Effect of Jet flushing with tilting nozzle in wire electrical discharge machining

A. Okada[1], T. Konishi[1], Y. Okamoto[1], H. Kurihara[2]
[1] *Okayama University, Japan*
[2] *Makino Milling Machine Co., Ltd., Japan*
okada@mech.okayama-u.ac.jp

Keywords: Wire EDM, Jet flushing, Tilting nozzle

Abstract

In order to reduce the debris stagnation in the kerf in wire electrical discharge machining (EDM), a new jet flushing method using tilting nozzle to wire running direction is investigated, based on the simulation results of flow field obtained by computational fluid dynamics (CFD) analysis. As a result, the tilting nozzle could decrease the debris stagnation area, and the removal rate could be improved.

1. Introduction

Since the demand for fine precision machining has recently increased along with the miniaturization of industrial products, the optimization of machining condition and the development of fine wire have been enhanced in wire EDM. Better exclusion of debris from the machined kerf is also important. A lot of debris stagnation in the gap results in secondary discharges and discharge concentrations, which leads to wire breakage, low machining rate and shape accuracy [1].

The debris exclusion from the gap has been conventionally carried out by a jet flushing using upper and lower nozzles. However, the flow fields in the wire EDMed kerf has not yet been made clear sufficiently, and it was reported that the conventional jet flushing method was not always effective, since wide debris stagnation area generates near the wire electrode [2, 3]. In this study, a new jet flushing method using tilting nozzle to wire running direction is proposed, based on the flow fields and debris tracks analyzed by computational fluid dynamics (CFD) simulation. Then, the effectiveness of this flushing method is verified by the wire EDM experiments using the proposed tilting nozzle method.

2. CFD analysis model

Figure 1 shows CFD analysis model for solving the flow fields in wire EDMed kerf using jet flushing nozzle. This three dimensional model is based on an actual wire EDM for steel plate using deionized water under 1st-cut conditions. The model includes the inside regions of upper and lower nozzles. On the upper and lower boundary surfaces, flow inlet circles of 6 mm in diameter were set, in which the flow rate was set to 6.0 L/min. The workpiece thickness is 10mm and the length of machined kerf is 10mm. The nozzle stand-off distance is 0.5mm. The wire electrode diameter is 200μm, the width of kerf is 250μm, and the gap is 25μm.

The simulations are processed by solving the governing differential equations of the flow physics including Navier-Stokes equations by numerical means on a computational cell. The fluid flows and the debris tracks were calculated by a finite volume method as an unsteady turbulent flow with K-ε model [4]. A downward velocity of 10 mm/min was given to the wire circumference surface to realize the actual wire electrode running. A pressure boundary condition was set to a level of 10mm above the upper surface workpiece. No slip conditions were applied to the surfaces of workpiece, nozzle and wire electrode.

3. Results and discussion

Our previous study showed that wide stagnation area always generated near the wire under any flushing conditions in conventional nozzle flushing [2]. In order to reduce the area, a new flushing method with a tilting nozzle was discussed. Figure 2 shows the illustration and the photo of tilting nozzle used in the experiment. The jetting hole tilts forward for the machining direction, and the angle is set to 30 degrees.

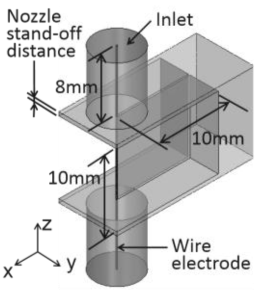


Figure 1: CFD analysis model

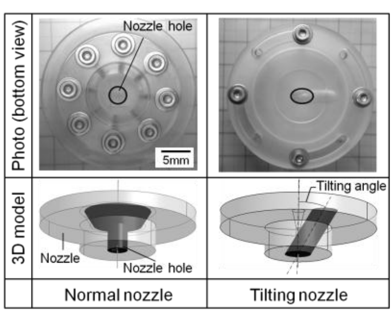


Figure 2: Normal nozzle and tilting nozzle

Figure 3 shows the analyzed flow fileds in the kerf, the debris tracking simulation results, and the photographs of side wall in wire EDMed kerf using the conventional normal nozzle and the tilting ones. For comparison, two flushing methods with the positive and negative tilting angles for machining direction were discussed. When the positive tilting nozzle is used, the stagnation area becomes very small near the middle of front wall in machined kerf. On the other hand, it is wider than that using the normal nozzle and negative tilting one. Also, it is noticed that the debris tracks and distributions agree well with each flow field.

Furthermore, dark marks can be clearly observed on any wire EDMed wall surfaces. It was confirmed with SEM observation that a lot of debris and heat resolved carbon from dielectric kerosene fluid during machining adhered on the surface in the dark coloured areas. This indicates that a flow with dense debris passes through the dark parts and/or much debris stagnates. When the positive tilting nozzle is used, the dark mark is concentrated in a small area at the middle near the wire electrode. Whereas, it becomes wide in the case of the negative tilting nozzle. Furthermore, these dark regions on the wire EDMed surface correspond well to the stagnation area obtained by the CFD analysis. Therefore, the flow fields and the debris tracks analyzed by the CFD analysis can well express an actual debris movement in wire EDM.

The reduction of debris stagnation area by the tilting nozzle flushing would improve the wire EDM characteristics. Figure 4 shows the variations of removal rate with discharge current were investigated using three types of nozzle. The setting discharge current was increased until wire breakage occurred. Wire EDM with higher discharge current is possible when both tilting nozzles are used. In the case of positive tilting

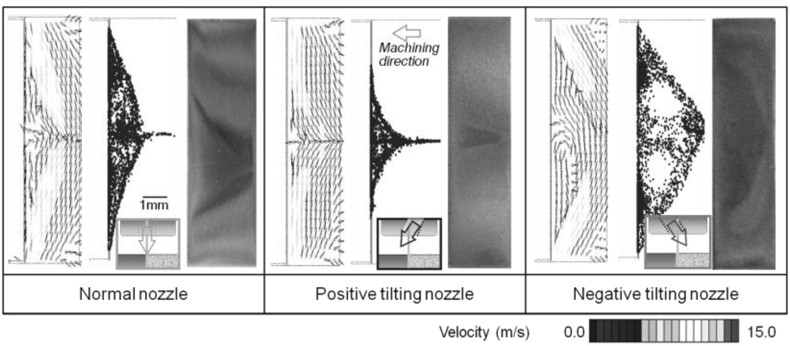
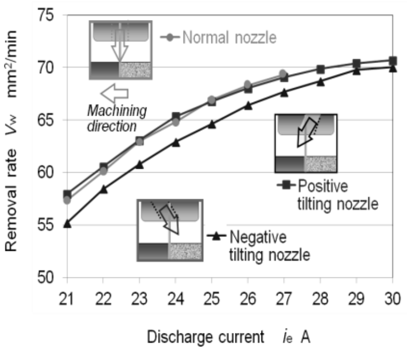


Figure 3: Velocity map and optical images of side wall of wire EDMed kerf

nozzle, the stagnation area is decreased, which leads to more stable machining. As a result, higher discharge current can be applied and the removal rate can be improved. In the case of negative tilting nozzle, it is guessed that the generated debris would be dispensed widely because of wide expansion of vortex flow as shown above. Thus, higher discharge current also can be applied even in the case of negative tilting nozzle.

Figure 5 shows the change in kerf width in the direction of workpiece thickness using three types of nozzle. The average clearance between the electrode of ϕ200μm in diameter and the side wall surface in the case of positive tilting nozzle is the smallest. On the other hand, the clearance is widest in the case of negative tilting nozzle, since the stagnation area is large and includes a lot of debris in the area. In addition, the straightness of the side wall is higher in the case of conventional normal nozzle. It is guessed that the debris density around the wire electrode is large but uniform along to wire direction, as shown above. Therefore, uniformly low debris concentration around the wire electrode is ideal for wire EDM with higher shape accuracy.

discharge current



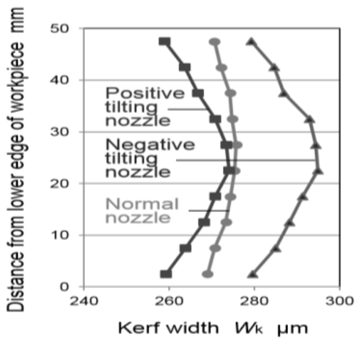


Figure 4: Variations of removal rate with

Figure 5: Side wall shapes of wire EDMed kerf

References:

[1] W. Koenig, et al., Annals of the CIRP, 25(1) (1977) 71–76.
[2] A. Okada et al., Annals of the CIRP 58(1) (2009) 209–212.
[3] T. Fujimoto et al., Key Engineering Materials 516 (2012) 73-78.
[4] D.C. Wilcox; Turbulence Modelling for CFD. 2nd ed. DCW Industries, (2002).