The limitations of conventional machining processes engineering essay

Introduction

Electro Discharge Machining (EDM) is an electro-thermal and non-conventional machining process, where material is removed due to thermal energy of the spark. EDM uses electrical energy to generate electrical spark which travels through a dielectric fluid at a controlled distance. Electrically conductive parts irrespective of their hardness, shape and toughness can be machined by EDM since the material removal rate is related to the melting point of the metal to be machined. It is one of the prominent methods used in die manufacturing and has a very good accuracy and precision with no direct physical contact between the machine tool electrode and the work piece so that mechanical stress is not exerted on the work piece.

Electric Discharge Machining Process

Working Principle: Electrode advances into the steel die material. On supplying the electric current, spark is generated between tool electrode and die material creating high temperature which melts the die metal and vaporizes it. The molten and vaporized metal is removed away from the spark gap (gap between the electrode and metal) [1] by the flow of dielectric fluid. The temperature is controlled by regulating the spark gap between the electrode and the metal. Both electrode and the die metal should have good electrical conductivity to generate the good spark. The quality of the surface finish and the material removal rate are controlled by the frequency and the spark intensity. Generally to obtain better surface finish of the die, high frequency and low current are used [1].

Figure1: working priciple of EDM[1]

There are two main types of EDMs, the Sinker and the Wire-EDM. Each is used for machining very small and precision parts and large items like automotive stamping dies as well.

In Sinker EDM machines, the tool/electrode is fixed to the ram which is connected to positive terminal; the die metal is connected to the negative terminal of a pulsed power supply. The metal is then positioned in such a way that there is gap between metal and the tool. Dielectric fluid is flooded in the spark gap. By supplying the power, current impulses of very high frequency pass through the gap, beginning the machining process. The temperature range of the sparks generated is from 14, 000° to 21, 000° F [1]. As the metal erosion continues, the tool/electrode advances into the metal while maintaining a constant distance from the metal. The shape of the electrode is the mirror image of the finished die metal cavity. After machining, the die metal cavity is larger than the electrode when measured. This dimensional difference is termed as the overcut or kerf.

Figure2: Schematic illustration of the electrical discharge machining process [10]

Following are the sub-systems of Sinker EDM:

DC power supply with controls for voltage, current, frequency, and polarity

Dielectric system to flush away work and electrode debris, this fluid is mostly a hydrocarbon or silicone based oil

Servo system to control feed, tool path of the electrode and to maintain gap maintenance

The Wire EDM process has an electrically charged wire with diameter ranging from 0. 002 to 0. 013[1] inches used for machining complex, intricate profiles and cuts. This type is specifically useful in cutting fine details in pre-hardened blanking dies and pre-hardened steels. An electric wire drive system continuously releases out the fresh wire for long periods without operator attention to cut the metals so it has no wear problem of tool electrode. These wires will create a kerf slightly greater than their own diameter. A . 012 wire will leave a 0. 015 kerf, just 0. 003[1] inches larger. The four basic subsystems include:

DC power supply

Dielectric system

Wire feeding system

Work positioning system

Different techniques are employed in order to improve the material removal rate MMR. Following are the different techniques discussed to improve MRR.

Electrode profile: Computer numerical controlled EDM machines which are now available can generate complicated shapes within less time, economically without using usual and traditional 3-D complex shaped Electrodes . To have the higher MRR frame type tooling is used for the die shapes having linear or axi-symmetrical swept surfaces. The plate type tool has better material removal rate compared to a 3-D form tool.

Figure 3 shows differnces between 3D-form tool, frame tool, and plane type tool[1].

Controlling process parameters: The MRR can be controlled and improved by controlling process parameters like discharge voltage. This parameter is generally related to dielectric strength and spar gap. Higher voltage setting results in higher spark gap, improves flushing conditions which ultimately increases in both MRR and tool wear. Flushing conditions can be improved by introducing electrode rotation, increasing flushing pressure, and tube electrode design and work piece rotation.

EDM Variations: MMR can be increased greatly by implementing ultrasonic vibration. MRR is higher for a discharge pulse-on time for ultrasonic vibration assisted machining. Ultrasonic vibration EDM is mostly used to create small and deep holes products.

Figure 4: Vibratory, rotary and vibro-rotary electrode [1]

Powder Mixed Dielectrics: Powder mixed electric discharge machining (PMEDM) has improved capabilities of the EDM process. In this process, a suitable material in fine powder is properly mixed into the dielectric fluid to improve its breakdown characteristics. This results in decreasing the insulating strength of the dielectric fluid, and finally leading to the increase in the spark gap. Increased spark gap distance makes the flushing of debris uniform, thus improving MRR and surface finish.

Figure 5: principle of powder mixed EDM [1]

Dry EDM is a process which gas is the dielectric medium. Due to thermally activated chemical reaction between the gas and die material the discharge power density on the working surface exceeds a certain threshold limit which increases the MRR. The MRR of dry EDM milling is about 6 times greater than that of oil EDM milling.

Figure 6: principle of dry EDM [1]

Some Other Techniques: Use of the multiple electrodes simultaneously increases the MRR and relative electrode wear ratio. We can use multiple electrodes either in linear orientation or just like a planet gear model in which planets are electrodes and gear is the die or work piece metal. This is usually used for cutting pipes etc.

Figure7: Multi Spark EDM, Difference between conventional & multi electrode EDM[1]

The Effects on Surface Quality

Electrical discharge machining (EDM) gains importance these days because of its ability of accuracy and complicated shapes cutting. EDM machine is evaluated in terms of its effectiveness of material removal rate, surface roughness of the work piece, and relative wear ratio.

The electrical discharge machining process involves interaction of mechanical, thermal, chemical and electrical phenomena. The input discharge energy influences the machining

characteristics such as surface roughness.

During the process, electrical energy is converted into heat energy which bases upon heat transfer equations. Then the fraction of the energy transfers to the work piece.

Figure8. The electrical sparks fuse the surface of the die

Models are made for EDM tests showing that the testing can efficiently make material removal rate and parameter of surface roughness with errors up to 94% accuracy. The optimum parameters of heat transfer and the optimum utilization of input discharge energy will help improving the technological performance.

Figure9. Different tool parts made by EDM machine

Surface modification of steel die is important when doing electrical discharge machining (EDM). Work piece of the steel die surface may be provided certain sort of material through using powder-mixed dielectric or the eroding tool electrode. Some other factors such as breakdown of the hydrocarbon dielectric also cause steel surface modification.

As recent research provided, machining processing parameters for the best value of micro-hardness of steel die piece are found to be same.

Figure10. Surface view of the work piece after electrical discharge machining

Material Selection

When it comes to selecting materials for EDM, two functions of the material are very important. Those functions are the conductivity and erosion resistance of the material. The material in this case is also called the electrode. Since the process calls for the use of an electric current, the cutting efficiency depends of the conductivity. Erosion resistance is a factor of melting point, hardness, and structural integrity of an electrode. Strong qualities will provide more use out of the electrode and as a result, and therefore, fewer times that the electrode needs replacing. These properties are the factors looked at when selecting an electrode, which makes choosing the right material important. The type of EDM process and the material chosen then have to be applied to the manufacturing of steel dies.

There are several different types of material to choose from that would work sufficiently for EDM. These materials include but are not limited to brass, graphite, copper, and tungsten. The two types of material being considered here are graphite and copper.

The properties of these two materials as well as the type of EDM process being used factor in to making the decision. For instance, when using Wire EDM, an electrode with high ductility is sought. This is compared to Sinker EDM, where an electrode that conducts heats well and is easily machinable is most efficient to use. Copper is a good use for Wire EDM while graphite is a good use for Sinker EDM.

Graphite is very widely used and its many advantages are the reason why. It has a much lower density than copper resulting in lighter electrodes being used. It is very easily machined. The electrical resistivity is very low which means the conductivity to heat is high. Graphite does not have a melting point; it skips the liquid state and goes directly from a solid to a gas at high temperatures. All of these attributes are contributing factors to reduce the wear resistance of graphite. Graphite is relatively inexpensive, too.

Copper is also commonly used. Copper has good strength and conductivity, making it more wear resistant than materials such as brass. There is no comparison to graphite for resistance, though. Unlike graphite, copper does not leave any dust behind when being machined and therefore, is a much cleaner process. This keeps the machines much cleaner, too.

Table1. Physical properties of graphite and copper electrode [26]

Physical properties

Graphite

Copper

Electrical resistivity (Î¼Î©/cm)

0. 12

1. 96

Electrical conductivity compared with silver (%)

0. 11

92

Thermal conductivity (W/m K)

160

380. 7

Melting point (°C)

455

1083

Specific heat (cal/g °C)

0. 17-0. 2

0. 092

Specific gravity at 20 °C (g/cm3)

1. 75

8. 9

Coefficient of thermal expansion (Ã-10âˆ’6 °Câˆ’1)

7. 8

6. 6

To conclude, the comparison of graphite and copper when it comes to manufacturing steel dies has its advantages and disadvantages. Using a copper electrode will produce a more rough finish, whereas, with a graphite electrode a finer finish is achieved. Copper has a greater material removal rate than graphite and graphite has a higher wear resistance than copper. Graphite is the material of choice here.

Limitations of the Material

Despite all of its advantages, graphite does have its limitations. One major limitation in the tooling of the electrode is that graphite has very poor ductility, eliminating it from consideration when choosing Wire EDM. Another less inhibiting limitation is how dirty graphite can be. Having a proper process in place to remove the dust during the machining process will solve this problem, but it is an issue nonetheless. Graphite dust can be harmful to the people working with the machines and to the machines themselves. This is why a proper dust removal process is essential to have in place.

Figure11. Graphite dust collection machine [28]

As with graphite, copper has some limitations as well. Copper is much more difficult to machine than graphite is due to it being so flexible. Copper electrodes also last a much shorter time than graphite electrodes do. To increase the level of machinability, tellurium is added to copper. Although, this solves issue of machinability, wear resistance and metal removal rate is lower in the process. Copper is more expensive than graphite is, too.

Cost Consideration

The cost involved in any manufacturing process is one of the most important factors a manufacturing engineer has to consider while selecting the process. The cost involved in the EDM process comprises of the cost of the electrode, the setup and the dielectric fluid. Of these, the most important is the cost involved in fabrication of the electrode. In the die-sinking EDM process, the shape of the electrode is a mirror image of the profile to be produced on the die, so the cost of fabrication of the electrode depends on the geometric complexity of the die to be manufactured and also on the type of the electrode material. For the die sinking EDM process, since we have chosen graphite as the electrode material, the fabrication of graphite, as we all know is difficult, so the cost involved in fabricating the graphite electrode will be more. One of the techniques which could be employed to decrease the cost is to use the ‘ worn out’ electrode which was used in the previous finishing operations, to perform roughing cut in the next operation or the next component. In this way, a considerable savings could be obtained in the total cost, especially in the case of mass production.

The cost of the setup involves the cost of the equipment, maintenance, degree of automation and labor cost (if applicable). This is one of the major disadvantages of the die-sinker EDM process. As we know that in the die-sinker EDM process, the workpiece has to be immersed into the Dielectric fluid prior to machining. The tank should be emptied before mounting a new workpiece, and the same is to be done while removing the machined part. This hampers the continuity of the process and makes it highly discontinuous and intermittent. This further results in longer cycle time and hence increases the cost. The dielectric has to be pumped in and out of the tank, this increases the energy consumption and hence the cost.

The cost of the dielectric involves the cost incurred in buying and maintaining the dielectric fluid. If we use kerosene as our dielectric fluid, then there is going to be an additional cost in taking the safety measures as to prevent the fire hazards. Also the conductivity of the dielectric has to be carefully maintained.

Environmental Impact

The EDM process has many environmental issues; some of them are as follows:

The high tension in the gap results in the generation of smoke, vapours and aerosols which are hazardous in nature.

If the dielectric fluid used in the EDM process is a hydrocarbon, then it will have an adverse effect on the skin.

There may be a possible fire hazard, if the dielectric fluid used is kerosene (as in our case).

In some conditions, explosions may also occur.

The electromagnetic radiations emitted during the process may also have an adverse effect on the skin.

The EDM process, the total amount of the vapors released may even exceed 5 mg/m3 [9] if proper measures are not taken. The amount of fumes and aerosols released depend on many factors such as the process, the electrode, and the dielectric fluid involved. These are produced more in the case of die-sinking EDM than in wire EDM process. Special care should take if nickel is present in any of the components involved in the process (either the workpiece or the electrode). This is because of the toxic nature of nickel. The amount of fumes released also depend on the viscosity of the dielectric fluid involved, lower the viscosity, lesser are the fumes. As a rule of thumb, the level of the dielectric fluid should be at least 40mm (80mm is recommended)

[8] higher than the erosion spot, so that a considerable part of the fumes gets condensed and absorbed in the dielectric fluid itself. But again disposal of the dielectric is also an issue.

A few of the hazardous fumes produced during the die sinking EDM process are: Polycyclic Aromatic Hydrocarbons (PAH), Benzene, mineral oil vapor, and mineral aerosols etc.

Apart from this, the metal debris from the interelectrode gap from the workpiece surface is also collected in the dielectric fluid, which needs proper disposal so as to avoid environmental pollution.

Conclusion

The use of die sinking electric discharge machining for the manufacture of steel dies is discussed. We conclude that, even though the die sinking EDM process has its advantages as well as disadvantages, it can be employed to efficiently manufacture steel dies.