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Machine Parameter Optimization for Wire-Electric Discharge Machining

F.R.M. Romlay[1,2] and A. Mokhtar[2]

Summary

This paper presents an optimization of the wire-Electric Discharge Machining (EDM) cutting parameter at welding joint area. The experiment is conducted during a gear shape optimization process by reducing the gear material and weight. Some area of the gear is welded for material joining process. The wire-EDM cutting process is conducted by cutting at the single material and welding area. The parameters of cutting process such as wire speeds, wire tensions and wire voltage are considered to be optimized. The cutting condition at the single and double materials area is compared. The result of the experiment shows that the cutting speed of the wire-EDM is affect by cutting parameters changing.

Introduction

Recently, non-conventional machining is well established used by component manufacturer as a manufacturing method. Non-conventional is not involved with the high force, with out tool ware and the most things for the environment it is a green process. The process is not deal with the metal chip and only water is used as an electrode. Wire electrical discharge machining (wire-EDM), EDM die sinking, water jet cutting and laser cutting are the most regularly used by the manufacturer.

Wire-EDM as a precision cutting technology is possible to fabricate from a small range of product until a large size of component. All type of good conductivity metal such as mild steel and copper are possible to be cut using wire-EDM. However, machine setting varies for each type of metals. So, certain parameters need to be clearly defined for each of materials.

In wire-EDM, to cut two types of material in one time or parallel cutting is a big challenge. Machine setting for both of the materials need to be considered and optimized.

Beside that, the machine setting is also base on the curve or profile to be cut. The setting is easy tuned for a straight line and become more difficult for the curve or part which is involving an angle. Limitation of cutting speed is applied by Sanchez et. al. (2007) in order to minimize the errors at different zones of the corner. Ninety degree angle is the most difficult section to be cut by wire-EDM because of the dramatically direction changing.

Literature Review

Usually, combination more than one material is found in the joint segment for

[1]Corresponding Author. Email: fadhlur@ump.edu.my
[2]Faculty of Mechanical Engineering, Universiti Malaysia Pahang, Malaysia.

example welding process. Two materials are melting together in order to joint the part of the component. Materials combination which is involved with the thermal energy is very strong joining because of the physical changing and chemical reaction between of the materials. The chemical reaction will give the totally new molecule structure which is stronger than the original structure.

Joining material which is called as electrode must be same type with the work piece. However, the material grade of the electrode and mild steel is possible to be different. The welding process will perform a rough surface and sometimes not a high density material content because of the material filling technique. A novel simulation method for wire-EDM in corner cut of rough cutting was introduced by Fuzhu et. el. (2007).

Due to the rough surface, cutting process at the welded area is very tough when involve with the vibration factor. Obara et. al. (1998) and Han et. al. (2005) were conducted a simulation to analyze the vibration problem by predicting the discharge locations.

Using wire-EDM, the cutting for combine materials need a lot of parameter changing compare to the single material cutting process. The parameters that need to be seriously considered are wire tension and wire speed.

Wire tension is important to be adjusting to avoid the wire stress over the limit. Below are the fundamental of stress applied at the wire during the cutting process as shown in Equation (1), (2) and (3).

$$\sigma_x(t) = \sum_{i=1}^{n} \sigma_{xi} F_i(t) \tag{1}$$

$$\sigma_y(t) = \sum_{i=1}^{n} \sigma_{yi} F_i(t) \tag{2}$$

$$\tau_{xy}(t) = \sum_{i=1}^{n} \tau_{xyi} F_i(t) \tag{3}$$

where n is the number of applied load histories and $\sigma_{xi}(t)$, $\sigma_{yi}(t)$, $\tau_{xyi}(t)$ are the stress due to a unit load. The stress is applied at a specific nodal and a same direction with the load history $F_i(t)$. In this condition, the analysis is chosen just for a certain moment from the whole mechanism.

The equation that involve with the wire tension, T is expressed in a steady state condition as stated in Equation (4) and (5) which $x(z)$ and $y(z)$ are the displacement of the wire in the x and y directions.

$$T\frac{\partial^2 x(z)}{\partial z^2} + f_x(z) = 0 \tag{4}$$

$$T\frac{\partial^2 y(z)}{\partial z^2} + f_y(z) = 0 \tag{5}$$

Reaction force of the wire can be modeled in a form of Equation (6) and (7):

$$f_x(z) = W_x H(z-a) - W_x H(z-b) \tag{6}$$

$$f_y(z) = W_y H(z-a) - W_y H(z-b) \tag{7}$$

where a is the distance between the upper side of the work piece and the upper wire guide, b the distance between the lower side of the work piece and the upper wire guide, $H(*)$ the step function, and W_x and W_y are the reaction force of the unit length in the x and y direction, respectively.

Experiment Methodology

The wire-EDM experiment is conducted for gear shape optimization by reducing the material and weight of the gear. The area between the gear teeth and shaft is removed as much as possible. At challenge is come from the welding section as shown in Figure 1.

Figure 1: The welding section on the mild steel gear

Work Piece Geometry

The thickness of the gear as shown in Figure 2 is 10 mm with the pitch diameter, d is 136.5 mm. Number of teeth, N is 39 to have a module, m 3.5 mm. The module, m is calculated base on Equation (8) below:

$$m = d/N \tag{8}$$

The welding section is existed because of the material added process in order to reuse the gear by changing the gear shaft. The joining process comes out with four sections of welding area. This is the tough part of the cutting process by using EDM wire cut.

Figure 2: Side view of the gear component

Machine and Wire Electrode Properties

The wire-EDM machine used in this study was Sodick model AQ535L. The wire electrode was KH Sodick with 0.3mm in diameter which is made from Cu-35wt%Zn.

Result of Wire – EDM Cutting at Single and Joining Point Section Material

The disadvantage of wire-EDM is it a slow cutting process. During the cutting process, the cutting time is very critical to be considered. The cutting parameters were optimized to perform a short period of cutting process. A small changing in cutting parameter can give a big effect to the cutting time. The results of the parameters considered are shown in the Table 1 below:

The cutting process is successful and really followed the shape that was suggests to be removed as shown in Figure 3 and Figure 4. The cutting edge is very smooth even at welding section.

Figure 3: The end shape of the work piece after wire-EDM cutting process

Conclusions

The result of the analysis has shown that the factor of wire speeds, wire tensions and wire voltage will affect the wire-EDM cutting process and cutting time.

Table 1: Differentiates of wire-EDM cutting parameters between a single and welding point cutting process

Parameter	**Single material cutting process**	**Welding point cutting process**	**Different (+/-)**
Wire speeds (mm/s)	100	40	60
Wire Tensions (N)	100	80	20
Wire Voltage (v)	8	8	equal
Speed Feed (mm/s)	30	10	20
Roughing On Time Current (Ampere)	16	14	2
Off Time Current (Ampere)	14	10	4
Finishing On Time Current (Ampere)	10	9	1
Off Time Current (Ampere)	14	12	2

Figure 4: Finish result of the gear shape optimization

The material properties also give a big impact to the cutting process methodology. Double materials content must have a cutting parameter review to optimize the cutting process and cutting time.

Vibration of the wire-EDM process is also affected by work piece surface roughness. Over tension of the wire electrode can made the wire cut and fail.

References

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