CHAPTER 4

FUNDAMENTALS OF WIRE ELECTRICAL DISCHARGE MACHINE

4.1 INTRODUCTION

Removal of certain portion or parts of the workpiece by machining, converts the raw material into the final product or semi finished product or assembly components. In the past few decades, the machining process has been rapidly developed and classified into two major types namely traditional machining and nontraditional machining. Traditional machining is the conventional type of machining, in which a tool, harder than the workpiece material hardness is used for machining of the workpiece. The relative motion between the tool and workpiece, penetration of the tool into the workpiece i.e. the field of the tool, are responsible for the machining of the workpiece in the traditional machining Hassan Abdel (2006). Hence, the productivity of the process depends upon the hardness of the workpiece material i.e. greater the work hardness, the lower the productivity. Moreover, it is difficult to assign a tool material for the economic machining of materials such as ceramics, alloys, composites, tungsten carbides etc. Kozak & Rajurkar (2001). Also achieving surface finish, close tolerances and production rate of these materials is very limited in the traditional machining process.
4.1.1 Introduction to Unconventional Machining

The limitations of traditional machining can be overcome by the unconventional machining processes, due to the absence of the workpiece-tool contact or relative motion of the tool to workpiece. In modern production industries, nontraditional machining processes have well established their capability of machining hard materials much easier than traditional machining process Misra (2005). The developments in the field of nontraditional machining process lead to the classification based on the machining action which helps in the removal of material from the workpiece Kim (2005). The features which classify the nontraditional machining processes are its process parameters, technological characteristics, machining system components and industrial applications Kumar Sandeep et al (2013).

Unconventional machining processes are classified based on the type of energy used for removal of the metal and are as shown in Table 4.1. In this process, energy is applied directly for removal of the metal by means of mechanical, thermal, electrochemical and chemical dissolution.

In mechanical types of machining process, mechanical energy is employed to remove material from the workpiece. In thermal process, heat energy is responsible for the thermal erosion of material from the workpiece surface. In electrochemical and chemical machining processes, the chemical reactions remove the metal from the workpiece. While considering the precision machining and ultra precision machining, these types of machining processes become still more important Kim (2005).

In the mechanical type of processes there are two categories i.e., machining processes and finishing processes. Machining process is used for bulk removal of material and finishing process is used for correcting
machining defects or for shaping the components and surface finishing of the components Hassan & Hofy (2005).

**Table 4.1 Classification of unconventional machining processes**

<table>
<thead>
<tr>
<th>Type of Energy</th>
<th>Process Name</th>
<th>Mechanism of metal removal</th>
<th>Source of energy</th>
<th>Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>USM</td>
<td>Erosion</td>
<td>Ultrasonic Vibration</td>
<td>Abrasive slurry</td>
</tr>
<tr>
<td></td>
<td>AJM</td>
<td>Or</td>
<td>Pneumatic Pressure</td>
<td>Air Abrasive jet</td>
</tr>
<tr>
<td></td>
<td>WJM</td>
<td>Abrasion</td>
<td>Hydraulic Pressure</td>
<td>Water jet</td>
</tr>
<tr>
<td></td>
<td>AWJM</td>
<td></td>
<td>Hydraulic Pressure</td>
<td>Abrasive water jet</td>
</tr>
<tr>
<td></td>
<td>IJM</td>
<td></td>
<td>Hydraulic Pressure</td>
<td>Ice Jet</td>
</tr>
<tr>
<td></td>
<td>AFM</td>
<td></td>
<td>Magnetic field</td>
<td>Media (abrasive)</td>
</tr>
<tr>
<td></td>
<td>MAF</td>
<td></td>
<td>Magnetic field</td>
<td>Magnetic brush</td>
</tr>
<tr>
<td>Thermal</td>
<td>EDM</td>
<td>Melting</td>
<td>High Voltage</td>
<td>Electrode</td>
</tr>
<tr>
<td></td>
<td>EBM</td>
<td>And</td>
<td>Ionized Material</td>
<td>Electrode Beam</td>
</tr>
<tr>
<td></td>
<td>IBM</td>
<td>Evaporation</td>
<td>Ionized Material</td>
<td>ION Beam</td>
</tr>
<tr>
<td></td>
<td>LBM</td>
<td></td>
<td>Amplified Light</td>
<td>Laser beam</td>
</tr>
<tr>
<td></td>
<td>PAM</td>
<td></td>
<td>Ionized Material</td>
<td>Plasma jet</td>
</tr>
<tr>
<td>Electro</td>
<td>ECM</td>
<td>Anodic dissolution</td>
<td>High current</td>
<td>Electrode</td>
</tr>
<tr>
<td>Chemical</td>
<td>ChM</td>
<td>Chemical Dissolution</td>
<td>Corrosive agent</td>
<td>Etchant</td>
</tr>
</tbody>
</table>

In the electrochemical type of process, the material removal takes place by electrochemical dissolution and this is also known as a contactless electrochemical forming process. In this process, the electrical energy is used to produce a chemical reaction, as a result, the machining process based on this principle is known as electrochemical machining (ECM).
In the thermal type of processes, material is removed from the workpiece surface by melting and or vaporisation. This type of machining process can be applied to an electrically conductive material and can machine big components with the desired material removal rate, exactness, accuracy and tolerances.

4.1.2 Classification of Electrical Discharge Machine

In the thermal type of unconventional machining process, EDM is one, which is most commonly used on the shop floor. Wherein, energy of electric sparks is utilised for controlled heating, melting and evaporation of work material resulting into material removal Huang & Liao (2003). The classification of the electrical discharge machine is as shown in Figure 4.1

![Figure 4.1 Classification of electrical discharge machine]
4.2 DESCRIPTION OF WIRE ELECTRICAL DISCHARGE MACHINE

Wire Electrical Discharge Machine (WEDM) is an unconventional machining process which is widely used to produce a precise, complex intrinsic – extrinsic irregular shaped job and difficult to machine electrically conductive materials due to its high strength and bending stiffness, improved fatigue characteristics, good damping capacity and low thermal expansion which makes them the potential material for modern day industrial applications like composites, super alloys and ceramics. It is also used in manufacturing of moulds for plastics, dies Castro et al (2007) for forgings and castings of press tools, aerospace, automotive and surgical components Kamlesh V Dave & Patel (2012).

4.2.1 History of WEDM

Electrical Discharge Machining (EDM) is a non-traditional concept of machining which has been widely used to produce dies and moulds. The EDM process was invented by two Russian scientists, Dr. B.R. Lazarenko and Dr. N.I. Lazarenko in 1943. The first numerically controlled EDM was invented by Makino in Japan. This technique was developed in the late 1940s, where the process is based on removing material from a workpiece by means of a series of recurring electrical discharges between the tool called the electrode and the workpiece, until the gap is small enough so that the voltage is large enough to ionise the dielectric fluid (Sarkar et al 2005, Yan et al 2005, Rozenek et al 2001). Short duration discharges are produced in a liquid dielectric gap, which divides tool and workpiece. Thus the material is removed with the erosive effect of the electrical discharges between tool and workpiece. In EDM, since there is no direct contact between the electrode and the workpiece, eliminating mechanical stresses and vibration problems during machining Tosun et al (2004).
Wire electrical discharge machining is a manufacturing process, whereby a required precise shape is obtained using sparks that occurred due to electrical discharges Yang et al (2009). It is considered as a unique adoption of the conventional EDM processes, which uses an electrode to initialise the sparking process. WEDM technology has grown tremendously, since it was first applied before over decades ago. In 1974, D.H. Dulebohn practically applied the optical-line follower system for automatic control of the shape of the components to be machined by the WEDM process (Aggarwal 2010). By 1975, wire electric discharge machine’s popularity rapidly increased, as the process and its capabilities were better understood by industry. It was only towards the end of the 1970s, when Computer Numerical Control (CNC) systems were initiated into WEDM, which brought about a major evolution of the machining process.

4.2.2 Importance of WEDM in Industry

The wide potential of wire electrical discharge machine has allowed it to encompass the manufacturing, surgical, aerospace and automotive industries and almost all areas of conductive material machining. This is because WEDM provides the best option or sometimes the only substitute for machining conductive, high strength, exotic and temperature resistant materials, conductive engineering ceramics with the range to produce intricate shapes and profiles (Kozak et al 2004, Lok & Lee 1997). WEDM has incredible potential in its applicability to present day metal cutting industry for achieving a substantial dimensional accuracy, surface finish and curve generation features of products or parts. Moreover, the cost of wire contributes about 10% of the operating costs of WEDM process. The difficulties encountered in the die sinking EDM are avoided by WEDM, because the complex design tool is replaced by moving conductive wire and relative movement of wire guides.
4.2.3 Principle of WEDM

The study by Donald B Moulton revealed the principle of wire electrical discharge machine as spark theory and the basic principles are as shown in the Figure 4.2. In WEDM, the conductive materials are machined with a series of electrical discharges called sparks that are produced between an accurately positioned moving wire which will act as a tool electrode and the workpiece. High frequency pulses of alternating or direct current were discharged from the wire to the workpiece with a very small spark gap through an insulated dielectric fluid.

Donald B Moulton also stated that huge numbers of sparks can be observed at one time. This is because actual discharges occur more than one hundred times per second, with discharge sparks lasting in the range of 1/1,000,000 of a second or less than that. The amount of the metal removed during this small period of spark discharge depends on the preferred cutting speed and the required surface finish.

![Figure 4.2 Schematic diagram of basic principles of WEDM](image)

Figure 4.2 Schematic diagram of basic principles of WEDM
The heat of each spark occurs due to electrical discharge is estimated to be around 15,000 to 21,000°F, erodes that is vaporising and melting a small amount of material from the workpiece Kumar (2013). Along with the material from the workpiece some of the wire material is too eroded. These eroded materials are flushed away from the cutting zone with the stream of dielectric fluid through the top and bottom flushing nozzles and this fluid also prevents building up of heat in the workpiece Yang et al (2009). Without this cooling thermal expansion of the workpiece would affect the size and position accuracy during the machining process. The on time and off time of the spark that is repeated again and again, not just the flow of electric current removes the material Narcis Pellicer et al (2011).

### 4.2.4 Components of WEDM

Typically, a WEDM machine can be formed with four major components based on its working. Present numerical control WEDM machine is produced with the requirements of the operator in mind. Programs, machine coordinates, cutting speeds and other relevant information are displayed on a colour monitor, with an easy to use list of options. The control unit displays all options that are intended to give top priority to operability. The keyboard is used to input the characters and commands Bhavesh (2013). The system is very easy to use, permitting the operator to rapidly become familiar with the operations of WEDM machine.

Along with executing numerical control data for positioning movement of the axes, the control modifies these movements when using offsets, tapering, scaling, rotation, mirror images or axis exchange. To guarantee high accuracy positioning, the control also compensates for any pitch error compensation or repercussion error in the axes drives. The
machine has different coordinate systems and work specimens can be programmed in complete or incremental modes saving valuable programming time. Also, multiple work specimens can be setup on the work table, while storing the separate reference points or locations of these jobs in specific coordinate registers.

The numerical control offers the capabilities of rotation, imaging, scaling, mirror, axis exchange and assists programs. This facilitates the operator to produce an entire set of parts from a single program without editing the program. For left and right handed parts, available mirror imaging is the best option Huang et al (1999). When working with shrink factors for plastic cavities or extrusion dies scaling is a very useful option. Assist programs finds the edge of parts, vertically align the wire and perform centering processes that are very useful to the operator when setting up jobs. Other options include technology to aid the prevention of wire breaks, background editing and graphic display of programs while the machine is running. Programs are generated and written in the centre of the wire to follow the outline of the part.

4.2.4.1 Power supply

When WEDM machines are introduced for the first time, they are equipped with power supplies that could achieve less than one square inch per hour. Nowadays, most machines are rated to cut over twenty square inches per hour and faster. The range of speeds, i.e. fast or slow speed can be obtained depending on the workpiece thickness, workpiece material, wire diameter, type of wire, nozzle position, flushing condition and accuracy of the machining. Another feature is the anti-electrolysis circuitry that prevents the risk of electrolysis while cutting workpiece that are in the machine for extended periods. This AC circuit also removes the blue discoloration that
emerges when cutting titanium alloys with DC circuits and is an advantageous attribute when cutting aluminum alloys.

4.2.4.2 Mechanical section

The machine movement is accomplished with precision lead screws with recirculation ball bearings on all axes that are driven by AC motors. The position of the machine is checked for any errors or repercussions and are corrected by pitch error compensation that is permanently stored in the computer’s memory which is available with the WEDM machine.

4.2.4.3 Wire and wire path

At the introductory period of WEDM, copper wire is used on the machines since it is best in conducting electricity. As the machining speed increases, the drawbacks of copper wire are discovered. Due to the low tensile strength of copper wire, it is subject to wire breaks when too much tension is applied. Next drawback is the poor flush ability due to the copper’s high thermal conductivity. A good amount of the heat from the WEDM spark is transferred to the wire and taken away from work zone instead of using that to melt and vaporize the workpiece. At this stage, a huge set of wires chosen from brass wire widely used for machining, substituting the copper wires for all workpiece material. In addition molybdenum, graphitised, thick and thin layered composite wires are available and used based on its different applications.

Requirements for various wires include: optimising for maximum cutting speeds, cutting thick workpieces or cutting large tapers. The diameter of the wire ranges from 0.004 inches to 0.014inch with 0.010inch being the most commonly used. The wire starts from a supply spool and then passes through a tension device. Then it comes in contact with power feed contacts
where the electric current is applied. The wire then passes through a precision set, round diamond guides and then it is transported into a waste bin. The wire can only be used once, since it gets eroded from the EDM process.

The new improved designs help to achieve automatic wire threading (AWT) and dependent reliability of the WEDM process. This feature also permits multiple openings to be cut in die blocks, progressive dies, production and prototype workpieces automatically and unattended without the intervention of an operator resulting in higher productivity. With the addition of the programmable Z-axis, work specimens with different thickness can also be machined. The cutting and threading of the wire can be controlled by program code.

If there is a wire break during machining, the machine returns to the start point of that opening, re-threads the wire and move through the program path to the position where it broke, powers up and continues cutting as if the wire had never broken. In some machines, rethread of the wire is done through the slot of the machine. The threading process of the automatic wire threader takes place automatically if there is a breakage in wire or by a command in the program stored in the machine. In a wire break situation, the end of the wire will be a sharp point of supply wire. The wire tip segment that was clamped is disposed of in a wire tip disposal unit. The supply wire is then directed into the lower guide. The wire then proceeds to the back of the machine where it is discarded in a sharp wire bin. AWT offers the ability to cut multiple openings in a workpiece without operator intervention. Parts with multiple openings or even several jobs are cut overnight while many jobs can be cut over the weekend without operator intervention.
4.2.4.4 Dielectric system

When compared to a vertical electric discharge machine which uses oil as dielectric fluid, WEDM uses de-ionised water as the dielectric fluid. The dielectric system comprises the units like the water reservoir, filtration system, water chiller unit and deionisation system. During machining, the used dielectric fluid is drained into the unfiltered side of the dielectric reservoir where the dielectric fluid is then pumped and filtered through a paper filter and returned to the clean side of the dielectric tank. Next is the filtration process, the clean dielectric fluid is measured for its conductivity, and if required it is passed through a vessel that contains a mixed bed of anion and cation beads. This mixed bed resin or the ion exchange unit controls the resistivity of the dielectric fluid to set the values automatically. This clean dielectric fluid fills the clean side of the dielectric reservoir and flows to the cutting zone. Used fluid is drained and returned to the unfiltered side of the dielectric reservoir to complete the cycle.

A water chiller unit is provided in the WEDM to thermally stabilize the standard equipment to keep the dielectric fluid, workpiece, worktable, control arms and fixtures. During the cutting process the chips from the material that is being cut, gradually changes the dielectric fluid conductivity level. Dielectric fluid resistivity levels are set according to the cutting requirements of the workpiece material being machined on the WEDM machine. The most commonly used dielectric fluids are mineral oils, kerosene and distilled and de-ionized water. Clear, low viscosity fluids are also available, although they are more expensive.
4.3 PERFORMANCE PARAMETERS OF WIRE EDM

The achievement of the precise cut of profile on the workpiece insert on the WEDM is very important. To achieve this precision and accurate profile cut, proper machining parameters are to be selected and set based on the kind of workpiece material and thickness of the workpiece material Parveen Kumar et al (2013). This is because a small error in the accuracy of some of the machining parameters which affect the precision cut are pulse on time, pulse off time, peak current, servo voltage, wire feed, wire tension, cutting speed, spark cycle, spark energy, wire feed and wire tension Huang et al (1999). Factors affecting the WEDM process are as shown in the cause and effect diagram Figure 4.3.

4.3.1 Pulse on Time

During wire cut electrical discharge machining process, all the work is done during pulse on time i.e. pulse duration. The erosion rates are affected mainly by pulse parameter. The spark gap is bridged, current is generated and the work is accomplished. The longer the spark is sustained, the higher is the material removal from the workpiece. Consequently the resulting craters will be broader and deeper and therefore the surface finish will be rougher Kamal Jangra et al (2011). Obviously with shorter duration of sparks the surface finish will be better.
4.3.2 Pulse off Time

While most of the machining takes place during on time of the pulse, the off time during which the pulse resets and the re-ionisation of the dielectric fluid takes place, can affect the speed of the operation in a large way. Longer the off time the greater will be the machining time. But this is an integral part of the WEDM process and must exist. The stability of the
process is also governed by this parameter. An inadequate off time can lead to erratic cycling and retraction of the advancing servo, slowing down the operation cycle. Moreover, the interval time also provides the time to clear the disintegrated particles from the gap between the electrode and workpiece for efficient cut removal. Also, the short pulse interval will increase the relative wear ratio and will increase the surface roughness of the machined surface.

4.3.3 Power Energy Selection

Peak current or power energy selection is an important primary input of WEDM process. The stronger the discharge current, material removal rate, overcut and surface roughness will increase. In other hand, it decreases the rate of electrode wear. To minimise the electrode wear and keep the current density within the tolerance limit it is necessary to select an appropriate value of peak current.

4.3.4 Working Current Range

The specific voltage determines the width of the spark gap between the leading edge of the wire electrode and the workpiece. High voltage settings, increase the gap and hence the flushing and machining. Some material may be necessary for high open-open voltage due to high electrical resistance and high discharge voltage.

4.3.5 Wire Feed

Wire feed is known as the rate at which the wire electrode travels and continuously fed along the wire guide path for continuous sparking. The wire feed range available on the present WEDM machine is available in two levels, first one is low, i.e. 4m/sec and second one is high speed i.e.11 m/sec. In order to avoid wire breakage maximum wire feed is required. Moreover to
have better machining and better material removal rates proper setting of wire feed is essential.

4.3.6 Wire Tension

The rate of stretch in the wire between the upper and lower wire guides is called the wire tension and it is measured as gram equivalent load. In order to keep the wire straight between two guides wire is kept continuously kept under tension. Wire tension is directly proportional to the thickness of the workpiece i.e. more the thickness of workpiece more is the tension required. Improper setting of this parameter wire tension may result in the inaccuracies as well as wire breakage, which increases the machining time and wastage of wire electrode material as well as the workpiece material.

4.3.7 Rapid Capacitor

For WEDM, rapid capacitor is used to determine the cutting speed, which is an important feature and in general, it should be as high as possible to give least machining cycle time. The current cutting speed is digitally displayed on the machine display screen. The machining time “s” is recorded by the WEDM machine time indicator. The cutting speed is measured after the machining the specimen and recorded. This parameter plays an important role and decides the time taken for the machining, which is a crucial factor for any type of manufacturing industry.

4.3.8 Spindle Feed

Spindle feed depends upon the spark gap or overcut and is one of the responses which is very effective in this machining process. This spark gap decides the amount of material removal in one spark by the electric discharge between the wire electrode and work material. This parameter is
measured in order to study the correlation between machining parameters and the spark gap. The unit mostly used is inch. Spark gap can be calculated by the following formula.

\[
\text{Spark Gap} = \frac{\text{Kerf Width–Wire Diameter}}{2} \tag{4.1}
\]

\[
\text{Kerf width} = \frac{\text{hole dimension–block dimension}}{2} \tag{4.2}
\]

### 4.3.9 Electrode Tube Diameter

Electrode tube diameter varies are based upon the size of the wire electrode. During roughing operations, the on-time is usually extended for high rates of metal removal, thus there are fewer of these cycles per second. Finishing operations are carried out at much shorter on and off times and have many cycles per second. During pulse on-time the metal removal process takes place, whereas during pulse off-time the re-ionisation of the dielectric takes place. In addition interval time also provides the time to clear the distinguished particles from the gap between the electrode and workpiece for the efficient cut removal.

### 4.3.10 Flow Rate

Flow rate or flushing pressure, represents the flushing pressure input of the dielectric fluid. High flow rate of dielectric water is required for cutting with higher values of pulse energy and also while cutting the workpiece of greater thickness.
4.3.11 Stable

Stable indicates the working stability of the machine and can be noted for the values in sixteen steps. This value eliminates variations due to factors like voltage gap, wire electrode wear and flushing pressure of the dielectric fluid.

4.4 WORKING OF WEDM

In wire electrode discharge machining, a thin single-stranded metal wire is fed through the workpiece. This process is similar to contour cutting with a band saw, a slowly moving wire travels along a prescribed path, cutting the workpiece. This process is used to cut plates as thick as 300mm and to make punches, tools, and dies from the hard metals that are too difficult to machine with other methods. It also creates intricate components for the electronic and surgical industries. The wire, which is constantly fed from the spool, is held between upper and lower diamond guides.

Guides move in the x-y plane, usually being CNC controlled and on almost all modern machines the upper guide can also move independently in the z-u-v axis, giving rise to the ability to cut tapered and transitioning shapes and can control axis movements in x-y-u-v-i-j-k-l-. This gives the WEDM the ability to be programmed to cut very intricate and delicate shapes.

The wire is controlled by upper and lower diamond guides that are usually accurate to 0.004mm and can have a cutting path or kerf as small as 0.12mm using 0.1mm diameter wire, though the average cutting kerf that achieves the best economic cost and machining time is 0.335mm using 0.25mm diameter brass wire. The wire is usually made of brass, copper, tungsten, or molybdenum and multi-coated wire. The wire diameter is typically about 0.3mm for roughing cuts and 0.2mm for finishing cuts. The
wire should have high electrical conductivity and tensile strength, as the
tension on it is typically 60% of its tensile strength. The wire usually is used
only once, as it is relatively inexpensive compared to the type of operation it
performs. It travels at a constant velocity in the range of 0.15 to 9m/min, and
a constant gap, i.e. kerf, is maintained during the cut.

The trend in the use of dielectric fluids is towards clear, low
viscosity fluids. The reason that the cutting width is greater than the width of
the wire is because sparking also occurs from the sides of the wire to the
workpiece, causing erosion. This overcut is necessary, predictable, and easily
compensated for. Spools of wire are typically very long. For example, an 8kg
spool of 0.25mm wire is just over 19 km long.

Nowadays, the smallest wire diameter is 20 µm and the geometric
precision is not far from +/- 1 µm. The WEDM process uses deionised water
as its dielectric with the water’s resistivity and other electrical properties
carefully controlled by filters and de-ioniser units. The water also serves the
very critical purpose of flushing the debris away from the cutting zone.
Flushing is an important determining factor in the maximum feed rate
available in a given material thickness, and poor flushing situations
necessitate the reduction of the feed rate. Along with tighter tolerances multi-
axis WEDM machining centre has many added features such as multi-heads
for cutting two parts at the same time, controls for preventing wire breakage,
automatic self-threading features in case of wire breakage, programmable
machining strategies to optimise the operation.

**Step 1**

In the first step, the generation of volts and amps through the
WEDM power supply as the workpiece and wire electrode is surrounded by
deionised water, i.e. the dielectric fluid and it is shown in the Figure 4.4.
Step: 2

In this step, dielectric fluid acts as a resistor until enough voltage is applied. Then the fluid ionizes and controlled sparks are produced between workpiece and wire electrode which helps with erosion and hence precisely melts and vaporise the work material as shown in Figure 4.5. The mechanism of material removal in WEDM machining mainly involves the removal of material due to melting and vaporisation caused by the electric spark discharge generated by a pulsating current power supply between the electrodes. In this process, the wire electrode is a continuously moving wire and the positive electrode is the workpiece. The sparks will generate between two closely spaced electrodes under the influence of dielectric fluid. Deionised water is used as dielectric in WEDM, because of its low viscosity and rapid cooling rate.

Figure 4.4 Dielectric fluid surrounds the wire and workpiece
Figure 4.5 Erosion of workpiece,

Figure 4.6 Flushing of eroded materials
Step: 3

During pulse off time, the sparking process is complete and the pressurised dielectric fluid cools the material and flushes away the eroded particles as shown in Figure 4.6.

Step: 4

The melted workpiece material forms into chips and a filter system is used to filter these eroded particles from the dielectric fluid and the fluid is thus reused as shown in Figure 4.7.
4.5 ADVANTAGES OF WEDM

The various advantages of the wire electrical discharge machine are listed as follows;

- WEDM can machine complex and geometric intrinsic and extrinsic shapes in any electrically conductive material.
- Complex contoured shapes can be manufactured in one piece rather than several, in the exact configuration that is required.
- The rapid, economic production of prototypes and low run workpiece.
- The ability to accurately machine complex designs, can be immediately used in assembly, with little or no additional finishing.
- Precise machining of pre-hardened materials
- Because hardened materials can be EDM eroded, the need for the heat treatment of machined parts is eliminated, avoiding potential distortion.
- Machining to tight tolerances, avoiding distortion and stress.
- Very low machining forces allow tight tolerances of up to 2 microns to be achieved. With little or no stress imparted into the work only clamping is necessary. Thin materials can also be machined without distortion.
- The accurate and economic machining of exotic materials.
• Exotic materials, including A-286 super alloys, medical grade stainless. Titanium, Haste alloy, Tungsten carbide, Molybdenum, Aluminum alloys and Copper can be machined. Better utilisation of valuable materials is provided through chip less machining.

• Absolute consistency between machined parts.

• Because with wire EDM there is no contact between the cutting wire and the surface, there is no tooling wear and absolute consistency can be achieved in every machined part.

4.6 LIMITATIONS OF WEDM

Besides the precision and accuracy of the process, WEDM also have its own limitations and much research has been done and it is continuing to overcome those limitations which helps this machine to be one of the most important machines in the manufacturing industry. The limitations of the WEDM are,

• WEDM’s comparative slow material removal rate is a limitation, but in this process, there is no need of additional finishing work or very minimal finishing work only will be required. Since there is no rework, this limitation may not be so important.

• Reproducing sharp corners on the workpiece is difficult due to electrode wear. But in WEDM process, wire electrode is used for single pass and hence, this limitation may be negligible.
• This WEDM is limited for ferrous alloys, but no reaction works in non-ferrous such as plastic, fibre, wood and wax.

• The WEDM process depends on nearly 11 input process parameters and requires trial and error to setup the workpiece material on the machine and thus requires more setup time and high skill of the operator.

• Unable to interpret technical or manual data or drawing. WEDM machine has been enabled to interpret and receiving drawings from such as CATIA, AutoCAD, Unigraphics, Solid Edge and Solid Works.

• The control system of the electrode may fail to react quickly enough to prevent the tool and workpiece to get in contact with a consequent short circuit. It is unwanted because a short circuit contributes to the removal differently from the ideal case.

4.7 APPLICATIONS OF WEDM

WEDM has a wide range of applications which are growing by day by day. It is extensively used in automotive, aerospace, moulds, tool and die making industries. WEDM also has its applicability in the medical, optical, dental, jewelry industries. The machine’s ability to operate unattended for hours or even days further increases the attractiveness of the process. Accuracy of high value with intrinsic design and on exotic material has increased its applicability in medical and research and development areas. The conventional electric discharge machining technique process requires many hours of electrode fabrication as well as many hours of manual grinding and polishing. With WEDM the overall fabrication time is reduced by around
37% and the processing time is reduced by 66%. The major applications of WEDM are it can machine,

- Materials with high hardness and workpieces with high thickness.
- Parts with complex geometries can be machined easily.
- Parts requiring tolerances in the range of tenths, where the precision and accuracy is given high preference.
- The parts where burrs cannot be tolerated and it gives a high surface finish.
- Fragile parts that are prone to tool pressure machining are possible.
- Production of progressive, blanking, extrusion dies and trim dies are major application of WEDM process.
- Precious metals like titanium alloys, Inconel and etc. can be machined.
- Cutting of narrow slots and keyways are possible
- Production of mould components, tooling for forging or injection moulding operations can be done with high accuracy.
- Medical and dental instrumentation are another major area where the application of WEDM is widely seen.
- Cutting hardened materials such as carbide and machining of difficult to machine materials like Inconel and titanium can be machined rapidly.
• WEDM applications are also seen in the parts production in the engineering field of aerospace, defence and electronic.

• WEDM is also familiar with the production of prototypes of different parts.

4.8 SUMMARY

Thus in this chapter, the fundamentals of WEDM is discussed in detail. The cause and effect diagram is used to identify the various performance parameters of WEDM process and all the parameters are discussed in detail. Thus, this chapter gives a deep knowledge about the fundamentals, components, principles and process parameters and working of WEDM with its applications, advantages and limitations.