THE ROLE OF ELECTROLYTE FLOW VELOCITY IN EEDM

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ABSTRACT

This paper presents experimental investigations for the electroerosion dissolution machining (EEDM) under conditions of variable electrolyte flow velocity and machining rate. Effects of electrolyte velocity on the material removal process, machining stability, accuracy, surface roughness and productivity are evaluated. The role of electrolyte contamination level and gas generation process on the machining performance are also explained.

Keywords: Electrolyte velocity, Shorting limit, Process stability, Accuracy, Surface finish, Energy efficiency and, maximum cutting rate.

INTRODUCTION

The need for efficient and highly accurate machining process, for the new materials, is as important as the development of the material itself, if a practical application is ever to be found. Electroerosion dissolution machining, EEDM, is one of these processes that showed many advantages with respect to the machining rate, accuracy and surface quality [1]. The process has found wide range of applications in the field if hole drilling, wire cutting and cusp removal. Numerous parameters have been investigated in order to find optimum machining conditions. Among these parameters is the mode of electrolyte feeding [2]. However the role of electrolyte flow velocity has not been considered during EEDM.

EEDM combines electrolytic dissolution with electric erosion. The process is a further development to pulsed electrochemical machining (PECM) where, at high input power, phenomena that limit further dissolution may arise [3]. Under such circumstances, the machining medium changes to a gas-vapor mixture that interferes with the ion transfer in the electric field. If the field strength is high enough to cause gap breakdown, the nature of charge transfer is altered causing the combined action of EEDM. Such a machining process is associated with a glow similar to that observed during the direct current appeared in the inter electrode gap. The glow and the subsequent breakdown of the inter electrode gaps were localized at points were the gas content and temperature of the working medium is likely to be highest [1].During EEDM, the machining medium is subjected to varying contamination conditions. This is caused by many interfering phenomena such as gas generation, varying dissolution intensity, presence of different types of pulses that are responsible for the erosion phase in the form of metal re solidified particles, and the change of electrolyte flow rate are possible causes of gap contamination. The breakdown characteristics change with time and hence the initially required dimensional accuracy cannot be reached anymore. The gas liquid wedge, formed during electrolysis, is the determining factor in the combined process. In this regard, it has been found that the superposition of low-voltage pulse component stabilizes the combined process and makes it possible to reduce the breakdown voltage, enhance the machining productivity and reduces the surface roughness [4]. Pulsed electrochemical machining occurs at gap pressure of 0.1 MPa and current density 10 A/cm^2. The increase of gap pressure, electrolyte velocity and current density enhanced the erosion process.

Flushing of the machining medium, in EDM, has been considered by many researchers [5-11]. Zhixin et al [5] used ultrasonic vibrations as a gap flushing method in the mechanical pulse electrodischarge machining (MPEDM). Accordingly, cavitating bubbles and the ultrasonic field force prevent the sedimentation of the debris particles in the working fluid. The high frequency pumping action improves the working fluid circulation by pushing the debris away and sucking fresh fluid into the gap. These stoutly increase the discharge efficiency and give higher erosion rates. The flushing action has been reported to increase with vibration amplitudes. The work of Murti et al [6] added that with the application of ultrasonic the machining rate and surface finish improved significantly and although the tool wear rate increased, the wear ratio was not influenced significantly. Hewedy [7] found also that the increase of tool vibration up to 100μm enhanced the erosion rate due to the improved flushing action and hence the sparking efficiency. The presence of too much debris, in the electrode gap cause continuos arcing and short circuit that makes the process unstable [8]. The dielectric must therefore contain an appropriate amount of debris since too clean medium is another reason for gap short circuiting and the consequent troubles.

The breakdown distance of the field is greatly influenced by the contamination level of the machining medium. The gap distance between the two electrodes, therefore, changes from one place to another according to the local contamination level. Such a change causes dimensional error in the copying process. If the concentration is made uniform, anywhere in the inter electrode gap, the gap distance becomes uniform and an accurate copy is ensured. Ideal flushing must, therefore, maintain constant and uniform debris concentration. In this regard, jet flushing with nozzles sweeping, along the inter electrode gap, has been introduced by Masusawa et al [8] and, proved to be effective in precision EDM. Schumacher et al [9] concluded also that the gap contamination through eroded debris influences ignition delay as well as the discharge location in the gap. The role of dielectric fluid velocity in EDM has been investigated by Erden [10]. Wells and Willey [11] recommended a flow velocity of 6 m/s that reduced the electrode wear by a factor of 2, and the surface roughness by up to 50 %, increases the machining rate and decreased the thermal effects in the eroded workpiece surface.

This paper describes the machining characteristics of the combined EEDM under conditions of variable electrolyte flow velocity. Machining indices that can be used as measures of process productivity, stability, accuracy and surface finish are determined. The obtained data provide better understanding for the phenomena occurring in the machining gap. It can also assist in process optimization through proper monitoring and control of the machining variables [12].

EXPERIMENTAL CONDITIONS

The experimental work was conducted using the set up described in reference [2]. The anodic workpiece was 6 mm thick plate of mild steel that was cut using 0.25 mm copper wire electrode, wound at a speed of 1.0 m/min. The machining medium was 20 % aqueous solution of NaNo3 fed coaxial with the wire at nozzle flow rate of 6 l/min and different velocities of 4.3, 6.6, 9.8, 13.6 and 24.6 m/s. The supply voltage was high rectangular pulse generator, connected in parallel with the inter electrode gap at 95 volt and pulse duration of 170 μs. During each test, the volumetric removal rate, specific removal rate (mm^3/min. A) and energy efficiency (mm^3/J) were determined. Cut width and surface roughness were also measured using x-y microscope and a roughness meter respectively. Using the voltage recordings, the average ignition delay time, working voltage and moreover, the percentage of micro short circuit pulses were also evaluated.

RESULTS AND DISCUSSIONS:

Metal removal process:

Figure (1) shows that, for the different electrolyte flow velocity experimented, the increase of cutting rate raises the volumetric removal rate due to the enhanced erosion process. Such an increase reaches maximum level and then decreases probably due to the narrow inter electrode gap and the rise in gap contamination level together with the percentage of gas-vapor mixture. The machining rate corresponding to the maximum removal rate, in

Figure (1), increases with the electrolyte flow velocity. The same figure also shows that at small cutting rates, the effect of flow velocity on volumetric removal rate is greatly reduced as a result of the wide inter electrode gaps existed under such machining conditions. Further increase of machining rate, beyond the peak, is followed by consequent gap short circuiting and the termination of the machining process. Machining is, therefore, not possible in the shorting zone at the right hand side of Figure (1).

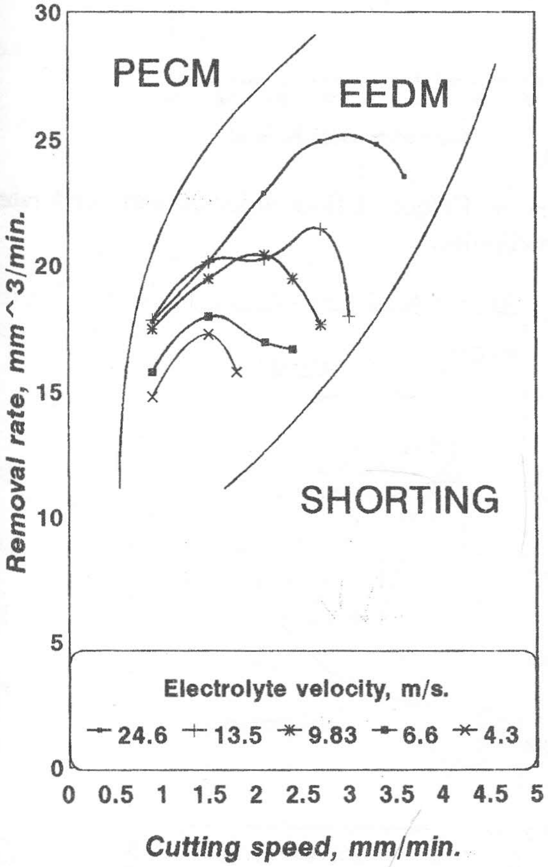

Figure 1. Effect of cutting speed and flow velocity on removal rate.

Pulse electrochemical machining PECM achieves at lower feed rates that avoid gap breakdown and the occurrence of discharges. The area of PECM is expected to be wider and higher machining rates may be obtainable at greater flow velocity as shown in the PECM area of Figure (1). Between the PECM and the shorting limit, the possible EEDM zone covers a wider range of cutting rates as the electrolyte flow velocity is raised. Figure (2) shows the effect of electrolyte flow velocity on the maximum possible feed rate and the PECM, EEDM and the shorting zones. The increase of volumetric removal rate with flow velocity in EEDM can be related to the efficient process of renewing the machining medium by removing away the machining products, in the form of gasses, metal debris and precipitates. Such a decrease, in gap contamination level, raises the average gap impedance, Figure (3). Consequently the breakdown voltage also rises which, in turn, enhances the process of gas generation during the delay time that is normally followed by the intensified erosion phase. Such an argument can be supported using the results displayed in Figure (4) with respect to the average removal/pulse that increases with the electrolyte velocity as well as the machining rate. The increase of removal rate with flow velocity can further be justified since the specific removal rate becomes greater with flow velocity and machining rate, Figure (5). The high removal rate and the decreased machining current, associated with high impedance, are the main reasons behind that observation. The efficiency of energy utilization is also affected by the magnitude of flow velocity passing across the inter electrode gap. Figure (6) illustrates that efficient machining achieves when increasing the flow velocity up to certain level and then falls down. Generally the energy utilization reaches maximum level at flow velocity around 12 m/s. For electrolyte velocity, 24.6 m/s, and cutting speed of 0.3 mm/min., the effect of flow channel length on the removal rate, specific removal rate and cut width is shown in Figure (7). Accordingly, for the cutting rate experimented, PECM is evident in zone I for small channel length up to 9 mm with the absence of discharge glow. Further increase, in flow channel length, electrolyte heating and the formation of discharges is greatly encouraged, zone II. At the longest channel length experimented, the metal removal process is decreased due to the formation of vapor mixture and the increased contamination level that limit further formation of discharges with consequent gap short circuiting at the reduced cut width, zone III.

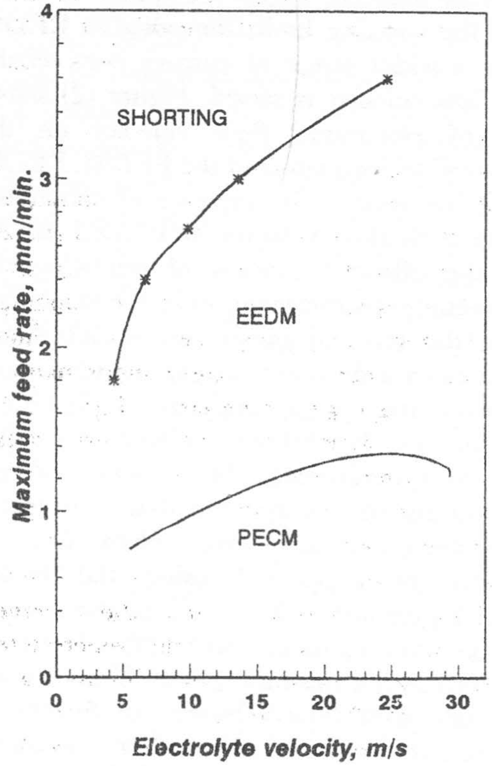

Figure 2. Effect of flow velocity on the maximum feed rate.

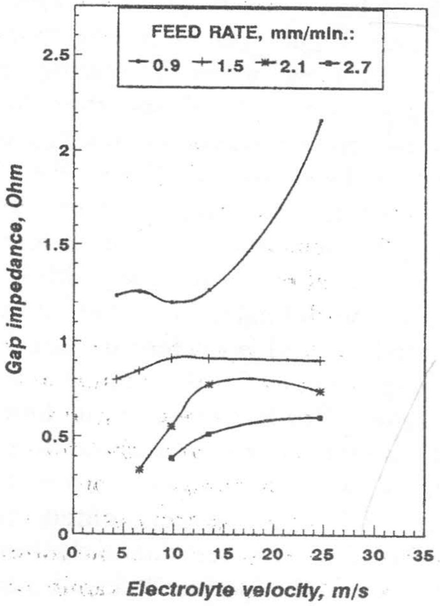

Figure 3. Variation of gap impedance with flow velocity and feed rate.

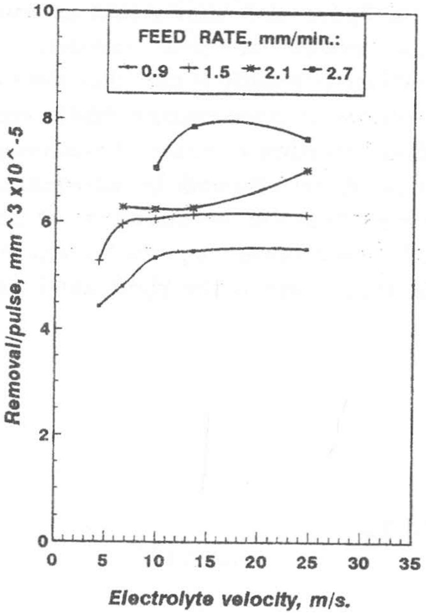

Figure 4. Effect of flow velocity and feed rate on removal/pulse.

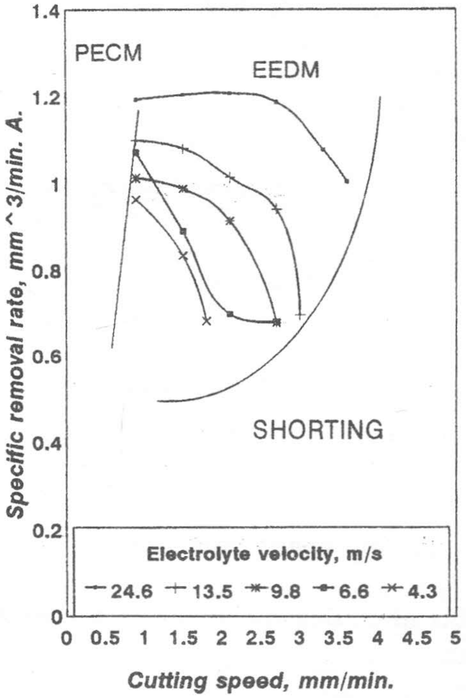

Figure 5. Variation of specific removal rate with flow velocity and feed rate.

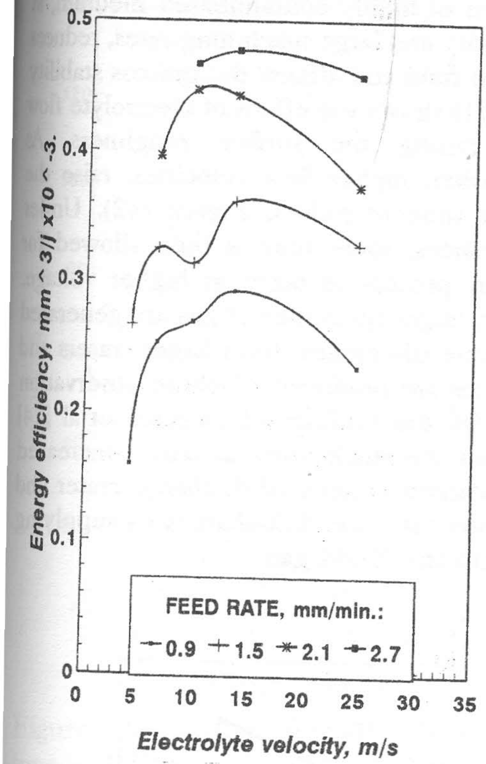

Figure 6. Variation of energy efficiency with flow velocity and feed rate.

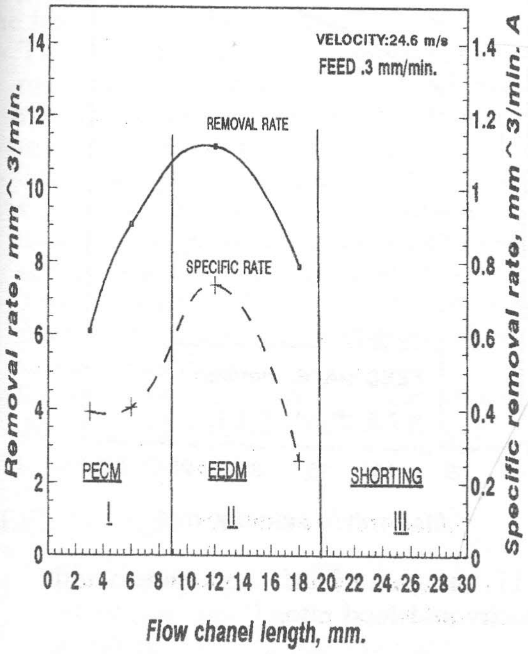

Figure 7. Effect of flow channel length on removal rate and specific rate.

Accuracy and surface roughness:

Figure (8) shows that, at a given feed rate, the increase of flow velocity enlarges the cut width. This trend may be directly related to the high volumetric removal rate and the efficient erosion process. The increased cut width is responsible for the reported gap impedance in Figure (3). Stable machining is, therefore, expected at increased flow velocity, as can be seen from the decreased percentage of micro short circuit pulses, Figure (9). It can be concluded that the increase of flow velocity stabilizes the EEDM process especially at high cutting rates. Similar observations have been reported, in EDM, with respect to gap pressure, fluid velocity and current density that enhance the erosion process [4]. Further stability index, in terms of the average working voltage to cutting speed ratio, is shown in Figure (10). The higher the index, the more stable is the machining process. Wider machining gaps exist at higher flow velocity as well as low machining rate. Consequently, the average voltage becomes higher and the process stability is enhanced at the expense of the machining accuracy and productivity.

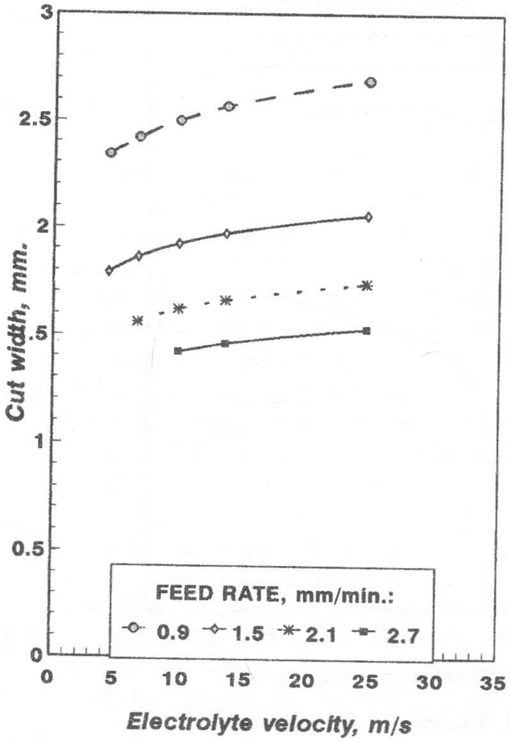

Figure 8. Effect of velocity and feed rate on the width of cut.

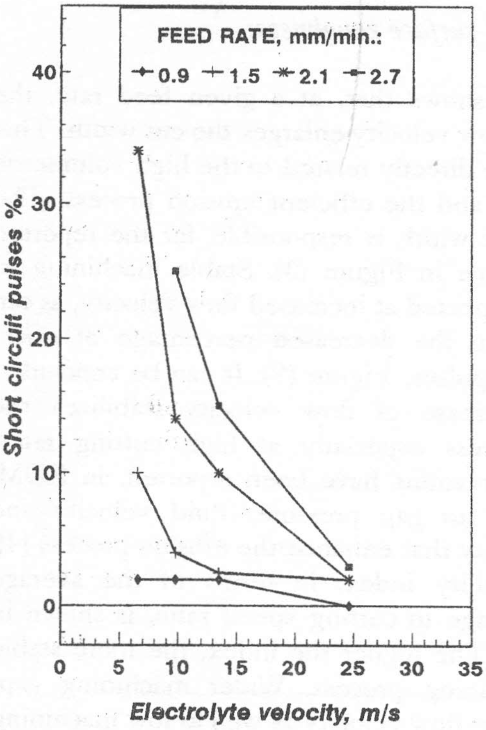

Figure 9. Effect of flow velocity and feed rate on the micro short pulses.

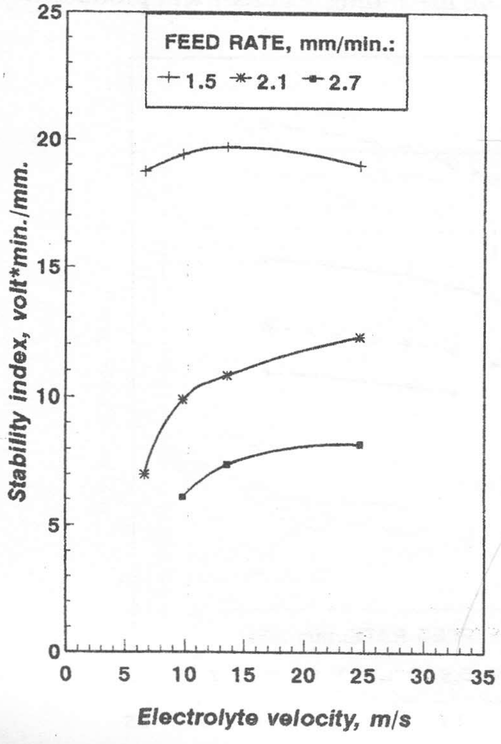

Figure 10. Variation of stability index with flow velocity and feed rate.

The presence of highly contaminated medium, at low fluid velocity and large machining rates, reduces the breakdown field and affects the process stability [13]. Figure (11) shows the effect of electrolyte flow velocity on raising the surface roughness. As mentioned earlier, higher flow velocities, raise the ignition delay time of pulses, Figure (12). Under such circumstances, more time is then allowed for the dissolution process to occur at higher voltage. Consequently, larger quantities of gas are generated that cause severe discharges, form larger craters and rougher surfaces are produced. Such an observation agrees well with the findings of Kuneida et al [14] who found that the stock removal rate is increased due to the enlarged volume of discharge crater and more frequent occurrence of discharges by supplying oxygen gas into the EDM gap.

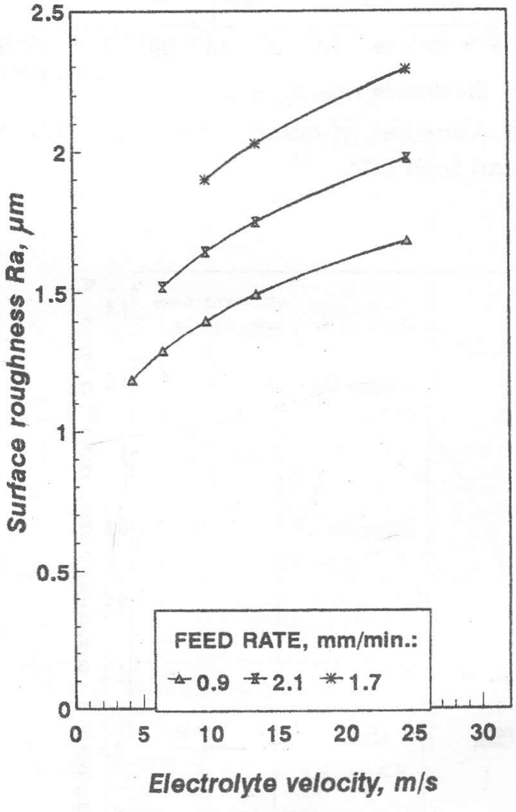

Figure 11. Variation of surface roughness with flow velocity and feed rate.

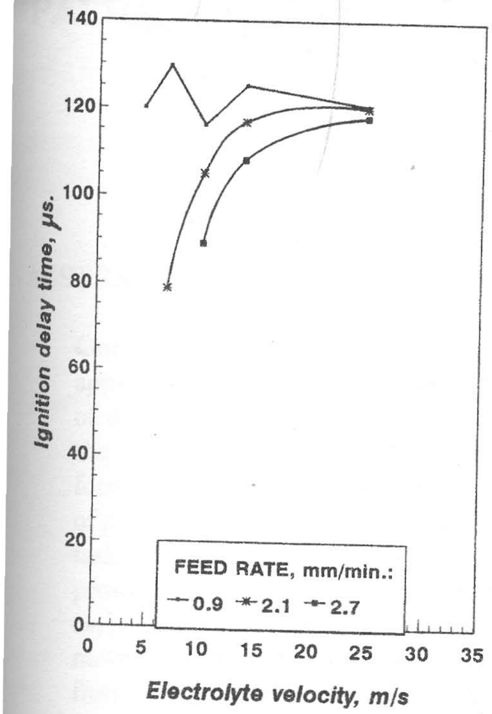

Figure 12. Variation of ignition delay time with flow velocity and feed rate.

CONCLUSIONS

From the experimental work undertaken with respect to the effect of electrolyte flow velocity, the following can be concluded:

1- The increase of flow velocity enhances the machinability in terms of volumetric removal rate, specific removal rate, energy efficiency and the maximum possible machining rate.
2- The wider cuts associated with greater flow velocities stabilizes the machining process through the reduced micro short circuit pulses and the increased voltage/cutting speed ratio.
3- The increased flow velocity encourages the discharging process with consequent increase of surface roughness.
4- Smoother surfaces can be obtained at conditions that lead to a reduced machining accuracy and productivity.

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