ELECTRICAL DISCHARGE MACHINING AND ITS APPLICATION TO BUNTER MANUFACTURING

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ABSTRACT

This manuscript presents an in-depth discussion of electrical discharge machining and its application in the manufacturing of bunters.

Introduction

Although the word "manufacture" comes from the Latin phrase "manu factus"—meaning "made by hand" [1]—it has been many decades since human hands played any substantive role in manufacturing. Conventional "hands on" machining methods such as milling, lathing, and drilling were formerly the standard manufacturing methods. However, manufacturing has always been a progressive field and as new technologies continue to drive industries to higher levels of efficiency and production capacity, these more technologically advanced methods have superseded conventional ones. Electrical Discharge Machining (EDM), which has become a standard machining technique in many industries around the world [2], is an example of such a method.

EDM has seen dynamic application in the ammunition industry as well. Specifically, EDM is widely employed in the making of bunters, which are used to stamp primer pockets and head lettering onto cartridges. Bunters were formerly made using hobbing techniques, but now every major cartridge company, including Remington, Winchester, and Federal, uses EDM to manufacture their bunters. Because of the prevalence of the technology in the field and the potential it holds for making identifications, it is important for a firearms examiner to know the basic principles of EDM and how it is applied to the manufacturing of bunters.

Overview

Fundamentally, EDM removes metal from a work piece through a combination of vaporization and thermal erosion by electrical discharges. A dielectric fluid is used to facilitate this process. The work piece and the electrode, which are oppositely charged, are brought within micrometers of each other. Large voltage differences between the electrode and the work piece are generated by a direct current power supply. In microseconds the voltage is high enough so that the dielectric material in the gap ionizes (becomes electrically charged) and a spark between the work piece and the electrode ensues. This electrical discharge is of high enough energy that the work piece metal is melted or vaporized along with a portion of the electrode. Because the electrode is made out of a material with a higher melting point than the work piece, the erosion on it is less than the erosion on the work piece.

Types of EDM

There are two primary types of EDM: die-sinking EDM and wire EDM [3]. Die-sinking EDM is typically used to plunge a hole, while wire EDM is the preferred technique for machining complex shapes. In the die-sinking process, the electrode is shaped like the desired image, only inverted. This image is then "impressed" onto the stationary work piece and metal is removed by the thermal energy in the discharges. This method is also known as Sinker, Ram-Type, Conventional, Plunger or Vertical EDM [4]. In the wire EDM process material is removed from the work piece by discharges through a small wire, typically made of brass [5]. The relative motion between the wire and the work piece is controlled by Computer Numerical Control (CNC) system [6]. Modern systems are capable of simultaneously controlling motion on up to six axes [7], which allows for increased precision and the machining of complex shapes.

Other less common types of EDM include ED Milling, ED Grinding and Electrode Rotation EDM. Recent research suggests that rotating the electrode yields superior results in the form of shortened machining times, less electrode wear and rounder holes in the work piece [8].

Components

The components of a die-sinking EDM system are the electrode, the dielectric medium, the power supply, the servo system, and the machine tool [9]. The electrode is often made from graphite, which is easier to produce and yields the fastest machining rates [10]. The primary requirement is that the electrode material has a higher melting point than the work piece material so that it will melt considerably less when the electrical discharge between the two metals takes place. The dielectric medium, in which the work piece and electrode are submersed, is usually non-flammable oil. This medium serves several vital purposes; it flushes away the molten metal particles (called "swarfs") which are created during the EDM process and also acts as a coolant, reducing the extreme temperatures in the gap.

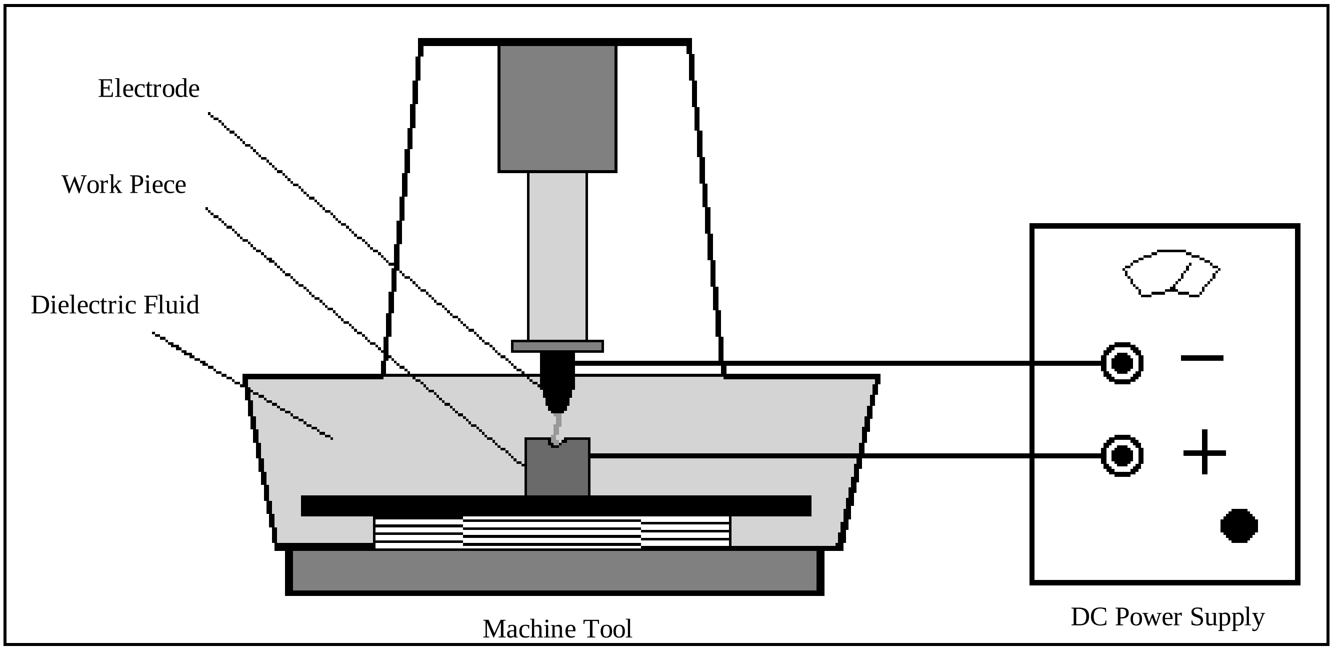

Diagram of a die-sinking EDM system which illustrates the various components.

The machine tool holds both the work piece and the electrode while the servo system, along with the power supply, controls the width of the gap between them. The power supply also controls the frequency and energy of the electrical discharges.

In wire EDM the main components are essentially the same as those used in die-sinking EDM. The main difference is that a thin wire acts as the electrode rather than a sinker. The relative motion between the work piece and the wire is controlled by CNC, thus there is no longer a need for the machine tool. In addition, de-ionized water is used as a dielectric instead of oil.

Principles of Operation

As stated earlier, EDM works by heating, partially vaporizing and melting the surface of the work piece metal through continuous electrical discharges of high energy. These transient arcs occur in the electrode–work piece gap and last from 0.1 microseconds to 8 milliseconds. The gap width can be varied but is usually very small, around 10 to 100 micrometers. A discharge will only occur when the voltage difference between the oppositely charged electrode and work piece is large enough, typically 60 to 300 volts, to ionize the dielectric fluid between them. The highly concentrated electrical energy is discharged along the path of least resistance, not unlike a lightning bolt striking the highest conducting object on the ground. At the time of each spark the path of least resistance is dependent upon relative erosions of the electrode and the working surface, which are both random processes. For this reason, exactly *where* the surface is affected by each discharge is impossible to predict. One would thus expect to find unique surfaces on each piece machined by EDM [11].

The discharges of electrical energy do not remove a great deal of metal: only 1 to 10% of the molten metal goes into the dielectric fluid as the partially vaporized metal expands and knocks pieces loose. The rest of the molten metal is recast as a hard and rough layer on the work piece surface. To compensate for this, the discharges occur at a high frequency, typically around 250,000 sparks per second. The heat from the discharge also erodes the electrode, though typically far less (1-10%) than the work piece due to the difference in the melting point of the materials [12].

The various operational parameters that one might wish to control include the electrode material and polarity, the pulse current and duration, the pulse off time, the average voltage, the average current, the gap voltage, the dielectric medium and the flushing mode. These parameters affect the metal removal rate, the relative electrode wear, the surface finish, and the thickness of the recast layer [13]. The peak current and pulse on–time change the machining conditions in the gap and lead to changes in the spark efficiency and distribution [14].

Advantages

EDM has many practical advantages over conventional machining processes from a manufacturing process. The first lies in the fact that EDM vaporizes material rather than cutting it [15]. This allows for the machining of materials that are harder than the electrode material, which is not possible with conventional machining. In addition, EDM is a non-contact process, so there is no adhesion of the work piece to the tooling [16]. A third advantage is that the vaporized metal of the work piece is removed by flushing burrs from the work piece with the dielectric fluid [17]. Tough burrs are created during conventional machining and must be removed by another machining process, involving more labor. This last advantage, however, the flushing of burrs while machining, has impact on examination work. The removal process that is necessary with conventional machining leaves random marks on the work piece. With EDM, however, this burr removal is not necessary and one potential source of distinguishing marks on a bunter's surface is thereby eliminated.

Application to Bunter Manufacturing

For the reasons enumerated above, EDM is the primary bunter manufacturing process used by the ammunition industry. In order to ascertain the facets of the EDM particular to bunter manufacturing, the author contacted a company that utilizes EDM in this capacity. This company, which preferred to remain anonymous, graciously provided the information contained in the following paragraphs.

Die-sinking EDM is used to press the letters onto the bunter, whereas wire EDM is more suitable for machining complex shapes and is usually employed for this purpose. A non-conductive fluid is used as the dielectric, one common choice being Texco ADM Fluid. The system is under manual control and runs at around 90 volts DC. Each bunter takes about 15 to 20 minutes to machine using EDM, depending on the caliber.

Rather than using the common graphite electrode, bunters are made mostly using an electrode composed of a copper/tungsten alloy. This electrode displays less "burn-away" (thermal erosion) than the graphite electrode. It is therefore more reliable and gives clearer reproduction of the letters. In machining one bunter, 0.3-0.4 inches are typically lost from the surface of the electrode, with each one yielding only four or five bunters before it must be re-pressed. After the electrode has worn beyond tolerance it is removed from the system, machined down using a steel lathe, and re-pressed using a master.

Conclusion

It is readily apparent how the EDM process produces bunters that are unique and identifiable. Each bunter is made using an electrode at a different stage of wear, so the lettering on each bunter made from that electrode will be slightly different than that of other bunters made from different electrodes. Under microscopic inspection this variation in wear is apparent and therefore a possible source of identification. Additionally, the steel lathing process, used to remove the worn letters from the electrode, will leave random and identifiable marks on the surface of the electrode as the letters are lathed away. Since lathing utilizes components in different stages of wear, there will be microscopic differences left on the electrode as it is machined down. The standard identification techniques should thus apply to the bunters made from this electrode.

Each bunter that is made by this process will be minutely different. Even bunters made from the same electrode will not have exactly the same microscopic detail as a result of the random nature of the electrical discharge process as explained earlier.

With all of these factors concurrently considered, the examiner should be confident that bunters made by EDM are unique, identifiable and capable of producing unique and identifiable stamps on cartridge cases.

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