Study of EDM Parameters on Surface Finish of Hot Die Steel-H13
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Abstract— EDM is a material removing process using electric discharge. The basic EDM system consists of a shaped tool (electrode) and the work piece, connected to a D.C. power supply and placed in a (dielectric, electrically non-conducting) fluid. When the potential difference between the tool and the work piece is sufficiently high, a transient spark discharges through the fluid removing a very small amount of metal from the work piece surface. After the machining process the major criteria is the surface texture of all machined components. It may be depends on the requirements of the customer and the application.

In this study the work material Hot Die steel-H13 is selected. The main objective of the study is to find surface finish of the work material machined in EDM. The process parameters like spark gap, working current and dielectric fluid flow are varied and experiments are conducted. The parameters that affect the surface finish of work material can be found out by experimental observations i.e by visual method.

Keywords— EDM, Surface Finish, Hot Die Steel

I. INTRODUCTION

Accompanying the development of mechanical industry, the demands for alloy materials having high hardness, toughness and impact resistance are increasing. Nevertheless, such materials are difficult to be machined by traditional machining methods.

Hence, non-traditional machining methods including electrochemical machining, ultrasonic machining etc, are applied to machine such difficult to machine materials. EDM process with an electrode transforms electrical energy to thermal energy for cutting materials. With this process, alloy steel, conductive ceramics and aerospace materials can be machined irrespective to their hardness and toughness.

In manufacturing industry, Electro Discharge Machining (EDM) is commonly used for producing mold and die component. This machine is use because the ability of the machining process that is very accurate in creating complex or simple shape within parts and assemblies. The cost of machining is quite high payable to its initial investment and maintenance for the machine but very desirable machining process when high accuracy is required.

Many studies have been carried out for improving or finding ways to obtain good surface quality of the EDM process. From the results, these study show that the machining parameter is the most important factor in producing good surface finish on the work piece.

Hence, with the information from previous studies about the effect of machining parameters on the surface roughness, the machining parameters can be set for maximum or optimum machining.

Product designers constantly strive to design machinery that can run faster, last longer, and operate more precisely than ever. Modern development of high speed machines has resulted in higher loading and increased speeds of moving parts. Bearings, seals, shafts, machine ways, and gears, for example must be accurate - both dimensionally and geometrically. Unfortunately, most manufacturing processes produce parts with surfaces that are either unsatisfactory from the standpoint of geometrical perfection or quality of surface texture.

As industry tries harder to approach perfection, interest has focused more closely than ever before on the micro finishing processes like honing, lapping, and super finishing. Each process was designed to generate a particular geometrical surface and to correct specific irregularities and so must be applied carefully to a given production sequence.

Also, each process is a final operation in the machining sequence for a precision part and is usually preceded by conventional grinding. This primer begins by explaining how industry controls and measures the precise degree of smoothness and roughness of a finished surface.

The Qualitative studies of Surface finish by selecting the working current in EDM Machine and observed macroscopically by taking the photograph of machined part.

The Qualitative studies of Surface finish by selecting the various flow rates of die-electric fluid in EDM Machine and observed macroscopically by taking the photograph of machined part.

The Qualitative studies of Surface finish by selecting the various spark gaps EDM Machine and observed macroscopically by taking the photograph of machined part.

In the above three cases each one sample is observed under optical microscope.
A. Electric discharge machine (EDM)

Electric discharge machining (EDM), sometimes colloquially also referred to as spark machining, spark eroding, burning, die sinking or wire erosion, is a manufacturing process whereby a desired shape is obtained using electrical discharges (sparks).

Electrical discharge machining is a machining method primarily used for hard metals or those that would be very difficult to machine with traditional techniques. EDM typically works with materials that are electrically conductive, although methods for machining insulating ceramics with EDM have also been proposed. EDM can cut intricate contours or cavities in pre-hardened steel without the need for heat treatment to soften and re-harden them. This method can be used with any other metal or metal alloy such as titanium, hastelloy, kovar, and inconel.

B. EDM Process

![Fig 1 EDM Process](image)

EDM is a process that is used to remove metal through the action of an electrical discharge of short duration and high current density between the tool and the work piece. There are no physical cutting forces between the tool and the work piece. EDM works by removing material by creating controlled sparks between a shaped electrode and an electrically conductive work piece. As part of the material is eroded, the electrode is slowly lowered into the work piece, until the resulting cavity has the inverse shape of the electrode. Dielectric fluid is flushed into the gap between the electrode and work piece to remove small particles created by the process and to avoid excessive oxidation of the part surface and the electrode. The EDM process uses electrical discharges to remove material from the work piece, with each spark producing a temperature of between 10,000-20,000°C. Consequently, the work piece is subjected to a heat affected zone (HAZ) the top layer of which comprises recast material. The thickness, composition and condition of this layer depend on the discharge energy and the make-up of the work piece, tool electrode and dielectric fluid, and both hard and soft surface layers can be produced despite perceived wisdom that the recast layer is always hard.

With ferrous work piece materials, the recast layer typically appears white and amorphous when viewed under a microscope, and is prone to tensile stress, micro cracking and porosity.

C. The Machine Tool

The Machine tool is a C-frame fabricated structure duly stressed relieved to ensure no deformation with time. The base is machined on the top surface. It is hollow inside and has provision for mounting, with four leveling pads. Bolts are provided with plates underneath for leveling the machine. A vertical column also fabricated, stress relieved and machined is fixed on the base. There is a provision to raise the height of the column by adding spacers between the base and the column, if needed. Care should be taken to ensure the spacers is machined and ground to ensure retention of accuracy of the machine.

The quill assembly is fixed on to the column of the machine and above the base at the front. The assembly consists of a quill spacer on which it is mounted. The front and back of the quill spacer is ground to accuracy.

The quill is fixed on to the spacer through rigid bolts. The quill consists of a rhomboidal moving member and ground to accuracy on all side which moves along hardened and ground guide-wax's and holds the electrode platen at the bottom.

This member is hollow and has a bronze nut at the top. A precision screw rod mover in the nut and has a timing pulley mounted on it. A precision stepper motor transmits the motion through a timing belt. The quill moves on V-guides on precision bearings. It is required to lubricate the screw-rod and the guide-ways daily before starting the machine. A front cover protects the quill bearings and the guide-ways from dust.

A dial indicator and a depth micrometer assembly are provided on the front cover along with the limit switch viz.. Depth stop when actuated by the depth micrometer trips the machine from further sparking process. The dial indicator records the depth of the machining. A top limit switch is provided at the top which limits the upward movement of the quill beyond a set distance. On the platen an insulating fiber plate is fixed that separates the anode with the cathode. An electrode holder is mounted below the fiber plate.

The work-table is another important, ingredient of the machine tool, which is made out of close grained cast iron, duly stress relieved, machined accurately and ground to accuracy. T-slots are provided on the table for easy clamping of the jobs. The work-table moves on hardened and ground linear cage bearings which are provided along the length of the movement. Hardened and ground precision screw-rod's of 4mm pitch moves the slide
against a ground nut. Below the work-table, is an intermediate table which is fixed with guide-ways and bearings for the cross movement. The entire assembly is fixed on the bottom table with V-guides and bearing which in turn is fixed on to the base. All the components of the table are precisely machined to achieve the required accuracy.

A work tank is fixed on the top of the worktable and consists of a door with a rubber gasket sealing. This gasket ensures tight sealing of the door to prevent leakage of the dielectric medium when closed. The left side of the tank has a partition that houses a quick oil drain mechanism. Turning the lever towards the left opens the drain and turning towards the right closes the drain. An adjustable overflow vent facilitates the adjustment of the dielectric level and helps in maintaining a constant level during the machining process.

An inlet is provided at the right bottom on the rear side of the tank through which filtered dielectric flows in. The work-tank is fixed on to the work-table through a neoprene rubber gasket which prevents the leakage of the oil below the work-tank. A float switch provides a safety interlock during machining. The level of the float switch is adjusted till about 50mm above the job to ensure sufficient dielectric level during machining.

Fig 2 EDM Machine
Make: VM Engineers Bangalore (SE2000V5030)

D Surface Finish

Surface finish is a characteristic of any machined surface. It is sometimes called surface texture or roughness. The design engineer is usually the person that decides what the surface finish of a work piece should be. They base their reasoning on what the work piece is supposed to do. Here are a few examples that the engineer considers when applying a surface finish.

- Good surface finishes achieve high efficiency. High quality surface finishes coupled with millionths of inch fit will produce less friction. For example a 75HP piston engine can loosen up to 5HP to the friction of the connecting rods, crank, and piston unless high quality finishes are applied.
- Good surface finishes increase the wear resistance of two work pieces in an assembly
- Good surface finishes reduce the friction between two work pieces in an assembly
- Good surface finishes have a cosmetic effect and make your parts “look good”.
- Good surface finishes are the norm in several industries, as in the microprocessor industry.
- Good surface finished permits the proper function of static and dynamic O-ring seals in hydraulic and pneumatic equipment.

The design engineer communicates their desires by using a blueprint. The blueprint is the communication medium that the machinist will use to make the work piece. The surface finish is defined and measured as a surface profile. The main components of a surface profile are waviness and roughness.

Fig 3: The component of a surface profiles

There are three general methods by which the surface texture and the surface geometry may be explored and evaluated: electronic, optical, and visual or tactual.

Electronic: There are two types of electronic instruments which measure actual surface texture: averaging (or velocity type) and profiling (or displacement type). Averaging or tracer-type instruments employ a stylus that is drawn across the surface to be measured. The vertical motion of the tracer is amplified electrically and is impressed on a recorder to draw the profile of the surface or is fed into an averaging meter to give a number (AA) representing the roughness value of the surface. Profiling equipment is used principally in laboratories for research and development applications. Considerable skill is required to operate the equipment and analyze and interpret the data.

Optical: Optical or area systems use optical methods for surface evaluation. Equipment ranges from exploration of the surface with simple
microscopes or three-dimensional micro-topography to highly sophisticated techniques such as interferometry.

Area systems inspect the entire surface, not simply one line across it. The surface texture in this process is clearly distinguished from the surface geometry. Because there is no stylus, the surface is not mechanically contacted, and thus there can be no damage to the work-piece surface. Another important advantage of optical inspection methods is that the biasing effect of the stylus radius is eliminated.

**Visual or Tactual:** The visual or tactual is the simplest and most straightforward method of surface measurement. Comparators of this type are readily available with various surface finish from 2 to 1000 in. is available. The scales, used with or without a magnifier, are placed adjacent to the workpiece under examination and the surfaces are compared visibly or tactualy by drawing the tip of the fingernail across each at right angles to the tool marks. The fingernail touch or "feel" will be the same when both finishes are identical. Another method is using Macroscopic Observation in which comparison is done by using photographs.

**E. Workpiece Material And Tool Material**
In the project selected work material is HD13 steel and the tool material is copper. The compositions and the properties are explained below.

Table 1: Chemical composition of Hot Die Steel (H13)

<table>
<thead>
<tr>
<th>Constituents</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Cr</th>
<th>Mo</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Composition</td>
<td>0.38</td>
<td>1</td>
<td>0.5</td>
<td>5</td>
<td>1.4</td>
<td>1</td>
</tr>
</tbody>
</table>

**F. Applications**
- Suitable for making of aluminum, zinc and copper alloy extrusion dies, casting dies and hot shearing blades, etc
- Small silver polish steel (scaled and cold drawn), which is an ideal material for ejection pins and sleeves.
- Also suitable for manufacture of plastic molds of high productivity and long service life.

Hardness: 52 to 56 HRC

**G. Characteristics**
XFH13 is general-purpose hot die steel containing chromium-molybdenum-vanadium (Cr-Mo-V) alloy with the characteristics. It is applicable to be used in die-casting, hot extrusion and hot forging die, with advantages as follows:

- With good cold-hot fatigue resistance
- With high thermal strength under the high temperature of 600
- With good fracture toughness and ductility
- With good dimensional stability for heat treatment and hardenability
- With good polishing performance

**Fig 4 Hot Die Steel-H13**
The HD13 steel is selected for the study because when there is some complicated shapes are to be cut which are of smaller size and shapes it is difficult to machine by conventional methods in the selected material. The material is mainly used for making Die cast dies, Plastic moulds and Injection moulds. EDM Process is suitable for machining such small complicated shapes in Dies.

**H. Electrode Material OR Tool Material**
Electrode material should be such that it would not undergo much tool wear when it is impinged by positive ions. Thus the localized temperature rise has to be less by tailoring or properly choosing its properties or even when temperature increases, there would be less melting. Further, the tool should be easily workable as intricate shaped geometric features are machined in EDM. Thus the basic characteristics of electrode materials are:

- High electrical conductivity – electrons are cold emitted more easily and there is less bulk electrical heating
- High thermal conductivity – for the same heat load, the local temperature rise would be less due to faster heat conducted to the bulk of the tool and thus less tool wear
- Higher density – for the same heat load and same tool wear by weight there would be less volume removal or tool wear and thus less dimensional loss or inaccuracy
- High melting point – high melting point leads to less tool wear due to less tool material melting for the same heat load
- Easy manufacturability
- Cost – cheap
- The followings are the different electrode materials which are used commonly in the industry:
  - Graphite
  - Electrolytic oxygen free copper
  - Tellurium copper – 99% Cu + 0.5% tellurium
  - Brass
II. DESIGN OF EXPERIMENT

The study includes the various EDM process parameters like Current Density, Dielectric Fluid Flow, and Spark Gap etc. By changing the process parameters, the effect of Machining on the Materials HP5-13 is observed and surface finish is qualitatively measured. The various selected process parameters for the study are

- Working current.
- Dielectric Fluid Flow.
- Spark Gap

The results may vary +/- 10% based on the following conditions mentioned below:

- Less than 2% in AC supply voltage.
- By use of clean dielectric fluid.
- By maintain average current density of 5 amps/sq-cm
- It should be noted that the different configure relation of electrode and work piece, the results obtained may vary.

Table 2: TOOL MATERIAL – COPPER (Cu)

<table>
<thead>
<tr>
<th>Electrode Shape</th>
<th>Size</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexagon</td>
<td>19mm across flat</td>
<td>Copper(Cu)</td>
</tr>
<tr>
<td>Circular</td>
<td>ø 25mm</td>
<td>Copper(Cu)</td>
</tr>
<tr>
<td>Rectangle</td>
<td>11x24mm</td>
<td>Copper(Cu)</td>
</tr>
</tbody>
</table>

Fig 5 Electrolytic Oxygen free copper Tool material

Table 3: Shows selection of Variation in Working Current

<table>
<thead>
<tr>
<th>PULSE ON</th>
<th>PEAK CURRENT (amps)</th>
<th>WORKING CURRENT (amps)</th>
<th>SPARK GAP (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
<td>2</td>
<td>0.06</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>5</td>
<td>0.12</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>6</td>
<td>0.13</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>8</td>
<td>0.18</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
<td>12</td>
<td>0.25</td>
</tr>
<tr>
<td>9</td>
<td>25</td>
<td>25</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 4: Shows selection of Variation in Spark Gap

<table>
<thead>
<tr>
<th>PULSE ON</th>
<th>PEAK CURRENT (amps)</th>
<th>WORKING CURRENT (amps)</th>
<th>SPARK GAP (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>3</td>
<td>3</td>
<td>0.07</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>7</td>
<td>0.15</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>9</td>
<td>0.20</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>35</td>
<td>0.35</td>
</tr>
<tr>
<td>7</td>
<td>25</td>
<td>25</td>
<td>0.40</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>43</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Table 5: For a current of 3 amps and spark gap 0.07 mm

<table>
<thead>
<tr>
<th>Position of Valve</th>
<th>Time taken for Machining</th>
<th>Time taken for collecting 1 ltr (sec)</th>
<th>Flow Rate (ltr/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>7</td>
<td>4680</td>
<td>16</td>
</tr>
<tr>
<td>Medium</td>
<td>67</td>
<td>4020</td>
<td>11</td>
</tr>
<tr>
<td>High</td>
<td>70</td>
<td>4200</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 6: For a current of 6 amps and spark gap 0.13 mm

<table>
<thead>
<tr>
<th>Position of Valve</th>
<th>Time taken for Machining</th>
<th>Time taken for collecting 1 ltr (sec)</th>
<th>Flow Rate (ltr/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>7</td>
<td>420</td>
<td>15</td>
</tr>
<tr>
<td>Medium</td>
<td>8</td>
<td>480</td>
<td>10</td>
</tr>
<tr>
<td>High</td>
<td>11</td>
<td>660</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 7: For a current of 10 amps and spark gap 0.2 mm

<table>
<thead>
<tr>
<th>Position of Valve</th>
<th>Time taken for Machining</th>
<th>Time taken for collecting 1 ltr (sec)</th>
<th>Flow Rate (ltr/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>04</td>
<td>240</td>
<td>14</td>
</tr>
<tr>
<td>Medium</td>
<td>05</td>
<td>360</td>
<td>11</td>
</tr>
<tr>
<td>High</td>
<td>05</td>
<td>360</td>
<td>07</td>
</tr>
</tbody>
</table>

Table 8: For a current of 25 amps and spark gap 0.4 mm

<table>
<thead>
<tr>
<th>Position of Valve</th>
<th>Time taken for Machining</th>
<th>Time taken for collecting 1 ltr (sec)</th>
<th>Flow Rate (ltr/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>02</td>
<td>120</td>
<td>15</td>
</tr>
<tr>
<td>Medium</td>
<td>02</td>
<td>120</td>
<td>12</td>
</tr>
<tr>
<td>High</td>
<td>02</td>
<td>120</td>
<td>08</td>
</tr>
</tbody>
</table>
III. RESULTS AND DISCUSSIONS

By changing the working current some experiments are carried on EDM machine. The photo taken by high resolution camera for the observation of the machined samples, these photographs are gives the comparisons of the surface finish in the work material for the related working currents.

Fig: 6 comparatively fine surface

In the first machined sample, which is machined by selecting working current 2 amps. The result of finishing is comparatively fine to other samples by tactually and visually and the zoomed photograph also shows less peaks and valleys.

Fig: 7 Medium rough surface

In second machined which is machined by selecting working current 5 amps has some rough surfaces while it is zoomed as shown in above fig. it have some peaks and valleys which will have some distances.

Fig: 8 Medium rough surface

In the third machined sample which is machined by selecting working current 6 amps has medium rough surface compare to 5 amps machined surfaces as shown in above fig.

Fig: 9 Rough surfaces

Fourth sample is shows which machined by working current 8 amps has medium rough surface. There is less deviation in selecting of current.

Fig: 10 Rough surface

In the machined sample five the working current is 12 amps shows rough surface by observation.

In the machined sample six the working current is 25 amps shows roughest surface by tactual and visual observation.

Result: By observing all the machined samples the surfaces finish is depends upon current density retardation of tool lead and the spark gap. For the good surface finishing the components are to be machined at low working current with more time machining operation but it is not economical. But for HD13 steel the machining can be done at medium level of working current for medium rough finishing and less amps are used for good surface texture. If the gap is more than the current density is required more.

By varying the spark gap there are some observations in macroscopic some photograph zoomed and observed for the final result.

Fig 12 Comparatively fine surface and shows a HAZ

The machined sample in figure above for which the selected spark gap is 0.07mm which shows some HAZ and patches but it remaining finish is good compared with other.

Fig 13 Medium Rough Surface

The machined sample in the figure above which selected spark gap of 0.15 mm in which there is no HAZ and patches but the surface finish texture is medium rough compared to first machined sample observed by the photograph view.

Fig 14 Medium Rough surface

The machined sample in the above figure for which the selected spark gap of 0.20 mm in which there is no effect of HAZ. Surface is rougher.

Fig: 15 Rough surface

The machined sample in the figure above for in which the selected spark gap 0.35 in which there is no effect of HAZ. Surface is rougher.

Fig 16 Highly Rough Surface
The machined sample in the figure above for which the selected spark gap of 0.40 mm is roughest surface finish. It is observed by the zoomed photographic view.

Fig 17 Highly Rough Surface

The last machined sample in the above figure for which the selected spark gap is more and is 0.5 mm it shows the roughest surface by the zoomed photography.

Finally by the above observations, the result is if there is more spark gap then the machine surface rougher for the selected current so proper spark gap are to be selected to obtain fine, medium and rough surfaces defending on the requirement for the work materials.

By varying dielectric fluid flow there are four working currents are related with the different flow

The figure A shows the zoomed photography of the machined sample for that flow is kept minimum with peak current is 3 amps. But if there is dielectric fluid flow is the finishing is good because of low working current. For the second machined sample flow is medium and the finishing is slightly rough when compared to the first one with the same working cutter of 3 amps as shown in fig B.

When the flow is medium for the same working current of 6 amps there is some slight changes is observed as shown in fig E.

In the fig F machined sample the zoomed photography shows some rough finish. It is justify the result that if more working current and high dielectric fluid flow the surface become as same as the first sample observed.

The fig G shows the zoomed photograph of machined sample for that selected working current 10 amps and for the minimum flow. There is great influence on the surface texture which is observed medium rough visually.

For the working current 10 amps and for the medium flow the surface finish is visually observed as same as the 7th sample as shown in fig H.

For the working current of 10 amps and for the high flow of the photograph as shown in fig I. medium rough finish as 7th sample.

The fig J shows the zoomed photograph of machined sample for that selected working current 25amps and minimum flow. The surface finish is rough. Because the flow is minimum.

For the working current 25amps and for the medium flow of the photograph below shows rough finish as shown in fig K.

For the working current 25amps and for the high flow of the photograph as shown in fig L. rough finish.

From the above observations it is found that for the lower working current if there is change in dielectric flow (for 3 amps and 6 amps) there is some influence on the surface finish of the work material i.e. for lower flow and lower working currents the surface finish become same for all the first 6 samples and the remaining samples shows medium rough and rough surfaces. So there is no great influence of the dielectric fluid flow on the higher working currents, because it is observed same surfaces visually and tactually.

A. Optical Microscopic Result

Optical Microscope is used to examine the EDM surface of the HD13steel. EDM surfaces are observed using optical microscope to see the surface texture. Under shorter pulse on time and lower working current produces good surfaces than higher pulse on and working current as shown in fig 19.

The micrograph also shows the peaks and valleys of different samples when there is variation is working current and variation in dielectric flow.
The below fig 8.15 graph shows the variation of working current and surface finish which shows that as the working current increases the surface finish decreases and vice versa.

The below fig 8.15 graph shows the variation of spark gap and surface finish which shows that as the spark gap increases the surface finish decreases and vice versa.

IV. CONCLUSIONS
The main conclusions which can be deduced from this project can be summarized as follows.
1. The photography from the different machined samples shows that the good surface finish can be obtained by low working current.
2. The dielectric fluid flow variation does not affect much on the surface finish of the HD13 steel.
3. The lower the spark gap higher the surface finish and higher the spark gap material removal rate will be more but lesser will be the surface finish.
4. The surface finish is mainly dependent on the working current and spark gaps.

REFERENCES