CHAPTER 1

INTRODUCTION

1.1 GENERAL

Manufacturing industry is becoming ever more time and quality conscious with regard to the global competence, and the need to use complicated and precise components having some special shape requirements. The demand for materials made from exotic, high strength and temperature resistive materials, tool and die steels and advanced materials are growing day by day. These trends have placed a premium on the use of new and advanced technologies for quickly turning raw materials into usable goods; with less time or possibly no time being required for tooling.

The conventional machining processes, in spite of recent technical advancement, are inadequate to machine complex shapes in hard, high strength temperature resistant alloys and die steels. Keeping these requirements into mind, a number of Non-traditional machining (NTM) processes have been developed. These can be classified depending upon the type of energies used,

(a) Mechanical Processes: In mechanical processes metal removal takes place either by the mechanism of simple shear (conventional machining) or by erosion mechanism where high velocity particles are used as transfer media and pneumatic/hydraulic pressure acts as source of energy. It
includes Abrasive Jet Machining, Ultrasonic Machining, Water Jet Machining etc.

(b) Chemical Processes: Chemical processes involve the application of resistant material (acidic or alkaline in nature) to certain portion of the work-piece. The desired amount of material is removed from the remaining area of work surface by the subsequent application of an etchant that converts the work-piece material into a dissolvable metallic salt. It includes chemical machining, photochemical machining etc.

(c) Electrochemical Processes: Electrochemical processes involve removal of metal by the mechanism of ion displacement. High current is required as the source of energy and electrolyte acts as transfer media. It includes Electrochemical Machining, Electro Chemical Grinding, Electro Jet Drilling etc.

(d) Thermal Processes: Thermal processes involve the application of very intense local heat. Here melting or vaporizing small areas at the surface of the work piece removes material. The source of energy used is amplified light radiation (Laser Jet Machining,), ionized material (Iron Beam Machining and Plasma Arc Machining,) and high voltage (Electric discharge machining,).

1.2 ELECTRICAL DISCHARGE MACHINING

Electrical discharge machining (EDM) is one of the most popular non-traditional material removal processes and has become a basic machining method for the manufacturing industries like aerospace, automotive, nuclear, medical and die-mould production. Major development of EDM was observed when computer numerical control systems were applied for the machine tool
industry. Thus, the EDM process became automatic and unattended machining method (Ho and Newman 2003).

In this process thermal energy is used to generate heat that melts and vaporizes the work piece by ionization within the dielectric medium. The electrical discharges generate impulsive pressure by dielectric explosion to remove the melted material. Thus, the amount of removed material can be effectively controlled to produce complex and precise machine components. However, the melted material is not completely flushed away and the remaining material resolidifies to form discharge craters (Kiyak and Cakır 2007).

EDM processes are classified into die-sinking EDM and Wire-EDM. The electrode of die-sinking EDM has the reversed shape of the part to be machined, while Wire-EDM uses thin wire, ranging from 0.01 to 0.36 mm in diameter, as the electrode.

1.3 WIRE ELECTRICAL DISCHARGE MACHINING

Wire Electrical Discharge Machining (WEDM) was first introduced to the manufacturing industry in the late 1960s. The development of the process was the result of seeking a technique to replace the machined electrode used in EDM. In 1974, D.H. Dulebohn applied the optical-line follower system to automatically control the shape of the component to be machined by the WEDM process (Ho et al 2004). By 1975, its popularity was rapidly increasing, as the process and its capabilities were better understood by the industry (Benedict 1987). It was only towards the end of the 1970s, when computer numerical control system was initiated into WEDM that brought about a major evolution of the machining process. As a result, the broad capabilities of the WEDM process were extensively exploited for any
through-hole machining owing to the wire, which has to pass through the part to be machined (Ho et al 2004).

WEDM is a process of material removal of electrically conductive materials by the thermo-electric source of energy. The material removal by controlled erosion through a series of repetitive sparks between electrodes, i.e. work piece and tool. Figure 1.1 shows the basic features of the WEDM unit (Tosun et al 2004).

![Figure 1.1 Basic features of WEDM Unit](image)

In the WEDM process there is no relative contact between the tool and work material, therefore the work material hardness is not a limiting factor for machining materials by this process. In this operation the material removal occurs from any electrically conductive material by the initiation of rapid and repetitive spark discharges between the gap of the work and tool electrode connected in an electrical circuit and the liquid dielectric medium is continuously supplied to deliver the eroded particles and to provide the cooling effect. A small diameter wire ranging from 0.05 to 0.25 mm is applied as the tool electrode. The wire is continuously supplied from the supply spool through the work-piece, which is clamped on the table by the wire traction rollers. A gap of 0.025 to 0.05 mm is maintained constantly between the wire
and work-piece. Deionized water is applied as the dielectric fluid. A collection tank that is located at the bottom is used to collect the used wire and then discard it. The wires once used cannot be reused again due to the variation in dimensional accuracy. The dielectric fluid is continuously flashed through the gap along the wire, to the sparking area to remove the byproducts formed during the erosion. Brass wire is most commonly used for wire cutting, and zinc or aluminum coatings are employed for high-speed cuts (Ramakrishnan and Karunamoorthy 2006).

WEDM has become an important non-traditional machining process, widely used in the aerospace, nuclear and automotive industries. This is because the WEDM process provides an effective solution for machining hard materials (like Titanium, Nimonics, Zirconium etc.,) with intricate shapes, which are not possible by conventional machining methods. In WEDM the cost of machining is rather high due to high initial investment for the machine and cost of the wire-electrode tool. The WEDM process is more economical, if it is used to cut difficult to machine materials with complex, precise and accurate contours in low volume and greater variety. The selection of optimum machine setting parameters plays an important role for obtaining higher cutting speed or good surface finish. Improperly selected parameters may also result in serious consequences like short-circuiting of wire and wire breakage. Wire breakage imposes certain limits on the cutting speed that in turn reduces productivity. As surface finish and cutting speed are most important parameters in manufacturing, various investigations have been carried out by several researchers for improving the surface finish and cutting speed of WEDM process. However the problem of selection of cutting parameters in WEDM process is not fully solved, even though the most up to date computer numerical control WEDM machine are presently available. WEDM process involves a number of machine setting parameters such as applied voltage, pulse on-time, pulse off time, servo-control reference mean
voltage, wire speed, wire tension, and high pressure flushing. The material of work piece and its height also influence the process. All these parameters influence surface finish and MRR and cutting speed to varying degree.

1.4 VARIOUS APPLICATION OF WEDM

WEDM has been called a non-traditional machining process because it erodes metal with electrical discharges instead of with cutting tools which form chips. It has been replacing drilling, milling, grinding, and other traditional machining operations in many industries throughout the world. WEDM is a widely used to manufacture components with intricate shapes and profiles. It has been commonly used in the automotive, aerospace, mould, tool and die making industries. Applications can also found in the field of medical, optical, jewellery and dental. Owing to high process capability, it is widely used in manufacturing of cam wheels, special gears, bearing cage, various press tools, dies, and similar intricate parts etc (Sarkar 2005).

1.4.1 Tool and Die Making Industries

WEDM is far most widely used machining process in precision mold and die industry. Its chief applications are in the manufacture and reconditioning of press tool and forging dies as well as moulds for injection mouldings. The examples are:

- Sheet metal press dies
- Stamping and extrusion tools and dies
- Fixtures and gauges
- Various types of blanks and punches
- Variety of miniature and micro-parts
- Grinding wheel form tools
1.4.2 Medical and Surgical Industries

Manufacturing in the medical market demands superior accuracy, requires top precision, and needs the flexibility to accommodate the incredible demands of a constantly-changing and rapidly evolving industry. WEDM specializes in manufacturing medical devices, medical components, medical tools and implants for all aspects of the field including Diagnosis, Therapy and Surgery.

The categories of medical field parts manufactured by WEDM are:

- Surgical screws, bolts and hardware.
- Medical implantation hand tools for inserting and extraction or recovery of implants.
- Surgical Cathodes and syringe components.
- Bone / Jaw reamers for Dental implants.
- Go / No Go Gauges for Medical inventory quality control.
- Breathing Regulator valves for oxygen masks.
- Various splints and supports for orthotic and prosthetic devices.
- Knee joint, shoulder joint and hip joint support apparatuses.
- Tooling and dies for manufacturing, and stamping medical equipment and tools.

Metallic materials are widely used in dental implants, orthodontic appliances as bands, arch wires, ligature wires, hooks, tubes, brackets and springs, and orthopedic devices as implants and prosthesis for fractured bones healing.
1.4.3 Aircraft and Aerospace Industries

WEDM plays a significant role in the manufacturing process for products in the Aircraft and Aerospace Industries. The following are manufactured in the field of aircraft and aerospace with WEDM,

- Rocket guidance systems
- Airframes for the aerospace industry
- Satellite structural component
- Fin deployment actuator housing for a missile
- Turbine blades
- Gyroscopes
- Jet engine blade sets
- Turbine diffuser

1.4.4 Automobile Industries

The demand for WEDM process is increasing among Automobile industries to enhance the performance of high-speed automotive engines. Few of the items manufactured by WEDM in automotive fields are:

- Engine mountings
- Car engine prototypes
- Fuel metering valves
- Gears and rear housing support for formula-1 race cars
1.4.5 General applications

Owing to high process capability WEDM is generally used in manufacturing of following parts.

- Prototype and special form inserts manufacturing
- Printer components such as magnetic reader heads, printer hammer etc
- Cam wheel
- Special gears
- Stators for stepper motors
- Watch parts
- Metallic and Plastic gears
- Grinding tools
- Collets
- Flextures
- Keyways
- Extreme tapers
- Bottling industry
- Graphite and copper electrodes
- Containers- beverage, food and perfume etc.,

1.5 ADVANTAGES OF WEDM

- An important number of CNC features, such as automatic threading of the wire and restarting the operation in the case of wire rupture, improve the performance of WEDM as a manufacturing process.
- WEDM can machine any complicated profiles in electrically conductive materials.

- Physical and metallurgical properties of the work material, such as strength, hardness, toughness, microstructure, etc. are no barriers to its application.

- The process has high surface finish.

- Complicated contours in hard materials can be produced to a high degree of accuracy and surface finish.

- It eliminates the geometrical changes occurring in the machining of heat-treated steels.

- WEDM process simplifies the fabrication of precision work pieces.

- WEDM produces a sharp, burr-free edge, so it is a highly desirable machining choice for work pieces such as medical implants and die openings.

- Tool manufacturing and storage is avoided.

- The time utilization of WEDM is high as it can continuously work throughout the day.

- Small batch productions including prototypes can be economically machined as most of the CNC program is easily done.

- It avoids wastages and rejections due to initial planning and checking of the program.

- The process can be readily applied to electrically conductive and semi-conductive materials.
- Although the metal removal is due to thermal effects, there is no heating in the bulk of the material.

- Heat treatment usually unnecessary.

- It does not require a special shaped electrode.

- During machining, the work piece is not subjected to mechanical deformation as there is no physical contact between the tool and work.

1.6 LIMITATIONS OF WEDM

- Its application is limited to small thickness conductive materials.

- Material Removal Rate is comparatively low.

- Electrolysis can occur in some materials.

- Slow cutting rates.

- Not suitable for very large work pieces.

- High capital cost.

- Precision uniform wire is required.