"Finite Element Analysis for Wire Electrical Discharge Machining (WEDM)"

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ABSTRACT

Wire electrical discharge machining (WEDM) is widely used in machining of conductive materials when precision is considered as a prime importance. This work proposes a three dimensional finite element model (using ANSYS software) and new approach to predict the temperature distribution at different pulse time as well as stress distribution in wire. A transient thermal analysis assuming a Gaussian distribution heat source with temperature-dependent material properties has been used to investigate the temperature distribution and stress distribution. Thermal stress developed after the end of the spark and residual stress developed after subsequent cooling. The effect on significant machining parameter pulse-on-time has been investigated and found that the peak temperature sharply increases with the parameter

Keyword : - *WEDM, Residual stress, Thermal stress, Temperature*

1. INTRODUCTION

Wire electrical discharge machining (WEDM) process is a mostly used as a non-conventional material removal process. This is used for manufacturing difficult shapes and profiles of hard materials. This is considered as a distinctive variation of the conventional electrical discharge machining process. In the WEDM, demand is growing for high rate cutting speed and high accuracy machining to improve the productivity of the product and also to achieve high excellence quality in machining job. In wire electrical discharge machining process a travelling wire electrode made of thin copper, brass or tungsten of diameter 0.05–0.3 mm is used, which is precisely controlled by a CNC system. Here role of CNC is very important. The function of CNC is to unwind the wire from a first spool, and feed throughout the work-piece, and taking it on a second spool. Generally wire velocity varies from 0.1 to 10 m/min, and feed rate is 2 to 6 mm/min. A direct current is used to generate high frequency pulse to the wire and the workpiece. The wire (electrode) is hold in tensioning device for decreasing the chance of producing inaccurate parts. In wire electrical machining process, the workpiece and tool is eroded and there is no direct contact between the workpiece and the electrode, and this reduces the stress during machining.

WEDM was initially developed by manufacturing industry in the 1960s. The development technique is replaced the machined electrode used in electrical discharge machining. In 1974, D.H. Dulebohn introduced the optical line follower system which automatic controls the shapes of the part to be machined by the wire electrical discharge machining process. In 1975, it was popular rapidly, and its capability was better understood by manufacturing industry. When the computer numerical control system was introduced in WEDM process this brought about a most important development of the machining process.

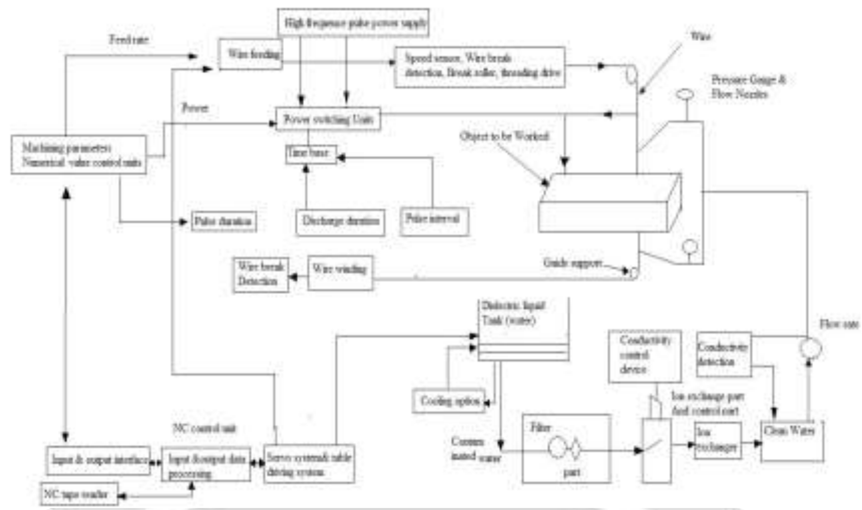

Fig. 1: Schematic diagram of WEDM (Source: Datta and Mahapatra, [1])

1.1 Wire-EDM process

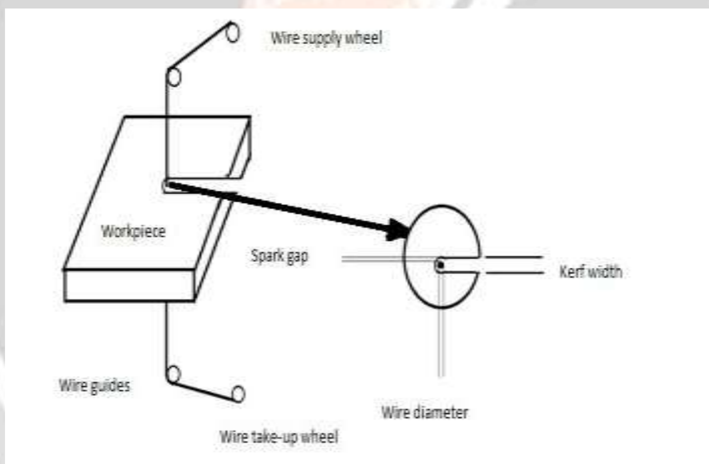

Fig.2. WEDM process (Source: Datta and Mahapatra, [1])

The method of material removal in wire electrical machining is as like to the conventional electrical discharge machining process concerning the erosion effect on workpiece by the spark. In wire electrical discharge machining, material is eroded from the workpiece by a cycle of spark occur between workpiece and wire which is separate by dielectric liquid, which is continuously fed to the machining zone. But now-a-days, wire electrical discharge machining process is commonly conducted in fully submerge container fill with dielectric liquid. This type of submerge method of wire electrical discharge machining promotes temperature stabilization and efficient flushing in case where the workpiece has variation in thickness. The wire electrical discharge machining process generally use of electrical energy generate the plasma channel between the cathode and anode and create thermal energy at a temperature in the range between $8,000^0$C to $12,000^0$C or as higher as $20,000^0$C and create considerable amount of heat and melting of the materials on the surfaces of each pole. When the pulsating direct current power supplying occurs between 20,000 and 30,000 Hz is turned off, the plasma channel breaks down. This causes sudden decrease in the temperature, allow circulate dielectric liquid to implore the plasma channel and flushing the molten particle from the each pole surface in the form of microscopic debris. The WEDM machining process is as shown in Fig. 2.

2. WEDM applications in industry

- Dies and punches for Electronic and hierological components.
- Micro surgical tools and biomedical devices.
- Precision flexures for micro positioning systems.
- Miniature spool valves.
- Thin walled structural parts for aerospace industries.
- Precision form gauges for different profiles
- WEDM developments

3.Literature Review

Kunieda and Furudate [1] defined the development of a new dry wire electrical discharge machining method. They were conducted an experiment without using dielectric liquid, instead of dielectric liquid they used only gas atmosphere. For improving the accuracy of finish cutting, the vibration of the wire electrode is required to be minimizing with the negligibly small process reaction force. High accuracy and finish cutting may be recognized in dry-wire electrical discharge machining. But, some disadvantages of dry wire electrical discharge machining like lower material removal rate comparison to conventional wire electrical discharge machining and lines are more likely to be generated over the finish surface.

Okada et al. [2] introduced a fine wire electrical discharge machining using thin wire electrode. In wire electrical discharge machining process, uniform distribution of spark location is essential to achieved for stable machining performance. But, it is difficult to precisely evaluate the distribution of spark location by the conventional branched electric current method when workpiece is considered as thin. Hence, they proposed a new method to analyze the distribution of spark location using a high-speed video camera. From this camera, locations of sparks are identified and analyzed through the recorded images. The machining parameters such as servo voltage, pulse interval time and wire running speed are significantly effects on the distribution of spark location.

Cabanesa et al. [3] introduced a methodology which facilitated to avoid wire breakage and unstable situations as both phenomena reduce process performance and can cause low quality components in wire electrical discharge machining. The proposed methodology establishes the procedures to follow in order to understand the causes of wire breakage and instability. In order to quantify the trend to instability of a given machining situation, a set of indicators in relation to discharge energy, ignition delay time, and peak current has been defined. Wire breakage risk associated to each situation was evaluated comparing the evolution of those indicators with some previously defined threshold values. The result obtained will be used to develop a real-time control strategy for increasing the performance of the WEDM process.

Saha et al. [4] developed a simple FE model and a new method to predict the thermal distribution in the wire equally and precisely. The model can be used to optimize the different parameters of the system to avoid wire breakage. At any instantaneous of time, the spatial heat distribution profile of the wire can be mapped on the transient analysis of any point on the wire traversing through all the heat zones from the top spool to the bottom end. Based on this principle, the finite element model and optimization algorithm were used to determine the heat generated that mainly responsible for wire breakage. The model successfully predicted the thermal distribution profile accurately for various wire materials, for increased wire velocity and for reduction in heat transfer coefficient. This simple model was a precursor of development for 3-D finite element models which can be described the cross-sectional wire erosion as the workpiece cutting progresses. The modeling may lead to the development of a smart electro-discharge machining system with a sensor and feedback control to increase the cutting speed and minimize breakage.

Hou et al. [5] developed the double layer structure model that analyzed the effect of temperature field and thermal stress on material removal of insulating ceramics Si_3N_4 during the wire electrical discharge machining (WEDM) process. The distributions of temperature filed in conductive layer and Si_3N_4 and double layer structure model during single electrical discharge were compared. And the influences of peak current, pulse duration and the movement speed of wire electrode to discharge craters were researched. The simulation shows that the conductive layer on insulating ceramics makes a larger effect on thermal transmission in the radius direction of discharge crater when discharge occurs. The simulation for temperature field tells that, with the boiling removal form hypothesis, the material removal volume during single discharge is increasing with the increment of peak current and pulse duration but decreasing with the raising of wire electrode movement speed

Hada and Kunieda [6] investigated the optimum machining conditions in wire electrical discharge machining (wire-EDM). Discharge current was influenced by the impedances of the wire and workpiece electrodes which may vary depending on the diameter of the wire, height of the workpiece and materials of wire and workpiece even if the pulse conditions are the same. Hence, they developed a simulator to analyze the distribution of the current density, and magnetic flux density in and around the wire to obtain the impedances of the wire and workpiece electrodes using the electromagnetic field analysis by finite element method (FEM). The impedances measured using an LCR meter coincided with the analysis results. Thus it was confirmed that this analysis is useful to obtain the discharge current waveform which may change depending on the dimensions and material properties of the electrodes, serving a tool to optimize the machining conditions.
Cabanes et al. [7] discusses the results of the analyses of an exhaustive experimental database that reproduces unexpected disturbances that may appear during normal operation. The results of the analyses reveal new symptoms that allow one to predict wire breakage. These symptoms are especially related to the occurrence of an increase in discharge energy, peak current, as well as increases and/or decreases in ignition delay time. The differences observed in the symptoms related to workpiece thickness are also studied. Another contribution of this paper is the analyses of the distribution of the anticipation time for different validation tests. Based on the results of the analyses, this paper contributes to improve the process performance through a novel wire breakage monitoring and diagnosing system. It consists of two well differentiated parts: the virtual instrumentation system (VIS) that measures relevant magnitudes, and the diagnostic system (DS) that detects low quality cutting regimes and predicts wire breakage. It has been successfully validated through a considerable number of experimental tests performed on an industrial WEDM machine for different workpiece thickness. The efficiency of the supervision system has been quantified through an efficiency rate.

Cheng et al. [8] determined a method of the convective heat transfer coefficient in wire electro-discharge machining (WEDM) is introduced. A special device is developed to measure the average temperature increment of the wire after a period of short circuit discharges, and the thermal load imposed on the wire is also tracked and recorded in advance. Then, based on the thermal model of the wire, the convective coefficient can be calculated accurately. Some tuning experiments are carried out inside and outside a previously cut profile to examine the influence of the kerf on the convective coefficient. As soon as the wire cuts into the workpiece, the convective coefficient will decrease more than 30%. With this method, the effect of the coolant flushing pressure on the convective coefficient is also estimated. If the pressure is raised from 0.1 to 0.8 Mpa, the convective coefficient will increase more than 20%, and thus ameliorate the cooling condition of the WEDM process

Yan and Lai [9] presented the development and application of a new fine-finish power supply in wire-EDM. The transistor-controlled power supply composed of a full-bridge circuit, two snubber circuits and a pulse control circuit was designed to provide the functions of anti-electrolysis, high frequency and very-low-energy pulse control. Test results indicated that the pulse duration of discharge current can be shortened through the adjustment of capacitance in parallel with the sparking gap. High value of capacitance contributes to longer discharge duration. A high current-limiting resistance results in the decrease of discharge current. Peak current increases with the increase of pulse on-time and thus contributes to an increase in thickness of recast layer. Experimental results not only verify the usefulness of the developed fine-finish power supply in eliminating titanium's bluing and rusting effect and reducing micro-cracking in tungsten carbide caused by electrolysis and oxidation, but also demonstrate that the developed system can achieve a fine surface finish as low as 0.22 µm Ra.

4. Conclusion

- WEDM is used for manufacturing difficult shapes and profiles of hard materials. This is considered as a distinctive variation of the conventional electrical discharge machining process. In the WEDM, demand is growing for high rate cutting speed and high accuracy machining to improve the productivity of the product and also to achieve high excellence quality in machining job
- Different researcher work on different parameter to increase the efficiency and various mechanical parameters apart from this by controlling the spark time of the wire we can maintain the wire temperature so that wire will not break.

4.REFERENCES

[1] Kunieda, K. and Furudate, C. (2001) High Precision Finish Cutting by Dry WEDM, *Journal of Materials Processing Technology*, vol. 149 pp. 77–82

[2] Okada, O., Uno, Y., Nakazawa, M. and Yamauchi, T. (2010) Evaluations of spark distribution and wire vibration in wire EDM by high-speed. *Manufacturing Technology*, vol.59, pp. 231–234

[3] Cabanesa, I., Portilloa, E., Marcosa, M. and Sa´nchezb, J.A. (2 0 0 8) An industrial application for on-line detection of instability and wire breakage in wire EDM, *journal of materials processing technology*, vol. 1 9 5, pp. 101–109

[4]Saha, S., Pachon, M., Ghoshal, A.and Schulz d, M.J. (2004) Finite element modeling and optimization to prevent wire breakage in electro-discharge machining Mechanics, *Research Communications*, vol. 31,pp. 451–463

[5]Hou, P.J., Guo, Y.F., Sun, L.X. and Deng G.Q. (2013) Simulation of temperature and thermal stress filed during reciprocating traveling WEDM of insulating ceramics, *Procedia CIRP* vol. 6 PP. 410 – 415

[6]Hada, K. and Kunieda, M. (2013) Analysis of wire impedance in wire-EDM considering Electromagnetic fields generated around wire electrode, *Procedia CIRP* vol.6 245 – 250

[7]Cabanesa, I., Portilloa, E., Marcosa, M. and Sa´nchezb, J.A. (2 0 0 8) On-line prevention of wire breakage in wire electro-discharge machining, *Robotics and Computer-Integrated Manufacturing*, vol. 24, pp. 287-289.

[8]Cheng, G., Zhijing, H.and Feng (2007) Experimental determination of convective heat transfer coefficient in WEDM, *International Journal of Machine Tools & Manufacture*, vol. 47,pp. 1744–1751

[9]Yan, M.T. and Lai, Y.P. (2007) Surface quality improvement of wire-EDM using a fine-finish power supply, *International Journal of Machine Tools & Manufacture*, vol.47, pp. 1686–1694