A STUDY ON CUTTING TECHNIQUES AND APPLICATIONS OF ELECTRICAL DISCHARGE MACHINING

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ABSTRACT

In electrical discharge machining (EDM) the machining characteristics of the process directly depend on the discharge energy which is transformed into heat in the machining area. The generated thermal energy leads to high temperatures which result in local melting and evaporation of workpiece material. However, the high temperature also impacts various physical and chemical properties of tool and workpiece. Process parameters and machining characteristics of EDM are identified in this study. Based on the previous investigations, an analytical dependence was established between the parameters of discharge energy and technological performance. In addition, properties of discharge energy were experimentally investigated and their influence on productivity, accuracy and quality of EDM was established. Productivity and quality are two important aspects have become great concerns in today's competitive global market. Every production/manufacturing unit mainly focuses on these areas in relation to the process as well as product developed. Electrical discharge machining (EDM) process, even now it is an experience process, wherein still the selected parameters are often far from the maximum, and at the same time selecting optimization parameters is costly and time consuming. The results obtained represent a technological knowledge base for the selection of optimal conditions of EDM process.

Keywords: *electrical discharge machining (EDM), high temperatures, parameters of discharge energy, workpiece material, near-dry WEDM.*

INTRODUCTION

Electrical Discharge Machining (EDM) is classified as one of the earliest non-conventional machining processes, but it still finds extensive use and application in modern industry as a leading edge machining process in treating hard-to-cut materials. The fundamental principle of EDM is that material removal is resulted by means of rapid repetitive spark discharges, which occur between a working electrode and the workpiece. The improvement of MRR and the decrease of TWR are vital, in order for EDM to become economically competitive in comparison to conventional machining processes. Moreover, the decrease of TWR and the reduction of tool wear, affects beneficially the machining precision, as the electrode's profile and geometry change at slower pace, keeping the machining precision at high level. Since EDM is a multi-parameter process, extended experiments have to be carried out so that the machining of a range of materials under different parameters can be studied. Thus, the development of models and simulations procure the advance of research, limiting the need of experiments, while, and at the same time, a more adequate and in-depth analysis of the process can be attained. EDM has been successfully used in the machining of hard-to-cut material, facilitating and achieving high dimensional accuracy, in complex shapes and geometries. Moreover, EDM is a non-contact machining process, since no contact exists between the working electrode and the workpiece, thus, no cutting forces are developed, leading to absence of mechanically induced residual stresses in the workpiece material. Due to the inherent advantages of EDM in comparison with conventional cutting processes and its capability to handle any electrical conductive material, regardless of its mechanical properties, EDM finds extensive use in the production of dies and molds, in automotive and aerospace industry, as well as in the field of surgical components production.

LITERATURE REVIEW

Rajusing Rathod (2022) Titanium alloy has a high specific resistance, excellent machining performance is non-corrosive, and the capability to withstand greater temperatures while maintaining outstanding mechanical properties. This alloy is, therefore, the right choice for aerospace, maritime, biomedical, and industrial applications. In the EDM process, different techniques are used to understand the effects of process parameters such as polarity, peak current, electrode type, pulse on time, and gap voltage on material removal rate, tool wear rate, surface roughness, and wear ratio. This study critically investigates different types of EDM processes, experimental setups used for machining of titanium alloy, the effect of different tool electrodes and dielectric media on machining parameters, machined surface characteristics, and metal removal rate and tool wear rate.

B. A. Okorie (2021) Tungsten copper and molybdenum copper composites, with weight percent copper in the range of 20% - 40%, have been produced using the spark plasma sintering (SPS) technique. Other specimens having similar compositions were also developed using the conventional techniques of Liquid Phase Sintering (LPS) and Infiltration. Electrical conductivity measurements showed that the specimens produced by the SPS process had substantially higher levels of electrical conductivity than those produced by the other methods. The effect of porosity on electrical conductivity has been discussed and three standard models were assessed using results from porous sintered skeletons of pure tungsten and pure molybdenum.

Emmanouil L. Papazoglou (2021) Titanium alloys, due to their unique properties, are utilized in numerous modern high-end applications. Electrical Discharge Machining (EDM) is a non-conventional machining process, commonly used in machining of hard-to-cut materials. The machining performance indexes of Material Removal Rate, Tool Wear Ratio, and Average White Layer Thickness were measured and calculated for different pulse-on currents and pulse-on times. Moreover, the developed model that integrates a heat transfer analysis with deformed geometry, allows estimating the power distribution between the electrode and the workpiece, as well as the Plasma Flushing Efficiency, giving an insight view of the process.

Muslim Mahardika (2020) Micromachining in the micro-electric discharge machining (μ-EDM) process requires high material-removal rate with good surface quality. Power-mixed μ-EDM, a modified machining process by introducing specific powder into the dielectric fluid, is among the key inventions to achieving these requirements. This article presents a review of the implementation of powder-mixed micro-EDM processes for micro-fabrication. Special attention was given to the influence of the powder characteristics, such as the concentration, electrical conductivity, shape and size of the powder.

Finally, some of the varied methods that are used in powder-mixed µ-EDM and industrialization challenges are extensively elaborated.

Gheorghe Nagîţ (2020) Wire electrical discharge machining has appeared mainly in response to the need for detachment with sufficiently high accuracy of parts of plate-type workpieces. The improvements introduced later allowed the extension of this machining technology to obtain more complex ruled surfaces with increasingly high requirements regarding the quality of the machined surfaces and the productivity of the wire electrical discharge machining process. Therefore, it was normal for researchers to be interested in developing more and more in-depth investigations into the various aspects of wire electrical discharge machining. These studies focused first on improving the machining equipment, wire electrodes, and the devices used to position the clamping of a wire electrode and workpiece.

Electrical discharge machining

Electrical discharge machining (EDM), also known as spark machining, spark eroding, die sinking, wire burning or wire erosion, is a metal fabrication process whereby a desired shape is obtained by using electrical discharges (sparks). Material is removed from the work piece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. One of the electrodes is called the tool-electrode, or simply the tool or electrode, while the other is called the workpiece-electrode, or work piece. The process depends upon the tool and work piece not making physical contact. Extremely hard materials like carbides, ceramics, titanium alloys and heat treated tool steels that are very difficult to machine using conventional machining can be precisely machined by EDM.

Background of Electrical Discharge Machining

EDM machining techniques were discovered far back in the 1770s by an English Scientist. However, this technique was not fully taken advantage until 1943 when Russian scientists learned how its erosive effects could be controlled and used for machining purposes. It was developed commercially in the mid-1980s, wire EDM made lot of change that helped shape the metal working industry we see today. With the technological and industrial growth, devolvement of harder machining materials, which find wide application in nuclear engineering ,aerospace and other industries owing to their high strength to weight ratio, heat resistance and hardness qualities has been witnessed New developments in the field of material science have led to new engineering metallic materials, high tech ceramics and composite materials having good mechanical properties and thermal characteristics as well as sufficient electrical conductivity so that they can readily be machined by spark erosion.

Applications

- EDM is by far the most widely used machining process among the non-conventional machining methods
- EDM has long been employed in the automotive, aerospace, mould, tool and die making industries
- It has also made a significant inroad in the medical, optical, dental and jewellery industries, and

in automotive and aerospace R&D areas

Working Principle of Electric Discharge Machining

The workpiece and the tool are electrically connected to dc electric power. The workpiece is connected to the +ve terminal. It becomes the anode. The tool is the cathode. A gap, known as the 'spark gap' in the ranges of 0.005 to 0.05 mm is maintained between the workpiece and the tool. When a suitable voltage in the range of 50 to 450 V is applied, the dielectric breaks down and electrons are emitted from the cathode, and the gap is ionized. In fact, a small ionized fluid column is formed owing to the formation of an avalanche of electrons in the spark gap where the process of ionization collision takes place. When more electrons collect in the gap the resistance drops, causing the electric spark to jump between the workpiece and the tool. Each electric discharge causes a stream of electrons to move with a high velocity and acceleration from the cathode towards the anode and creates compression shock waves on both electrode surfaces. The formation of compression shock waves produces a rise in temperature.

Development in EDM

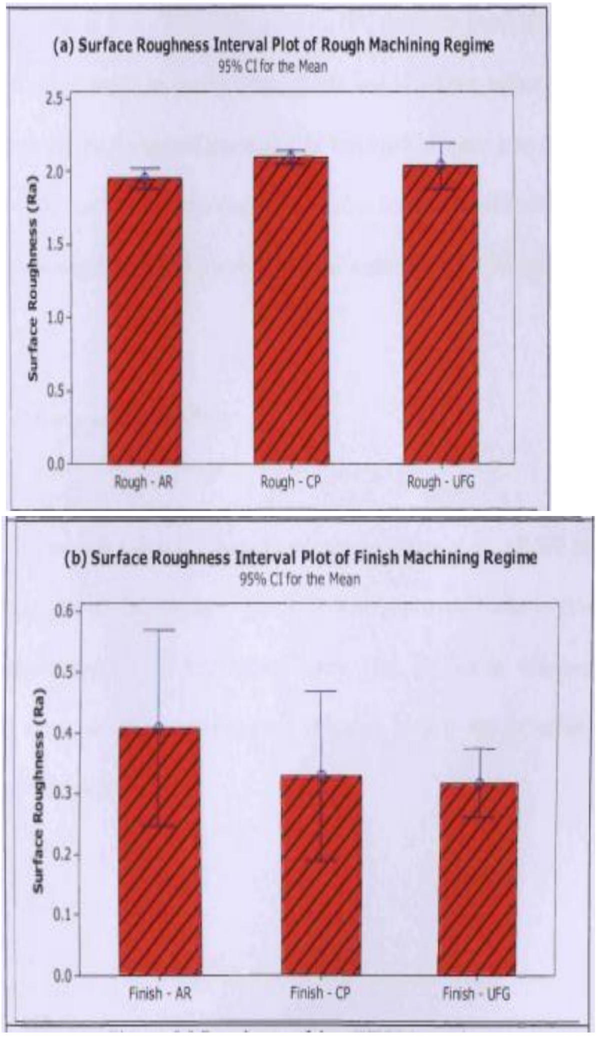
Lot of improvements, research and developments are made in the field of EDM from past few years but still there are gaps in its research process. Lot of improvements and developments have been done in the materials and modeling techniques in the past. Lot of researches is being made in the field of ceramics and composites. These researches are creating new and interesting research scopes in the process of EDM.

RESEARCH METHODOLOGY

As material usability is required in highly precise applications, therefore, it is subjected to EDM die sinking due to its popularity in die-making industries. In recent years, numerous research works were identified in the dry and near-dry EDM processes. For statistical analysis and EDM trials, Taguchi orthogonal arrays were used. For analysis and optimization, the signal-to-noise (S/N) ratio suggested by Taguchi was employed. Perform the designed experiment run on WEDM according to orthogonal array (Each experimental runs to be repeated thrice) in order to reduce process variability. For a response function, the signal represents mean values, while the noise represents the standard deviation. It was revealed that near-dry EDM is one of the emerging and significant machining processes. Dry and near-dry WEDM experimental studies are still required to improve the machining performance without environmental impact. It was observed that dry and near-dry EDM milling, drilling, turning processes were only performed. Very minimum research works have been performed in the near-dry WEDM. The relationship between the replies and the input parameters is correlated using this method. This is also employed in parameter optimization. Utility generally refers to how beneficial a process or product is in relation to the degree of expectations set by the customer through performance analysis based on multiple discrete objective functions. However, the extensive EDM/ WEDM literature helps to conduct the systematic near-dry WEDM experiments.

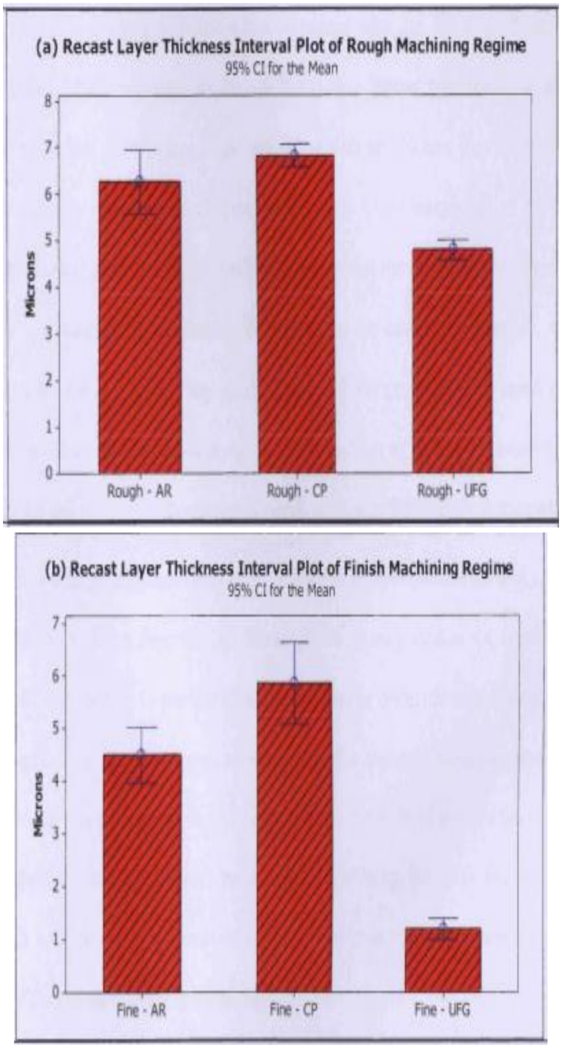
RESULTS AND DISCUSSIONS

The resulting surface roughness after pWEDM of the three test workpieces were measured employing a white light interferometer microscope. After the roughing machining regime all test workpieces displayed surface roughness that are comparable to each other. The surface finish values achieved on the UFG sample after the finishing cut were marginally better than those on the other two samples.



Graph 1: Roughness of the pWEDM samples: (a) rough and (b) finish

Also, it is worth noting that the surface roughness, Ra, o f the UFG sample improved almost 6 times after the finishing cut. The marginally better results achieved on the UFG sample together with the high level of improvement between the roughing and finishing cuts should be attributed to the material microstructure refinement. pWEDM is an electro thermal process, and by creating plasma channels between the wire and the workpiece the material is eroded by detaching clusters o f grains. Thus, in the case of the UFG sample the craters left on the machined surface would be smaller, which should lead to a better surface finish.

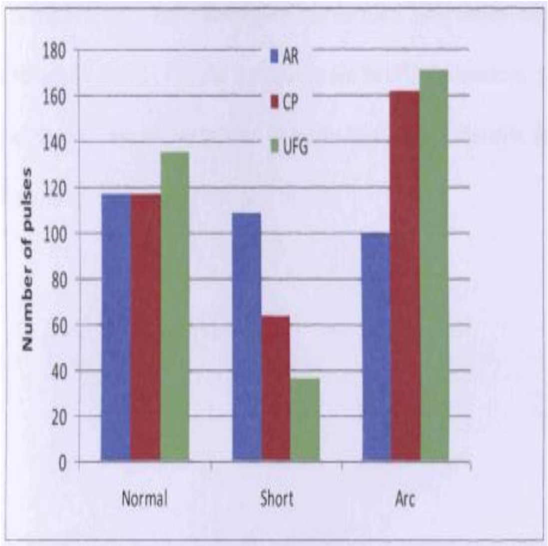


Graph 2: Recast layer thickness of the pWEDM samples: (a) rough and (b) Finish

As the workpiece has an ultra-fine grain structure the debris generated during pW EDM are much finer, which improves the efficiency of the evacuation process and thus results in a thinner recast layer. However, it is worth noting that the recast layer thickness on the AR and CP samples did not differ significantly from one another after both roughing and finishing cuts.

Material Removal Rates

By analysing pulse shape variations in the data sets the pulses are clustered in three categories as illustrated. The results show that the UFG material has a favourable EDM machining response when compared with the AR and CP samples. This favourable EDM response can be attributed to a higher proportion of normal pulses and much less short pulses in the respective data set.



Graph 3: Pulse characteristics for the three studied materials

Graph 3 shows a lower ratio between short circuits and normal pulses when machining the UFG test piece in comparison with the other two materials. This observation indicates a more efficient recovery of the dielectric breakdown strength.

CONCLUSION

Wire electrical discharge machining is a way of applying electrical discharge machining. In WEDM, a reduction in the influence of tool electrode wear was achieved using a moving wire along its axis, which usually unwinds from one storage roller and is wound on another roller. Based on the literature review, it follows that the electrical discharge machining (EDM) is a very common type of machining in manufacturing industries. Thereby, the machining characteristics of EDM mainly depend on generation and distribution of discharge energy within the machining zone. The energy generated depends on the discharge current and discharge duration, while the distribution of energy depends on physical and chemical characteristics of the discharge zone. The only limitation within the EDM is that the work piece ought to be semiconducting in nature. With the time there's heap of enhancements within the EDM and its aided processes in addition as development and improvement techniques that created some new analysis and increased scopes within the WEDM. Since the EDM process is complex and stochastic in nature, most attempts to model the technological performance of EDM process in literature, and has been reported to be based on electrothermal concepts. Developments in modeling techniques have created many opportunities and increased scopes within the EDM and improve the performance of EDM method. Thereby, for the modeling of EDM the experimental, mathematical, empirical or intelligent methods are used, with different characteristics and approximation results.

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