A review of flushing techniques used in electrical discharge machining

M.M.Makenzi and B.W.Ikua

Abstract—Flushing is a very important function in any electrical discharge machining (EDM) operation. It not only serves to remove the eroded debris from the spark-gap region but also has various other functions which highly influence the outcome of this machining process. Although the influence of flushing as a wholesome requirement on the efficiency and stability of machining conditions in EDM has been extensively investigated, little has been reported concerning the effects of the various individual flushing techniques that are available in the industry. An examination of the influence of flushing pressure and a review of the various flushing approaches utilized is presented in this paper.

Keywords—Flushing, Material Removal Rate, Surface Roughness, Wear ratio

I. INTRODUCTION

MATERIAL removal in electrical discharge machining (EDM) is achieved through preferential erosion of the workpiece as controlled discrete discharges are passed between the tool and the workpiece in a dielectric medium. Flushing is the process of removing debris from the spark gap. It is a very important function in any EDM operation. Schumacher [1] reported that too much debris in the discharge gap often causes a continuous arc and/or short circuit and makes the process unstable. Two key aspects of all flushing techniques are the dielectric fluid and the flushing configuration. In EDM flushing, the dielectric fluid is distributed through the spark gap to remove gaseous and solid debris generated during the machining operation and to maintain the dielectric temperature well below its flash point. The dielectric fluid serves a vital role in flushing [2]. Its other functions include:

(a) It helps in initiating discharge by serving as a conducting medium when ionised, and conveys the spark. It concentrates the energy to a very narrow region.
(b) It helps in quenching the spark, cooling the work, tool electrode and enables arcing to be prevented.
(c) It carries away the eroded metal along with it.

The dielectric fluid should posses certain characteristics which include: high dielectric strength and quick recovery after breakdown, effective quenching and flushing ability. Tool wear (TW) and material removal rate (MRR) are affected by the type of dielectric fluid used for flushing [3]. Commonly used dielectric media are hydrocarbon compounds and water. The hydrocarbon compounds are in the form of refined oil. Water is used for wire-EDM and high-definition die-sinking EDM where its low-viscosity and carbon-free characteristics are an advantage. There has also been much research on water-based solution as a dielectric in EDM [4]. Improper flushing can result in uneven and significant tool wear [5], [6]. It also affects accuracy and surface finish. Furthermore, it can also reduce removal rates due to unstable machining conditions and arcing around regions with high concentration of debris [7]. Various flushing configurations exist which present different flushing pressures, volume flow rate and flow direction of the dielectric.

Makenzi M.M, Department of Mechatronic Engineering, JKUAT (phone: +254721925032; e-mail: mmackenzi@jkuat.ac.ke).
Ikua B.W, Department of Mechatronic Engineering, JKUAT (e-mail: ikuabw@eng.jkuat.ac.ke).

II. TYPES OF FLUSHING TECHNIQUES

A. *Pressure flushing*

This is the most common and preferred method of flushing. It is also referred to as injection flushing. It can be performed through the tool or through the workpiece. The former is shown Fig.1.

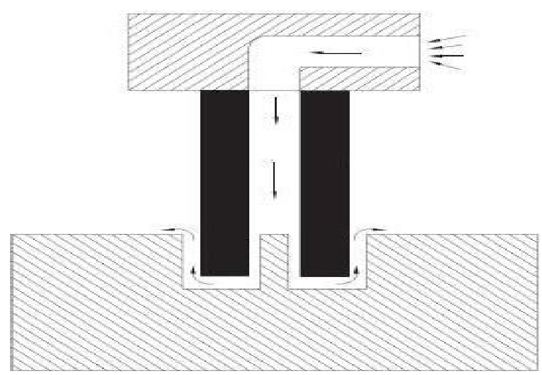

Fig. 1. Pressure flushing through the electrode

Fig.2 shows pressure flushing done by forcing the dielectric fluid through the workpiece mounted over a flushing pot. The advantage of this method is that it eliminates the need for holes in the electrode

Flow conditions must be properly regulated in these two methods of flushing; otherwise machining conditions may be unstable with reduced removal rate and uneven tool wear. The flow velocity can be monitored by measuring the differential pressure or volume throughput. Improper settings of control factors in EDM injection flushing method may result in poor process performance, increased in-process variability and decrease in the manufacturability of products and processes. Another advantage of this method of flushing is that the high flushing pressure through the centre of the electrode tends to

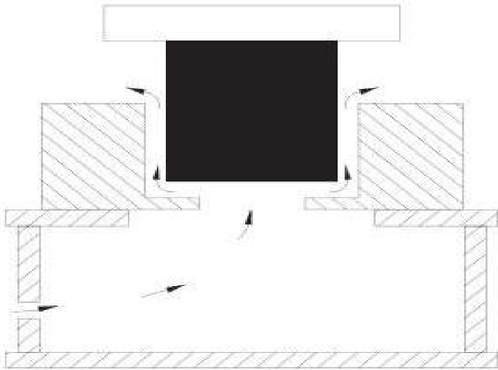

Fig. 2. Pressure flushing through the workpiece

stiffen it. Also, the dielectric being forced out of the hole produces a centering effect upon the electrode. With the aid of an electrode guide and the flushing effects on the electrode, EDM drilling can penetrate much deeper than almost any other drilling methods. The high flushing pressure helps keep the workpiece and electrode cool. This helps keep the heat-affected zone, or depth of recast level, at a manageable level [8].

The disadvantage of pressure flushing is that there is danger of a secondary discharge machining. Secondary discharge machining occurs as the eroded particles pass between the walls of the electrode and the workpiece. Fig.(3) shows the effect of secondary discharge on the workpiece.

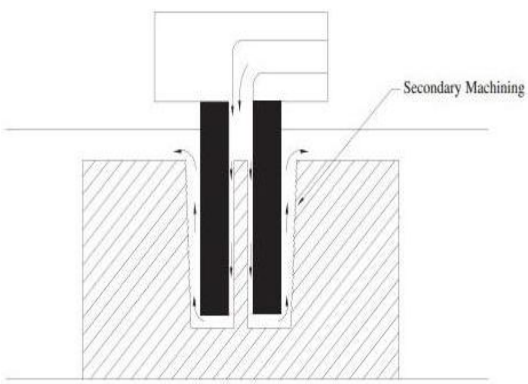

Fig. 3. Effect of secondary discharge machining

B. *Jet flushing*

Jet flushing is the simplest and oldest flush-method for EDM. A dielectric fluid jet is ejected from a nozzle (or several nozzles) towards the machining area. The pressure of the jet creates flow in the discharge gap and the debris is carried by the flow out of the gap. Jet flushing, in which a continuous jet of dielectric is directed at the gap, is used in wire-EDM or machining of narrow slots and cavities.

For jet flushing of an array of shallow cavities, important considerations are distribution of the nozzles, flow rates, angles at which the nozzles are directed at the gap, and layout of the cavities [17]. For shallow cuts or perforation of thin sections, simple immersion of tool and workpiece in a tank of circulating dielectric may be adequate. This method illustrated in Fig.4 is very widely used in factories because of its simplicity and good debris removal capability.

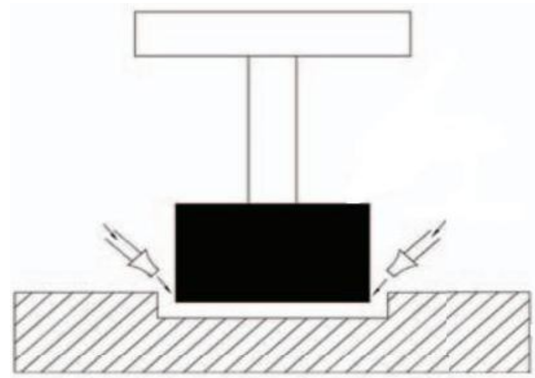

Fig. 4. Effect of secondary discharge machining

However, it is not easy to determine the most appropriate position of the nozzle(s).This position is usually decided by the operators based on experience, often without confidence. Another disadvantage of this method is that it does not ensure debris uniformity because the flow in the gap is almost fixed since the nozzle is fixed at a certain position [1]. This fixed flow causes a concentration change dependent on the flow field. Regardless of the above problems, the simplicity of this method is attractive, and if the position of the nozzle is adjustable and can be controlled during machining, a new direction in the progress of flushing may be opened up.

C. *Suction flushing*

Suction flushing, also known as vacuum flushing, has the capability of removing the eroded gap particles. It can be done through the electrode or through the workpiece. Fig.5 shows suction flushing through the electrode.

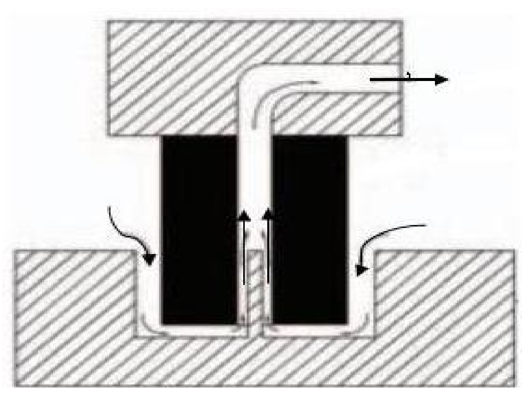

Fig. 5. Suction flushing

Suction flushing minimizes secondary discharge as well as tapering. The suction flushing pulls in dielectric from the work basin, not from the clean filtered reservoir as in pressure flushing. As such, efficient cutting is accomplished when the dielectric fluid in the work basin is clean. The disadvantage of this method is that there is no visible fluid stream and gauge readings are not always reliable regarding the actual flushing pressure. Another disadvantage is the danger that arises due to insufficient removal of gases. This can cause the electrode to explode. Also, the created vacuum can be so great that the electrode can be pulled from its mount , or the workpiece pulled from the chuck

D. *Other flushing techniques*

Other means of improving flushing conditions involve some form of relative motion between tool and workpiece [9]. A control feature that is available on many machines to facilitate chip removal is vibration or cyclic reciprocation of the servo-controlled tool electrode to create a hydraulic pumping action, perhaps with synchronized pulse flushing during the lifting of the electrode.

Orbiting of the tool or workpiece has also been found to assist flushing and improve machining conditions. The rotational movement of electrode is normal to the work surface and with increasing the speed, a centrifugal force is generated causes more debris to remove faster from the machining zone. According to Mohan [10], the centrifugal force generated throws a layer of dielectric in to the machining gap, induces an atmosphere for better surface finish, prevent arching and improves MRR. Soni and Chakraverti citesoni compared the various performance measures of rotating electrode with the stationary electrode. The results concluded an improvement in MRR due to the better flushing action and sparking efficiency with little tool wear but the surface finish was improved.

III. INFLUENCE OF FLUID FLUSHING PRESSURE ON PERFORMANCE PARAMETERS

A. *Influence on MRR*

Efficient flushing requires a balance between pressure and volume. For roughing operations, where there is a much larger gap, high volume and low pressure flushing is advised. For finishing operations where there is a small arc gap, higher pressure to ensure proper dielectric flow is required. Lee [11] investigated the effects of flushing pressure on the material removal rate, relative wear ratio and surface finish of the workpiece produced .The material removal rate does not change significantly with change in flushing pressure , even though there's gradual decrease in trend as shown in Fig. 6.

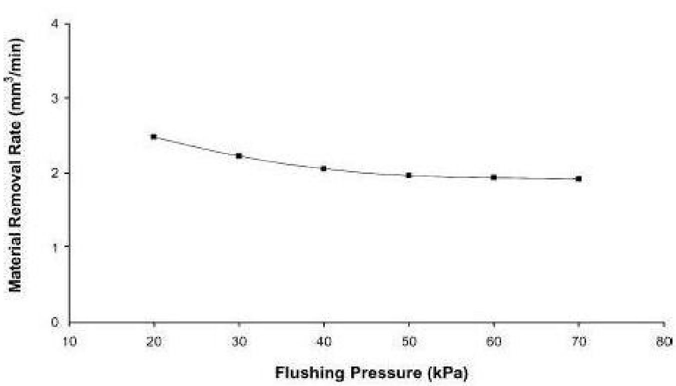

Fig. 6. Effect of flushing pressure on material removal rate [11]

Flushing is not a problem in roughing operations because there is a sufficient gap for the dielectric to flow. Flushing difficulties arise during finishing operations due to the smaller gap that inhibits proper dielectric flow. High flushing pressure can cause excessive electrode wear by making the eroded particles bounce around in the cavity.

B. *Influence on TWR*

The relative wear ratio first decreases and then increases again on further increase in the flushing pressure. This is shown in Fig.7. An optimal flushing pressure was found to be at about 50 Kpa after investigation with a peak current of 24A, a gap voltage of 120 V and using copper tungsten as the tool electrode material with a negative polarity.

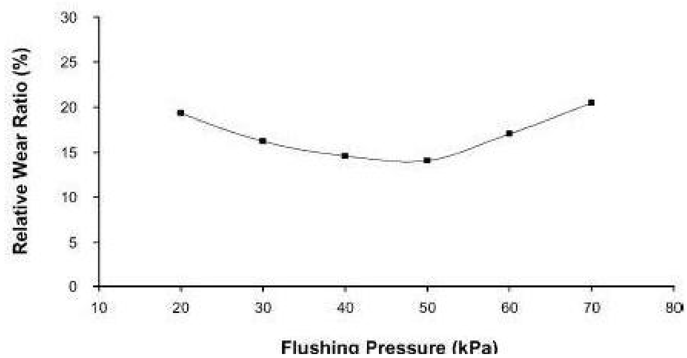

Fig. 7. Effect of flushing pressure on relative wear ratio [11]

C. *Influence on SR*

As shown in Fig.8, there is little variation in the surface roughness with flushing pressure.

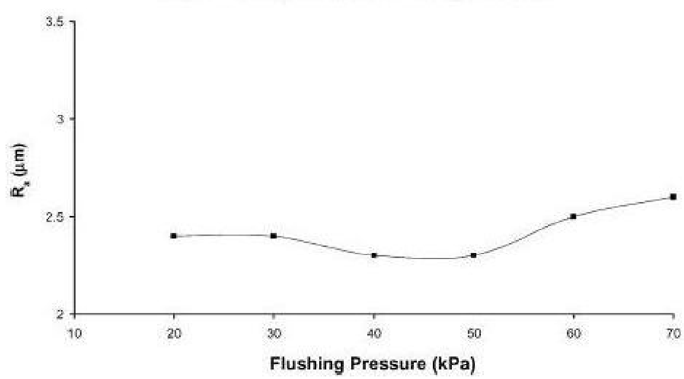

Fig. 8. Effect of flushing pressure on material removal rate [11]

Thus, when the flushing pressure is too low, the flushing cannot remove the gaseous and solid debris after each discharge. However, if the pressure is too high, no proper machining can be done as the ionized channel is continuously washed away and the relative wear ratio is increased. The material removal rate is slightly decreased with higher flushing pressure. Excessive pressure can also accelerate electrode wear and create turbulence in the cavity.

IV. Conclusion

The right selection of a flushing technique is necessary to ensure optimal performance parameteres in electrical discharge machining. A balance between dielectric flushing pressure and volume and the selection of the right dielectric media is very important. Generally, the material removal rate decreases gradually with the flushing pressure, and becomes constant at high values of flushing pressure. The relative wear ratio decreases with the flushing pressure at low flushing pressure and increases with the flushing pressure at high flushing pressure. There is an optimal flushing pressure for the relative wear ratio, which gives the minimum relative wear ratio. There is also an optimal flushing pressure for the machined workpiece surface roughness.

Research on an innovative flushing technique that utilizes magnetic energy to optimize EDM performance parameters in the finishing regime, is currently being undertaken by the authors.

References

[1] S. B.M, "About the role of debris in the gap during electrical discharge machining," *Annals of the CIRP*, vol. 39, pp. 197–199, 1990.

[2] B. S.C, *Principles of engineering manufacture*. Butterworth Heinemann, 1996.

[3] W. Y.S and L. L.C, "Effect of flushing on electro-discharge machined surfaces," *Journal of Materials Processing Technology*, vol. 48, pp. 299–305, 1995.

[4] L. Godinho and C. Noble, "The use of water as inter-electrode medium in pulsed edm," *Proceedings of the Fifth International Symposium for Electromachining (ISEM 6), Wolfsberg, Switzerland.*, pp. 63–67, 1977.

[5] H. D. Bruyn, "Some aspects of the influence of gap flushing on the accuracy in finishing by spark erosion," *Annals of the CIRP*, vol. 16, pp. 147–157, 1970.

[6] R. W. L.W. Koenig, R. Weill and W. Jutzler, "The flow fields in the working gap with electro-discharge machining," *Annals of the CIRP*, vol. 1, pp. 71–76, 1997.

[7] P. Wells and P. WiUey, "The effects of variation in dielectric flow rate in the gap on wear ratio and surface finish during electro-discharges," *Proceedings of IEE Conference UK*, vol. 133, pp. 110–117, 1975.

[8] S. Thao, O.; Joshi, "Analysis of heat affected zone in the micro-electro discharge machining," *International Journal of Manufacturing Technology and Management*, vol. 13, pp. 201–213, 2008.

[9] A.Astrop, *Robot-Served EDM Manufacturing Cell, Machinery and Production Engineering*. 1982.

[10] R. A. Mohan B. and S. K., "Electric discharge machining of alsic metal matrix composites using rotary tube electrode," *Journal of Materials Processing Technology, 153154, pp.978985*, vol. 153-154, pp. 978–985, 2004.

[11] S. Lee and X. Li, "Study of the effect of machining characteristics in electrical discharge machining of tungsten carbide," *Journal of Materials processing Technology*, vol. 115, pp. 344–358, 2001.