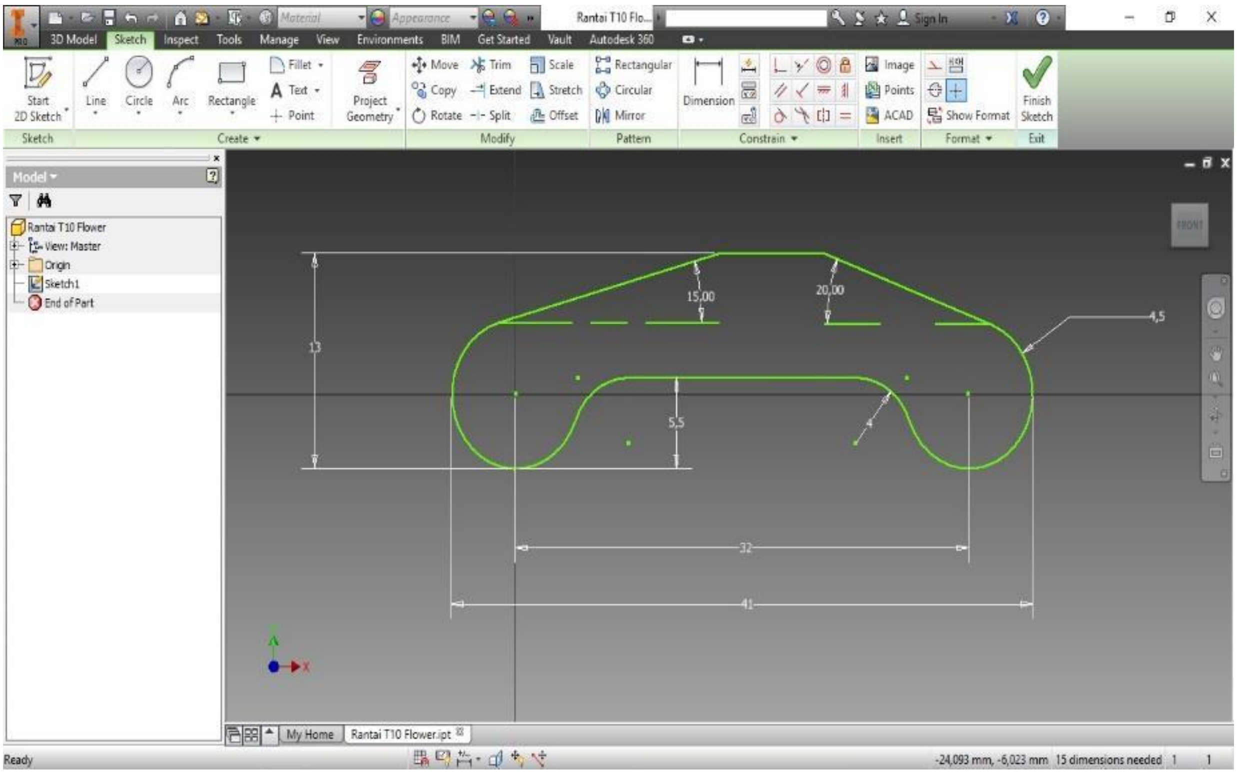


Fig 4. Design Using Autodesk Inventor Profesional 2015

Transfer the resulting CAD drawing design file to the Mastercam X4 application by exporting it then saving it in the form of a DWG file, and then the image is ready to be opened in the Mastercam X4 software. Fig 5. shows the mastercam application used.

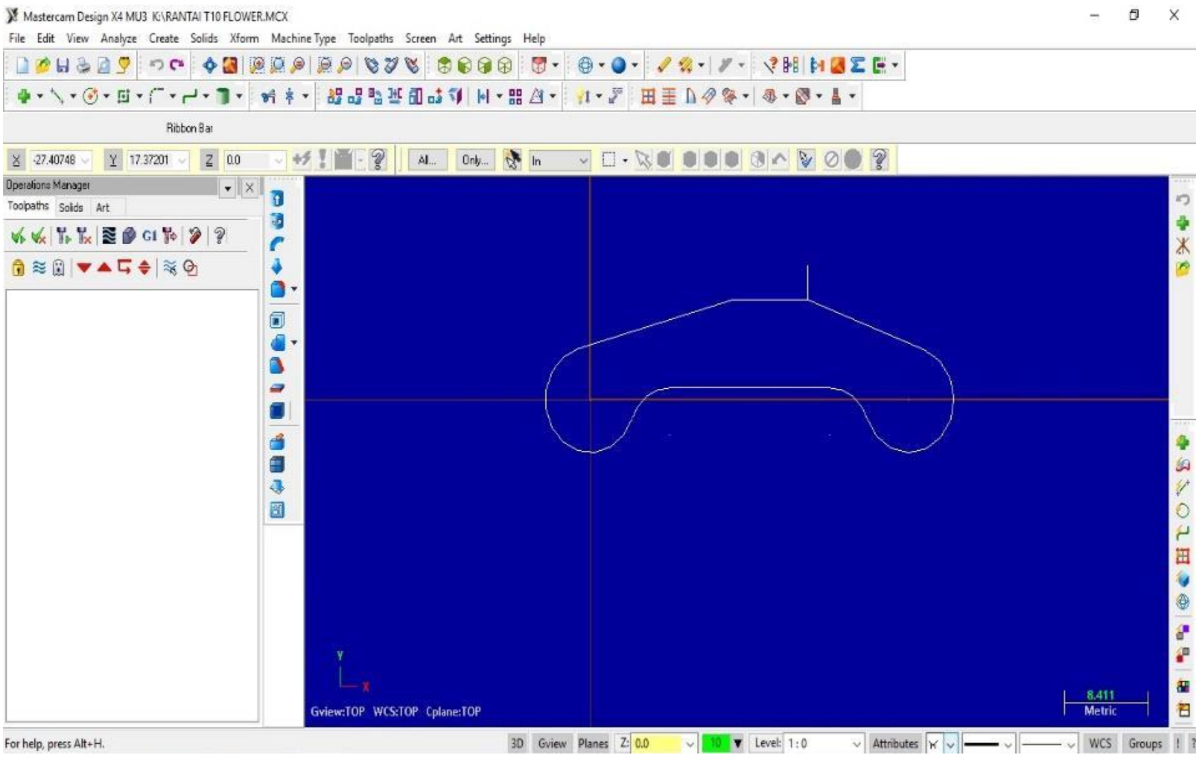


Fig 5. File Export Results to Mastercam X4

After the file is entered into the Mastercam X4 application, the next step is to determine the starting point of the wire path, setting the stock setup material, setting the toolpath, cut parameters. To ensure that the parameter setting results are correct, then the next step is to simulate or run the program that has been made. Fig 6. shows the results of a simulation program for making chain components using the Mastercam X4 application.

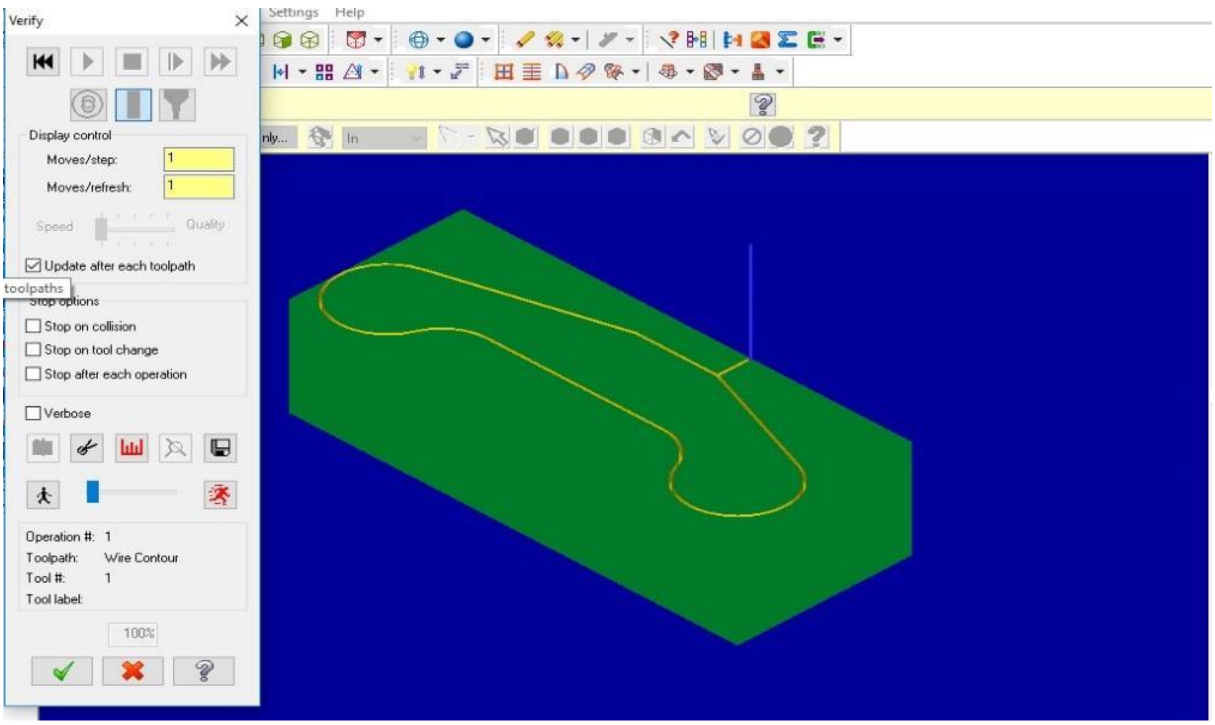


Fig 6. Simulation of the Chain Component Manufacturing Program

Result and Discussion

Running Program Machining Process With Integration CAD/CAM

The results of the simulation program that has been made in the form of NC code will then be transferred to the WEDM machine via flashdisk in preparation for running on the machine. After the program enters the next machine, setting 0 X, Y workpiece, setting the electrode wire to be used on the WEDM machine, simulating the program on the machine monitor screen, entering dielectric water into the machine work area and starting to run the program. Fig 7. Will explain the results of the running program into the WEDM machining process to work on the chain.

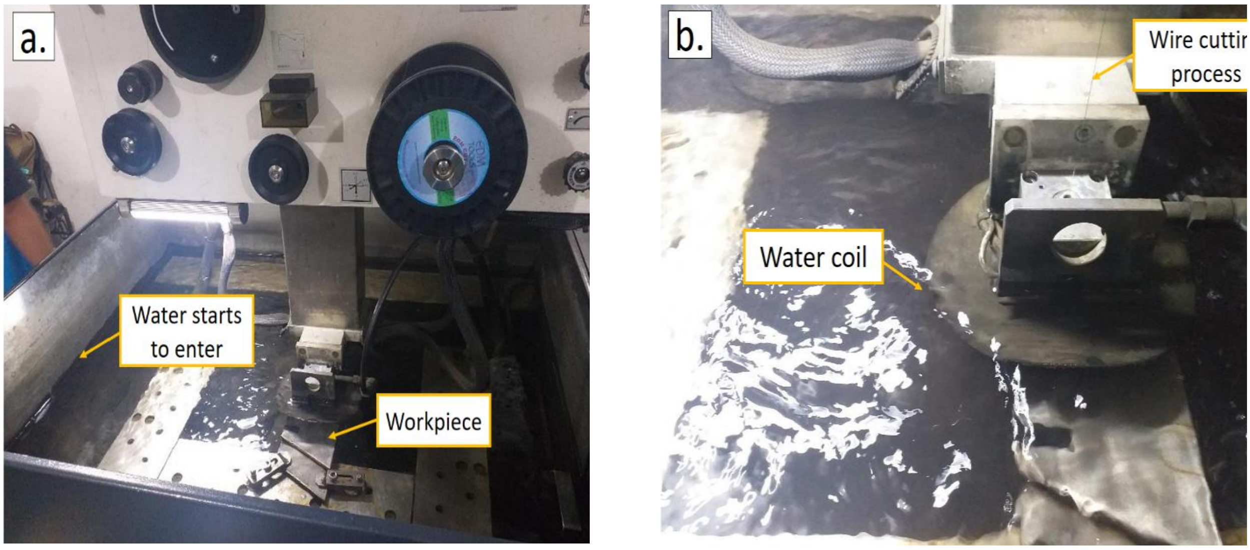


Fig 7. Process of Running Program Matching Process a. Dielectric Fluid Begins to Enter the Work Area, b. Workpiece Cutting Process

Based on Fig 7. It can be explained that the program integration created using software assistance between Autodesk Inventor Profesional 2015 to design chain drawings and Mastercam X4 to simulate programs can work well to create chain components, where the parameters and dimensions designed using the Inventor 2015 application and exported into the Mastercam application match the desired dimensions on the planned worksheet. These results illustrate that the Inventor application can be used as a supporting application for designing images with more complicated shapes such as logos, moldings, and other forms of objects to be worked on using WEDM. Because so far it has been found that designing images through Mastercam X4 is still difficult because the tools for drawing are incomplete compared to the Inventor 2015 application.

The process of scraping the workpiece occurs using a hot electrode wire that moves continuously and penetrates the workpiece. The spark comes from the anode (workpiece) and cathode (wire), between the wire and the object there is deionized water which is known as dielectric water [19].

This deionization process will cause water to become an insulator medium so that the wire will become very conductive. When the system is electrified, the water will be de-ionized, which will then cause electrical sparks to jump between the wire and the workpiece, besides that there will be electrical pulses that repeat thousands of times per second so that they can erode the workpiece. Meanwhile, the dielectric liquid is regulated to have a pressure that functions as a cooling medium for the workpiece and cleans the abrasive results from the electrode wire or workpiece. Related to the working principle of the WEDM machine will be explained below, namely in Fig 8. accompanied by an explanation of the results of the surface morphology.

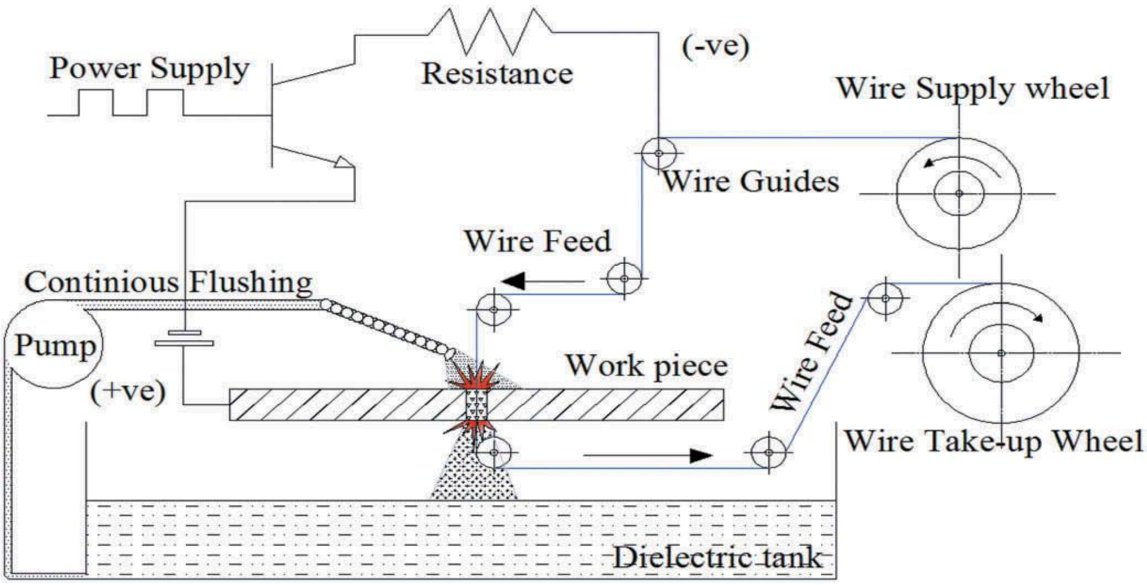


Fig 8. Principle of WEDM Process [20]

In the process the WEDM machine uses several parameters including pulse-on time, pulse off time, peak current, and wire speed, each of these parameters used will be able to influence the results of the workpiece being worked on. One of the parameters used in this study is the current strength. The current strength parameter is one of the parameters used to analyze the WEDM process by varying this value. Current strength is the amount of electrical energy that flows for the process of working on the workpiece at WEDM. The unit for strong current is A (Ampere).

The amount of electric current is regulated by the surface area of the cutting area on the workpiece. Peak current occurs when the pulse is conducted as long as possible and causes the peak current to increase. This increase in electric current will greatly affect the value of the material removal rate and also the surface roughness, so this parameter is very important for analysis in order to get the best parameters.

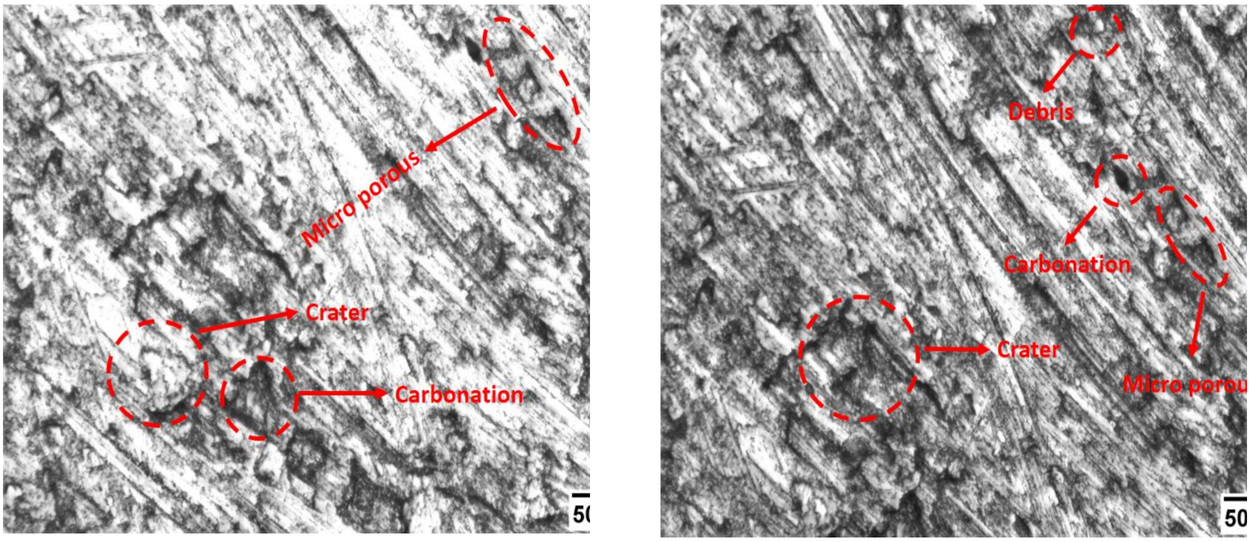
Surface Morphology

The results of the surface morphology in this study were carried out on the results of the chain components from the WEDM machine process using stainless steel material. During the processing process, the workpiece is treated with a variation of the peak current including 8, 10, and 12A. Then the results on the chain component objects will be analyzed for surface morphology using micro-photos Metallurgical Microscope with Inverted (Olympus PME), and macro-photos using a USB digital microscope CMOS.

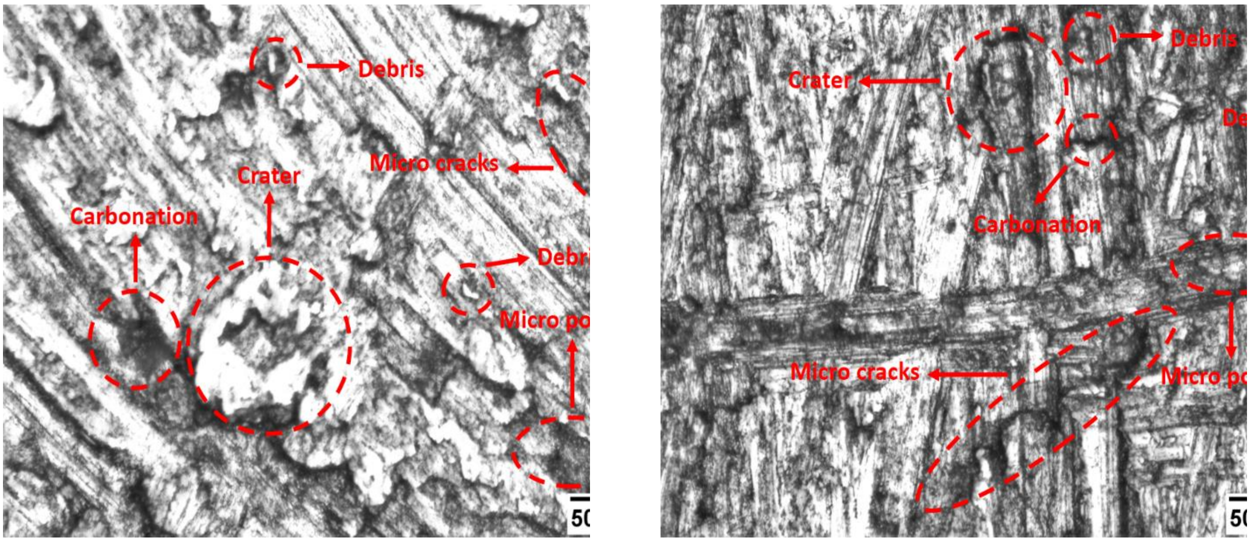
Fig 9. shows the surface morphology of the front view at the micro scale shown through the micro structure. This qualitative test is only applied to the surface resulting from the WEDM process with different current strength variations. Each variation will display only 2 micro-photos from a total of 3 specimens carried out in the WEDM process to further strengthen the results of the analysis of surface morphology.

While Table 4. Shows the morphology of the frontal surface at the macro scale which is displayed through the macro structure photos. This qualitative test is only applied to the surface resulting from the WEDM process with different current strength variations. Each variation will be shown 3 macro photos to determine the color of the morphology.

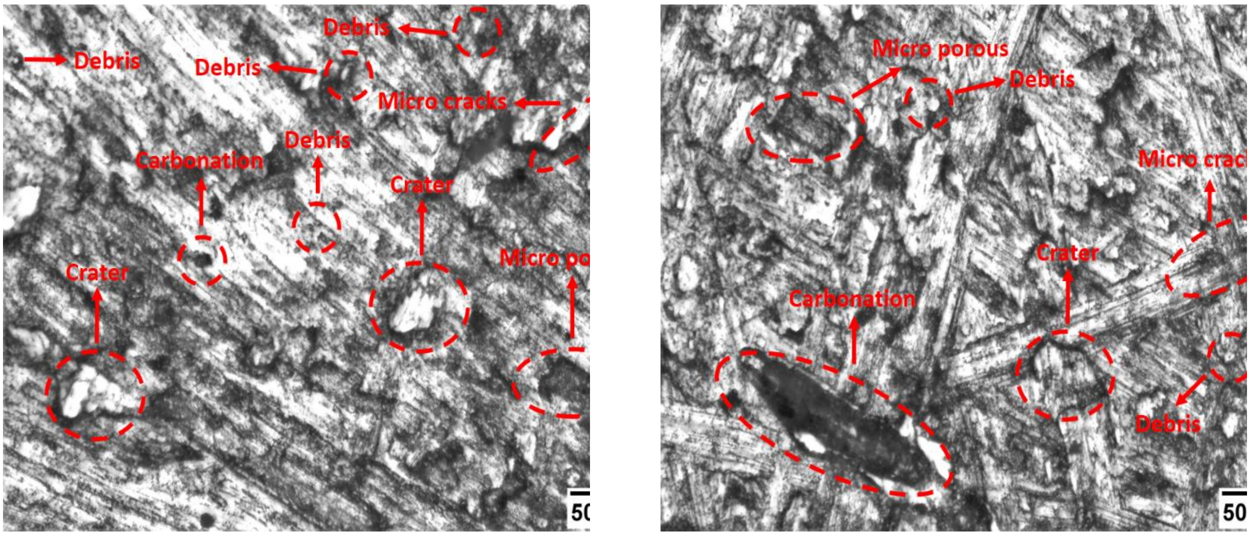
Analysis of Surface Morphology Using Micro-Photos



(a)



(b)



(c)

Fig 9. Surface Morphology of Samples Using Microstructure With Variation of Peak Current (a) 8A, (b) 10A, (c) 12A

Figure 9. (a), (b), and (c) shows the results of micro-photographs at 200x magnification showing layers of carbonization, craters, debris, micro porous, and micro cracks. Carbonization is a process of producing black slag on the surface of the workpiece which is formed from the decomposition of dielectric fluids. The decomposition of the dielectric liquid occurs due to the energy discharge factor when the heat from the spark can break down the dielectric liquid compound which is converted into hydrogen, carbon and then mixed by evaporation from the wire to form a black color due to the high chemical affinity of carbon [21]. Crater is a crater formed from the process of cutting material which is formed when discharge energy produces hot temperatures then melting and evaporation of the workpiece occurs [22]. Debris is a small particle left over from machining which is formed from the decomposition of dielectric fluids and material cutting. This debris increases in the gap of the workpiece being cut when the current strength is higher [23]. Micro porous or cracks are small micro-scale holes formed by irregularly overlapping craters caused by excessive melting of the workpiece due to too high discharge energy [24].

Therefore, based on the picture above, it shows a striking difference with different peak current variations. At high peak currents of 10 and 12A the number of craters produced is larger than the craters at a low peak current of 8A. Besides that, the debris produced on the surface morphology with a higher peak current has a larger size with a greater amount. It can also be observed that there are micro porous and cracks that occur on the surface morphology with increasing peak current used.

These results indicate that an increase in peak current in the WEDM process can also be associated with an increase in surface roughness, this occurs because the higher the current strength used in the WEDM process, the discharge energy generated on the surface of the material will be greater so that the workpiece surface is eroded through the process of cutting the wire is getting bigger and produces a thicker recast layer and will have a higher surface roughness.

These results can also be associated with an increase in peak current in the WEDM process which can also increase the MRR value. This happens because the higher the current strength used in the WEDM process, the greater the discharge energy to produce an electric spark that occurs between the wire gap and the workpiece during the material cutting process, the greater it will be and can trigger a high temperature increase which can increase the ability of the machine to melt. and cut the workpiece faster so that the MRR value can be higher. These results are in accordance with previous research [25]. which stated that the higher the current strength used, the higher the surface roughness followed by an increase in the MRR value of the workpiece results from the WEDM process.

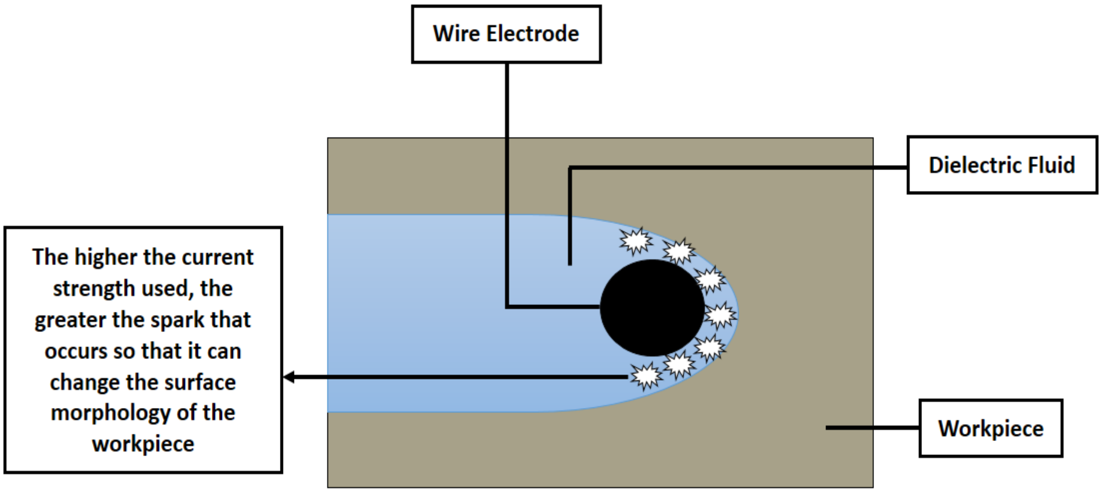


Fig 10. Illustration of Cutting in the WEDM Process

Analysis of Surface Morphology Using Macro-Photos

Table 4. Results of Macro Photographs of the Surface Morphology of the Chain Components

Peak Current	Work 1	Work 2	Work 3
8A			
10A			
12A			

Based on Table 4. Explains that the appearance of a different surface is produced on the chain component material where the higher the current strength used, the more visible the scar is as a result of the greater current strength used to cut the material. Fig 11. Will show the results of the chain components that are worked on.

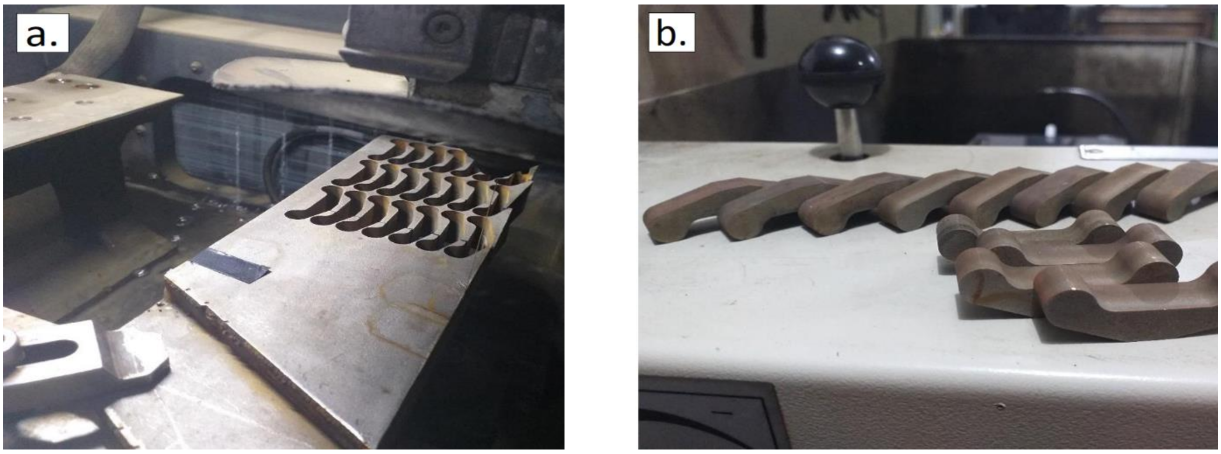


Fig 11. WEDM Process Results a. Cut Workpiece, b. Chain Component Results

Conclusion

In this study, we tried to study the effect of variations in the use of current strength parameters in the WEDM machining process by using integration between CAD/CAM software to create programs for manufacturing chain components. Then in the process of cutting the material will be given a variation of peak current treatment to determine the surface morphology.

It was concluded that in making the WEDM engine program for chain components, software integration between Autodesk Inventor Profesional 2015 was used, then the resulting images were exported to the Mastercam X4 application and could be run on the WEDM engine. In the process of making this program, two software integrations are used to make it easier to draw chain components according to the desired design and dimensions.

Based on the surface morphology images obtained, it shows a striking difference with different peak current variations. At high peak currents of 10 and 12A the number of craters produced is larger than the craters at a low peak current of 8A. Besides that, the debris produced on the surface morphology with a higher peak current has a larger size with a greater amount. It can also be observed that there are micro porous and cracks that occur on the surface morphology with increasing peak current used.

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