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Technology and research developments in powder mixed electric discharge machining (PMEDM)

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Abstract

Powder mixed electric discharge machining (PMEDM) is one of the recent innovations for the enhancement of capabilities of EDM process. In PMEDM, the electrically conductive powder is mixed in the dielectric of EDM, which reduces the insulating strength of the dielectric fluid and increases the spark gap between the tool and workpiece. As a result, the process becomes more stable, thereby, improving the material removal rate (MRR) and surface finish. Moreover, the surface develops high resistance to corrosion and abrasion. This paper presents a tutorial introduction, comprehensive history and review of research work carried out in the area of PMEDM. The machining mechanism, current issues, applications and observations are also discussed.

Keywords: Electric discharge machining; Surface roughness; Material removal rate; Tool wear rate

1. Introduction

Among all the non-conventional machining methods, electric discharge machining (EDM) is one of the most popular machining methods for the manufacturing of press tools and various dies. This process enables machining of any material, which is electrical conductive, irrespective of its hardness, shape and strength [1]. Even highly delicate sections and weak materials can be machined without any fear of distortion because there is no direct contact between the tool and the workpiece.

Since the invention of EDM in the 1940s, many efforts have been made to improve the machining performance and stability of EDM process. Process stability is the key factor for turning a natural material removal process into a controllable machining process [2]. Due to continuous process improvement, many EDM machines have become so stable that these can be operated around the clock if monitored by an adaptive control system. The demands for high machining precision with low surface roughness at relatively high machining rates arise in die, mold and tool manufacturing industries [2]. To fulfill this requirement, a relatively new advancement in the direction of process capabilities is the addition of powder in the dielectric fluid of EDM [3–5]. This new hybrid material removal process is called powder mixed EDM (PMEDM). The results show that the PMEDM can distinctly improve the surface finish and surface quality to obtain near mirror like surfaces at relatively high machining rate [5–7]. Moreover, the surface produced by PMEDM has high resistance to corrosion and abrasion [8,9]. In this process, a suitable material in fine powder form is mixed into the dielectric fluid of EDM. The added powder improves the breakdown characteristics of the dielectric fluid, i.e. the insulating strength of the dielectric fluid decreases and consequently, the spark gap distance between the electrode and workpiece [3,4,7] increases. Enlarged spark gap distance makes the flushing of debris uniform. As a result, the process becomes more stable thereby improving machining rate and surface finish.

PMEDM also termed as 'Additive EDM' was originally invented during late seventies as a revolutionary technique for achieving mirror like finish relatively at high machining rates on already machined components (using conventional methods) [10,11]. Numbers of researchers have conducted the experiments to investigate the effects of addition of powder

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into dielectric fluid on the performance of EDM. While going through the available literature on this process, a need is felt to summarize all the results and conclusions made by different researchers. Therefore, this paper is an attempt to provide a review of the various research activities carried out in the past decade involving the PMEDM process.

In this paper, the fundamental principle and major technological developments into the PMEDM process are described. Although the machining mechanism of PMEDM is not still clearly understood, the widely accepted principle of the process is presented here. The historical perspective of PMEDM process and its applications are discussed in the next section. The final part of the paper discusses the current problems and future direction for the PMEDM research.

2. Technology of powder mixed EDM

This section provides the basic machining mechanism of PMEDM.

PMEDM has a different machining mechanism from the conventional EDM [3]. In this process, a suitable material in the powder form is mixed into the dielectric fluid either in the same tank or in a separate tank. For better circulation of the powder mixed dielectric, a stirring system is employed. For constant reuse of powder in the dielectric fluid, a modified circulation system (Fig. 1) is used.

The experimental setup consists of a transparent bath like container, called machining tank. It is placed in the work tank of EDM and the machining is performed in this container. To hold the workpiece, a workpiece fixture assembly is placed in it. The machining tank is filled up with dielectric fluid (kerosene oil). To avoid particle settling, a stirring system was incorporated. A small dielectric circulation pump was installed for proper circulation of the powder mixed dielectric fluid into the discharge gap. The pump and the stirrer assembly are placed in the same tank in which machining is performed. The distance between powder mixed dielectric suction point and nozzle outlet is kept as short as possible (10 in.) in order to ensure the complete suspension of powder in the discharge gap. Magnetic forces were used to separate the debris from the dielectric fluid. For this purpose, two permanent magnets are placed at the bottom of machining tank.

The various powders that can be added into the dielectric fluid are aluminum, chromium, graphite, silicon, copper or silicon carbide, etc. Their thermo physical properties are tabulated in Table 1 [7].

The spark gap is filled up with powder particles. When a voltage of 80–320 V is applied between the electrode and the workpiece facing each other with a gap of 25–50 μm [12], an electric field in the range of 10^5–10^7 V/m is created. The powder particles get energized and behave in a zigzag fashion (Fig. 2). These charged particles are accelerated by the electric field and act as conductors. The conductive particles promote breakdown in the gap and increase the spark gap between tool and the workpiece. Under the sparking area, the particles come close to each other and arrange themselves in the form of chain like struc-

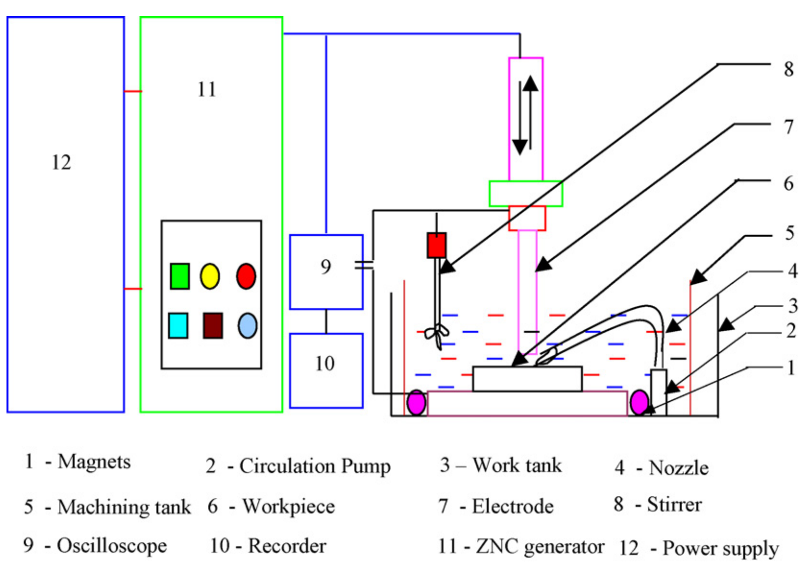

Fig. 1. Schematic of PMEDM experimental setup.

Table 1
Thermo physical properties of various additives [7]

Powder	Density (g cm^{-1})	Thermal conductivity (W cm^{-1} °C^{-1})	Electrical resistivity (μΩ cm)	Melting point (°C)	Specific heat (Cal g^{-1} °C^{-1})
Al	2.70	2.38	2.45	660	0.215
Cr	7.16	0.67	2.60	1875	0.11
Cu	8.96	4.16	1.59	1083	0.092
SiC	3.21	1.0–5.0	1×10^9	2987	0.18