Modelling of Wire EDM Processes

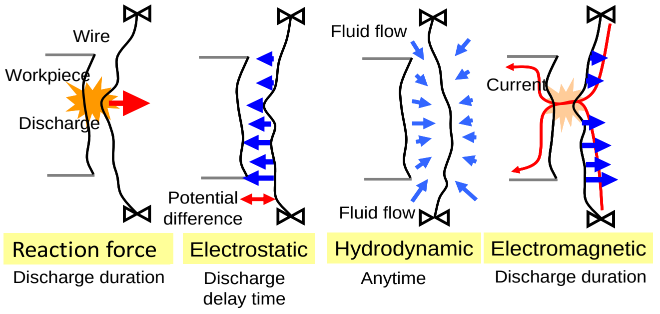


Fig. 44. Forces acting on wire electrode.

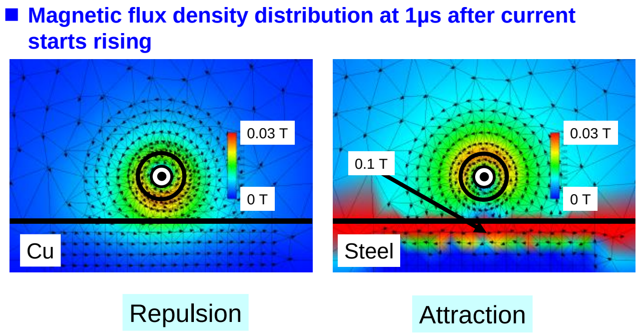
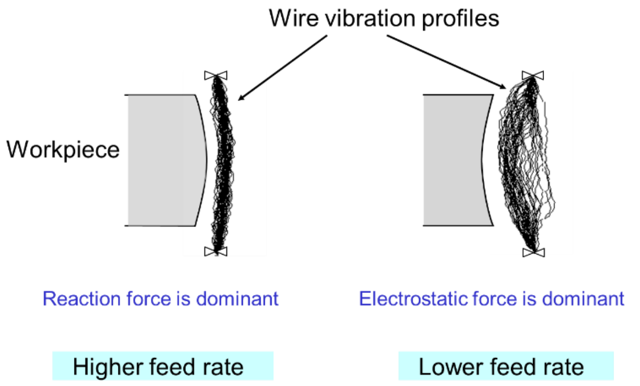


Fig. 45. Simulation of electromagnetic field in wire EDM to obtain electromagnetic force acting on wire [161].



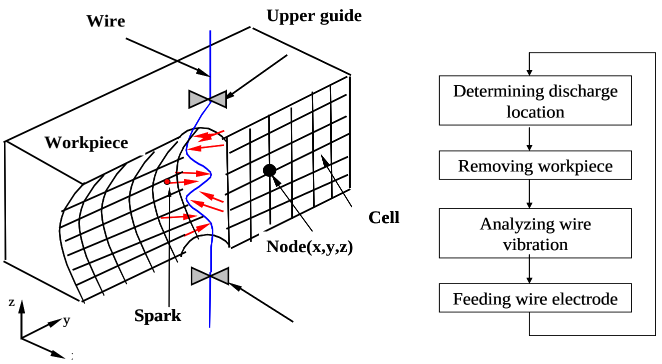


Fig. 46. Geometrical simulation of wire EDM.

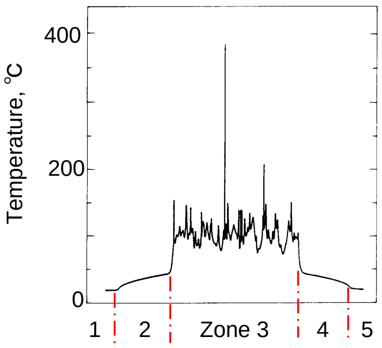


Fig. 47. Simulation of temperature distribution along wire electrode (discharge current: 90A, discharge frequency: 18kHz, wire diameter: 0.25mm, workpiece thickness: 100mm [90].

Forces acting on wire electrode

In WEDM, there are four kinds of forces applied to the wire electrode [1, 2]: discharge reaction force; electrostatic force; hydrodynamic force and electromagnetic force (see Fig. 44). The discharge reaction force is caused by the rapid expansion of a bubble at the discharge spot during the discharge. The electrostatic force acts mostly when open voltage is applied between the wire and workpiece during ignition delay time. The electromagnetic force acts on the wire during the discharge and can be calculated from the area integral of the vector product between the current density and magnetic flux density in the wire. The hydrodynamic force is the drag force generated by the flow of dielectric fluid. These forces cause vibration and deflection of the wire, thereby lowering machining accuracy, speed, and stability [3, 4].

Obara *et al.* [5] and Mohri *et al.* [6] obtained the reaction force from solutions of inverse problems in which wire vibrations calculated using assumed values of the force were compared with measured ones. They used thin workpieces to exclude the influences of electrostatic force and electromagnetic force. Obara *et al.* [7] measured the change in the resultant force involving the reaction force, electromagnetic force, and electrostatic force with various discharge frequencies. They then obtained the electrostatic force by extrapolating the resultant force to the limit of zero discharge frequency, because both the reaction force and electromagnetic force are zero when the discharge frequency is zero. As for the hydrodynamic force, Kuriyama *et al.* [8] conducted a CFD analysis of the force and investigated the influence of the jet flushing conditions on the wire deflection.

Regarding the electromagnetic force, Tomura and Kunieda [9] developed a FE analysis to calculate the electromagnetic field to obtain the electromagnetic forces as shown in Fig. 45. Tomura and Kunieda [10] found that, using a workpiece 40 mm thick, the reaction force is larger than the electrostatic force with large discharge energy, while their magnitudes are reversed with decreased discharge energy. The influence of the electromagnetic force on the wire vibration is not negligibly small under rough cutting conditions, especially with higher discharge frequencies and larger workpiece thicknesses.

Simulation of wire vibration and deflection

Obara et al. [11], Han et al. [12], and Tomura et al. [13] developed programs for WEDM simulation. The simulation shown in Fig. 46 is based on the repetition of the following routine: calculation of wire vibration considering the forces applied to the wire, determination of the discharge location considering the gap width between the wire and workpiece, and removal of workpiece at the discharge location. The electromagnetic force and hydrodynamic force were ignored, and the influence of debris particles was not considered. The geometrical simulation error was less than 1.5μm.

Wire breakage

Fig.47 shows the temperature distribution along the wire electrode obtained from the heat transfer analysis using FDM [14, 15]. Zone 3 indicates the part of the wire electrode where discharge occurs. Zones 2 and 4 show the part from the upper and lower feeding points to the upper and lower surfaces of the workpiece, respectively. Although the average temperature is around the boiling point of water, which is used as the working fluid, the temperature at the point where the preceding discharge occurred is significantly high so that the tensile strength of the wire weakens at this point. Consideration of this led to the development of adaptive control systems in which the pulse energy is reduced or stopped based on the distribution of discharge locations measured in process [16, 17, 18].

Optimization of wire electrode composition

Fine wire electrodes with diameter of 30 micrometre or less are becoming popular. To resist the tension force, high tensile strength materials such as tungsten or molybdenum are used. However, since these materials are rare metals, steel wires coated with brass or zinc are being developed [19]. Another requirement of the wire electrode is low impedance at the frequency components involved in the discharge current waveform. Thus, the electromagnetic field like Fig. 45 was analyzed to investigate the influence of the wire electrode and workpiece materials on the discharge current [20].

References

[1] Dekeyser WL, Snoeys R (1989) Geometrical Accuracy of Wire-EDM. Proc. of ISEM, 9: 226-232.

[2] Panschow R (1974) Über die Kräfte und ihre Wirkungen beim electroerosiven Schneiden mit Drahtelektrode. Dissertation, T. U. Hannover (in German).

[3] Dekeyser WL, Snoeys R (1989) Geometrical Accuracy of Wire-EDM. Proc. of ISEM, 9: 226-232.

[4] Kinoshita N, Fukui M, Kimura Y (1984) Study on Wire-EDM: In process Measurement of Mechanical Behaviour of Electrode-Wire. Annals of the CIRP, 33, 1: 89-92.

[5] Obara H, Makino Y, Ohsumi T (1995) Single Discharging Force and Single Machining Volume of Wire EDM. Proc. of ISEM, 11: 85-93.

[6] Mohri N, Yamada H, Furutani K, Narikiyo T, Magara T (1998) System Identification of Wire Electrical Discharge Machining. Annals of the CIRP, 47, 1: 173-176.

[7] Obara H, Ishizu, Kawai T, Ohsumi T, Hayashi T (2000) Simulation of Wire EDM (3rd report). J. JSEME, 34, 75: 30-37 (in Japanese).

[8] Kuriyama K, Okada A, Okamoto Y (2012) Analysis of Fluid Force Acting on Wire Electrode by Jet Flushing in Wire EDM. Proc. of Annual Meeting of JSEME: 31-34 (in Japanese).

[9] Tomura S, Kunieda M (2009) Analysis of Electromagnetic Force in Wire-EDM. Precision Engineering, 33, 3, 255-262.

[10] Tomura S, Kunieda M (2010) Influences of Electromagnetic Force Acting on Wire Electrode during Wire-EDM. J. JSPE, 76, 1: 106-110 (in Japanese).

[11] Obara H, Ishizu T, Ohsumi T, Iwata Y (1998) Simulation of Wire EDM. Proc. of ISEM, 12: 99-108.

[12] Han F, Kunieda M, Sendai T, Imai Y (2002) High Precision Simulation of WEDM Using Parametric Programming. Annals of the CIRP, 51, 1: 165-168.

[13] Tomura S, Kunieda M, Nakamura K, Ukai Y (2005) Simulation of Wire EDM under Rough Cutting Conditions. 3rd International Conference on Leading Edge Manufacturing in 21st Century: 767-772.

[14] Jennes M, Snoeys R, Dekeyser W (1984) Comparison of Various Approaches to Model the Thermal Load on the EDM-Wire Electrode. Annals of the CIRP, 33, 1: 93-96.

[15] Kunieda M, Takeshita S, Okumiya K (1998) Study on Wire Electrode Temperature in WEDM. Proc. ISEM 12: 119-128.

[16] Lauwers B, Kruth JP, Bleys P, Van Coppenolle B, Stenvens L, Derighetti R (1998) Wire rupture prevention using on-line pulse localisation in WEDM. Proc. of ISEM 12: 203-213.

[17] Obara H, Abe M, Ohsumi T (1999) Control of Wire Breakage During Wire EDM, 1st Report. IJEM, 4: 53-58.

[18] Shoda K, Kaneko Y, Nishimura H, Kunieda M, Fan MX (1992) Adaptive Control of WEDM with On-line Detection of Spark Locations. Proc. of ISEM X: 410-416.

[19] Schacht B (2004) Composite Wire Electrodes and Wire Electrical Discharge Machining. Ph.D. Thesis, K. U. Leuven.

[20] Hada K, Kunieda M (2013) Analysis of Wire Impedance in Wire-EDM Considering Electromagnetic Fields Generated Around Wire Electrode. Proc. of The 17th CIRP Conf. on Electro Physical and Chemical Machining (ISEM): 245-250.