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Review

A review on the use of dielectric fluids and their effects in electrical discharge machining characteristics

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ABSTRACT

Electrical discharge machining (EDM) is one of the earliest non-traditional machining processes. EDM process is based on thermoelectric energy between the work piece and an electrode. In electrical discharge machining (EDM), a process utilizing the removal phenomenon of electrical discharge in dielectric, the working fluid plays an important role affecting the material removal rate and the properties of the machined surface. Choosing the right dielectric fluid is critical for successful operations. This paper presents a literature survey on the use of dielectric fluids and also their effects in electrical discharge machining characteristics.

Contents

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1. Introduction

The electrical discharge machining (EDM) is one of the major manufacturing processes widely applied in die and mold making industry to generate deep and three-dimensional complex cavities in many different classes of materials under roughing and finishing operations [1]. This technique has been developed in the late 1940s [2] where the process was based on removing material from a part by means of a series of repeated electrical discharges between tools called the electrode and the work piece in the presence of a dielectric fluid [3]. The electrode is moved toward the work piece until the gap is small enough so that the impressed voltage is great enough to ionize the dielectric [4]. Short duration discharges are generated in a liquid dielectric gap, which separates tool and work piece. The material is removed with the erosive effect of the electrical discharges from tool and work piece [5]. However, it was only in early 1940 that electrical discharge machining started to become a well-known manufacturing process when Boris and Natalie I. Lazarenko discovered the decisive role of the dielectric fluid [6]. Since then, EDM has experienced a dramatic evolution. EDM process can be classified according to the type of dielectric fluid used. Dielectric fluid is an extremely important function regarding the quality of the machined parts. Since different dielectrics have different cooling rates and compositions, the choice of dielectric plays an important role in the EDM process. Dielectric media, circulated between the electrode and work piece, must be carefully selected and applied to maintain peak performance and control of the electrical spark. Another key factor is the dielectric media filtration system, which helps maintain consistent gap performance and dielectric cleanliness. The four basic functions of dielectric oil (specific to sinker EDMs and specially designed wire EDMs) are: insulation, ionization, cooling, removal of waste particles. Different kinds of dielectric fluid are available for machining the parts in EDM. Die sink EDM generally operates with hydrocarbon oil, while wire, micro-EDM and fast drilling usually work with deionized water [7]. It has already been observed that pure kerosene, which is used as the dielectric liquid in most of the conventional EDM systems, creates several problems while machining, such as degradation of dielectric properties, pollution of air, and adhesion of carbon particles on the work surface. All these phenomena obstruct the stable discharge between the two electrodes, i.e., tool and work piece and further result in lower machining efficiency. Investigation should be made to search out the alternative to kerosene dielectric with other types of dielectrics since the properties of dielectric are the effective machining parameter, which may overcome the above-mentioned problems. This paper will present a review on the use of different kinds of alternative dielectric fluid and their effects for die sink EDM characteristics.

2. Types of EDM

The EDM process is most widely used by the mold-making tool and die industries, but is becoming a common method of making prototype and production parts, especially in the aerospace, automobile and electronics industries in which production quantities are relatively low. It is also used for coinage die making, metal disintegration machining, etc. There are different types of EDM available which is briefly discussed below.

2.1. Sinking EDM

In the sinking EDM process, a mirror image of tool shape occurs on the surface of work piece. In this process, copper or graphite is generally used as electrode material. The numerical control monitors the gap conditions (voltage and current) and synchronously controls the different axes and the pulse generator. The dielectric liquid is filtrated to remove debris particles and decomposition products. In this process electrical energy turns into thermal energy through a series of discrete electrical discharges occurring between the electrode and work piece immersed in a dielectric fluid [8]. The thermal energy generates a channel of plasma between the cathode and anode. When the pulsating direct current supply is turned off, the plasma channel breaks down. This causes a sudden reduction in the temperature allowing the circulating dielectric fluid to implore the plasma channel and flush the molten material from the work piece surface [9].

2.2. Wire EDM

Wire-cut EDM (WEDM) is one of the most favorable variants owing to its ability to machine conductive, exotic and high strength and temperature resistive (HSTR) materials with the scope of generating intricate shapes and profiles [10]. It uses a thin continuously traveling wire feeding through the work piece by a micro-processor eliminating the need for elaborate reshaped electrodes, which are required in the EDM. The wire-cut EDM process uses a thin copper wire of diameter about 0.1–0.3 mm as the electrode and the work piece is mounted on a controlled worktable, enabling complex two dimensional shapes can be cut on the work piece by controlled the movement of the *X*–*Y* worktable [11]. Wire EDM process is widely applied not only in tool and die-making industry, but also in the fields of medicine, electronics and the automotive industry [12].

2.3. Micro EDM

The recent trend in reducing the size of products has given micro-EDM a significant amount of research attention. Micro-EDM is capable of machining not only micro-holes and micro-shafts as small as 5 μm in diameter but also complex three-dimensional (3D) micro cavities [13]. Micro EDM process is basically of four types: micro-wire EDM, die-sinking micro-EDM, micro EDM drilling and micro-EDM milling. In micro-wire EDM, a wire which has a diameter down to 0.02 mm is used to cut through a work piece. In die-sinking micro-EDM, an electrode is used containing micro-features to cut its mirror image in the work piece. In micro EDM drilling, micro-electrodes (of diameters down to 5–10 μm) are used to 'drill' micro-holes in the work piece. In Micro-EDM milling, micro-electrodes (of diameters down to 5–10 μm) are employed to produce 3D cavities by adopting a movement strategy similar to that in conventional milling [9].

2.4. Powder mixed EDM (PMEDM)

The mechanism of PMEDM is totally different from the conventional EDM [14]. A suitable material in the powder form is mixed into the dielectric fluid of EDM. When a suitable voltage is applied, the spark gap filled up with additive particles and the gap distance setup between tool and the work piece increased from 25–50 to 50–150 mm [15]. The powder particles get energized and behave in a zigzag fashion Fig. 1. These charged particles are accelerated by the electric field and act as conductors. The powder particles arrange themselves under the sparking area and gather in clusters. The chain formation helps in bridging the gap between both the electrodes, which causes the early explosion. Faster sparking within discharge takes place causes faster erosion from the work piece surface.

2.5. Dry EDM

In this process a thin walled pipe is used as tool electrode through which high-pressure gas or air is supplied. The role of the