UNIT 5 MODERN MACHINING METHOD

Structure

5.1 INTRODUCTION

Modern machining methods are also named as non-conventional machining methods. These methods form a group of processes which removes excess material by various techniques involving mechanical, thermal, electrical chemical energy or combination of these energies. There is no cutting of metal with the help of metallic tool having sharp cutting edge. The major reasons of development and popularity of modern machining methods are listed below.

(a) Need of machine newly developed metals and non-metals having some special properties like high strength, high hardness and high toughness. A material possing the above mentioned properties are difficult to be machined by the conventional machining methods.

(b) Sometimes it is required to produce complex part geometries that cannot be produced by following conventional machining techniques. Non-conventional machining methods also provide very good quality of surface finish which may also be an encouragement to these methods.

There can be a very long list of non-conventional machining methods. These methods can be classified as the basis of their base principle of working.

Objectives

After studying this unit, you should be able to understand

- introduction of modern machining methods and their difference with conventional machining methods,
- different classification criteria of modern machining methods and their classifications, and
- working principle, process details, applications and advantages and disadvantages machining.

5.2 PRINCIPLE OF WORKING OF ENERGY

The principle of working is the base of type of energy used to remove the material. Classification along with the principle of working is described below.

Use of Mechanical Energy

Mechanical energy is used for removing material from workpiece. In this process, cutting tool with sharp edge is not used but material is removed by the abrasive action of high velocity of stream of hard, tiny abrasive particles. The particles are kept vibrating with very high velocity and ultra high frequency to remove the material.

Electrical Energy

In this category of non-traditional machining electrical energy is used in the form of electrochemical energy or electro-heat energy to erode the material or to melt and vapourized it respectively. Electrochemical machining, electroplating or electro discharge machining are the examples work on this principle.

Use of Thermal Energy

According to this principle heat is generated by electrical energy. The generated thermal energy is focused to a very small portion of workpiece. This heat is utilized in melting and evaporating of metal. The example based o this principle is electric discharge machining.

Use of Chemical Energy

According to this principle of working chemicals are used to erode material from the workpiece. Selection of a chemical depends upon the workpiece material. Example of this type of machining is electrochemical machining. The dame principle can also be applied in reversed way in the process of electrochemical plating.

5.3 NON-CONVENTIONAL MACHINING PROCESSES

There can be one more way of classification of the non-conventional machining processes which is mechanisms of metal removal.

Abrasion and Shear

When small and hard metallic particles are made vibrating against the workpiece to be machined, the material is removed by shear action and abrasion. These phenomenon take place in case of ultrasonic machining.

Chemical Ablation and Ionic Dissolution

This is the dissolution of workpiece material into electrolyte solution (chemical) which takes place atom by atom. This happens in case electrochemical machining.

Vapourization by Spark Erosion

Concentrated heat is focused at a point of the workpiece by electric spark which melts and evaporates the workpiece material like electric discharge machining and LBM.

Different processes used in non-conventional machining are described below.

5.4 ELECTRIC DISCHARGE MACHINING (EDM)

It is also known as spark erosion machining or spark machining. Material of workpiece removed due to erosion caused by electric spark. Working principle is described below.

Working Principle of Electric Discharge Machining

Electric discharge machining process is carried out in presence of dielectric fluid which creates path for discharge. When potential difference is created across the two surfaces of die electric fluid, it gets ionized. An electric spark/discharge is generated across the two terminals. The potential difference is developed by a pulsating direct current power supply connected across the two terminals. One of the terminal is positive terminal given to workpiece and tool is made negative terminal. Two third of the total heat generated is generated at positive terminal so workpiece is generally given positive polarity. The discharge develops at the location where two terminals are very close. So tool helps in focusing the discharge or intensity of generated heat at the point of metal removal.

Application of focused heat raise the temperature of workpiece locally at a point, this way two metal is melted and evaporated.

Electric Discharge Machining Process Details

The working principle and process of EDM is explained with the help of line diagram in Figure 5.1. The process details and components are explained below serially.

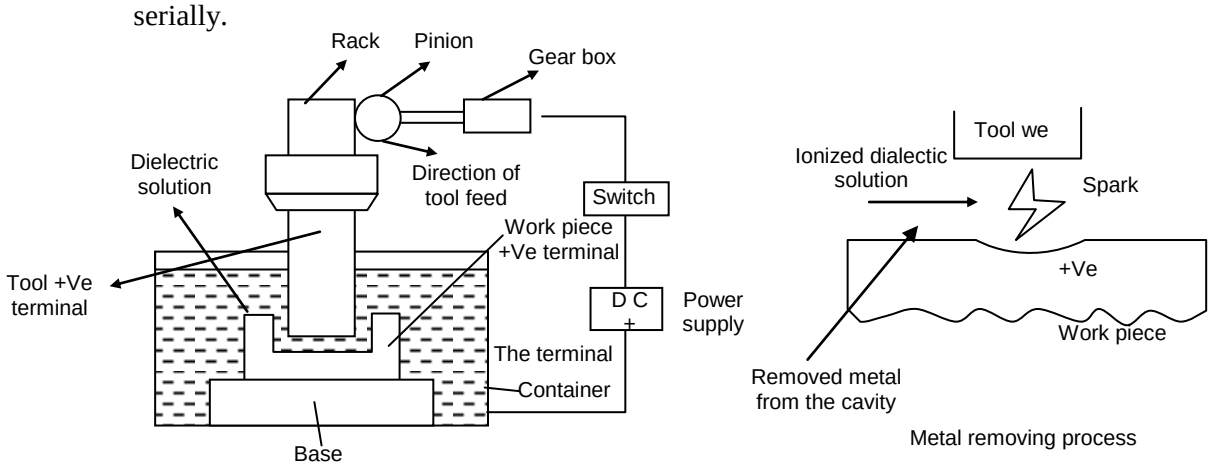

Figure 5.1 : Line Diagram Indicating Working Principle and Process Details of EDM

Base and Container

A container of non-conducting, transparent material is used for carrying out EDM. The container is filled with dielectric solution. A base to keep workpiece is installed at the bottom of container. The base is made of conducting material and given positive polarity.

Tool

Tool is given negative polarity. It is made of electrically conducting material line brass, copper or tungeten. The tool material selected should be easy to machine, high wear resistant. Tool is made slightly under size for inside machining and over sized for cut side machining. Tool is designed and manufactured according to the geometry to be machined.

Dielectric Solution

Dielectric solution is a liquid which should be electrically conductive. This solution provides two main functions, firstly it drive away the chips and prevents their sticking to workpiece and tool. It enhance the intensity of discharge after getting ionized and so accelerates metal removal rate.

Power Supply

A DC power supply is used, 50 V to 450 V is applied. Due to ionization of dielectric solution an electrical breakdown occurs. The electric discharge so caused directly impinges on the surface of workpiece. It takes only a few micro seconds to complete the cycle and remove the material. The circuit cam be adjusted for auto off after pre-decided time interval.

Tool Feed Mechanism

In case of EDM, feeding the tool means controlling gap between workpiece and the tool. This gap is maintained and controlled with the help of servo mechanism. To maintain a constant gap throughout the operation tool is moved towards the machining zone very slowly. The movement speed is towards the machining zone very slowly. The movement speed is maintained by the help of gear and rack and pinion arrangement. The servo system senses the change in gap due to metal removal and immediately corrects it by moving the tool accordingly. The spark gap normally varies from 0.005 mm to 0.50 mm.

Workpiece and Machined Geometry

The important point for workpiece is that any material which is electrical conductor can be machined through this process, whatever be the hardness of the same. The geometry which is to be machined into the workpiece decides the shape and size of the tool.

Application of Electric Discharge Machining

This process is highly economical for machining of very hard material as tool wear is independent of hardness of workpiece material. It is very useful in tool manufacturing. It is also used for broach making, making holes with straight or curved axes, and for making complicated cavities which cannot be produced by conventional machining operations. EDM is widely used for die making as complex cavities are to be made in the die making. However, it is capable to do all operations that can be done by conventional machining.

Advantages of EDM

(a) This process is very much economical for machining very hard material.

(b) Maintains high degree of dimensional accuracy so it is recommended for tool and die making.

(c) Complicated geometries can be produced which are very difficult otherwise.

(d) Highly delicate sections and weak materials can also be processed without nay risk of their distortion, because in this process tool never applies direct pressure on the workpiece.

(e) Fine holes can be drilled easily and accurately.

(f) Appreciably high value of MRRR can be achieved as compared to other non-conventional machining processes.

Disadvantages and Limitations of EDM Process

There are some limitations of EDM process as listed below :

(a) This process cannot be applied on very large sized workpieces as size of workpiece is constrained by the size of set up.

(b) Electrically non-conducting materials cannot be processed by EDM.

(c) Due to the application of very high temperature at the machining zone, there are chances of distortion of workpiece in case of this sections.

(d) EDM process is not capable to produce sharp corners.

(e) MRR achieved in EDM process is considerably lower than the MRR in case of conventional machining process so it cannot be taken as an alternative to conventional machining processes at all.

5.5 WIRE CUT ELECTRIC DISCHARGE MACHINING (WCEDM)

This is a special type of electric discharge machining that uses a small diameter wire as a cutting tool on the work. Working a principle of wire cut electric discharge machining is same as that of electric discharge machining.

Process Details of WCEDM

Process details of WCEDM are almost similar to EDM with slight difference. The details of the process are indicated in the line diagram shown in Figure 5.2. Its major difference of process details with EDM process details are described below.

Tool Details

The tool used in WCEDM process is a small diameter wire as the electrode to cut narrow kerf in the workpiece. During the process of cutting the wire is continuously advanced between a supply spoil and wire collector. This continuous feeding of wire makes the machined geometry insensitive to distortion of tool due to its erosion. Material of wire can be brass, copper, tungsten or any other suitable material to make EDM tool. Normally, wire diameter ranges from 0.076 to 0.30 mm depending upon the width of kerf.

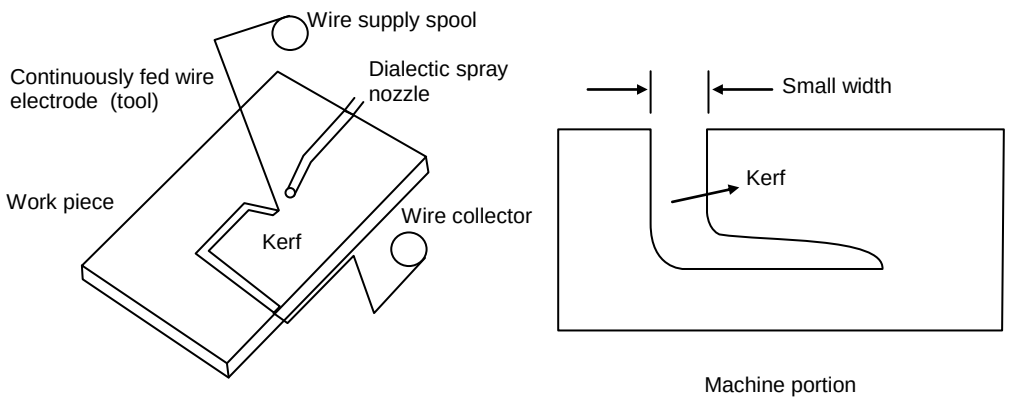

Figure 5.2 : Line Diagram for Process Details of Working of Wire Cut Electric Discharge Machining

Tool Feed Mechanism

Two type of movements are generally given to the total (wire). One is continuous feed from wire supply spoal to wire collector. Other is movement of the whole wire feeding system, and wire along the kerf to be cut into the workpiece. Both movements are accomplished with ultra accuracy and pre-determined speed with the help of numerical control mechanism.

Dielectric Fluid and Spray Mechanism

Like EDM process dielectric fluid is continuously sprayed to the machining zone. This fluid is applied by nozzles directed at the tool work interface or workpiece is submerged in the dielectric fluid container.

Rest of the process details in case of WCEDM process are same as that in case of EDM process.

Application of WCEDM

WCEDM is similar to hand saw operation in applications with good precision. It is used to make narrow kerf with sharp corners. It does not impose any force to workpiece so used for very delicated and thin workpieces. It is considered ideal for making components for stamping dies. It is also used to make intricate shapes in punch, dies and other tools.

Advantages of WCEDM

Advantages are listed below :

(a) Accuracy and precision of dimensions are of very good quality.

(b) No force is experienced by the workpiece.

(c) Hardness and toughness of workpiece do not create problems in machining operation.

Disadvantages and Limitations of WCEDM

The major disadvantages of this process are that only electrically conducting materials can machined. This process is costly so recommended for use specifically at limited operations.

5.6 ULTRASONIC MACHINING (USM)

Ultrasonic machining (USM) is one of the non-traditional machining process. Working principle of this process resembles with conventional and metal cutting as in this process abrasives contained in a slurry are driven at high velocity against the workpiece by a tool vibrating at low amplitude and high frequency. Amplitude is kept of the order of 0.07 mm and frequency is maintained at approximately 20,000 Hz. The workpiece material is removed in the form of extremely small chips. Normally very hard particle dust is included in the slurry like, Al_2O_2, silicon carbide, boron carbide or diamond dust.

Working principle of USM is same as that of conventional machining that is material of workpiece is removed by continuous abrasive action of hard particles vibrating in the slurry. Abrasive slurry acts as a multipoint cutting tool and does the similar action as done by a cutting edge.

Process Details

USM process is indicated in line diagram shown in Figure 5.3. Details of the process are discussed below.

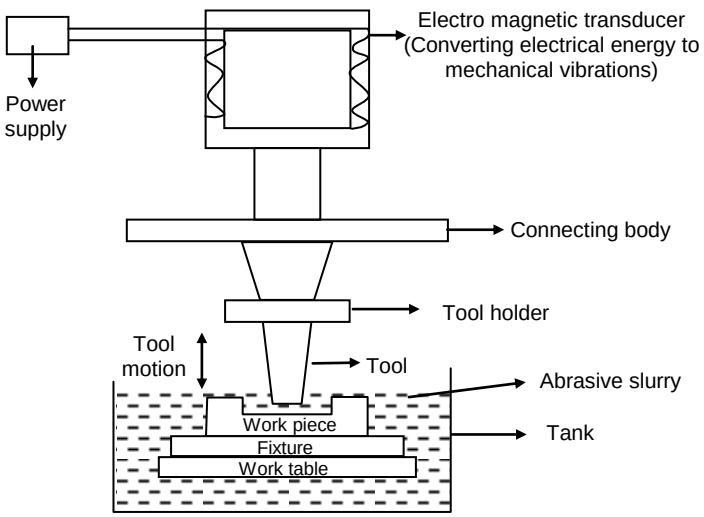

Figure 5.3 : Details of USM Process

Abrasive Slurry

Abrasive slurry consists of dust of very hard particles. It is filled into the machining zone. Abrasive slurry can be recycled with the help of pump.

Workpiece

Workpiece of hard and brittle material can be machined by USM. Workpiece is clamped on the fixture I the setup.

Cutting Tool

Tool of USM does not do the cutting directly but it vibrates with small amplitude and high frequency. So it is suitable to name the tool as vibrating tool rather than cutting tool. The tool is made of relatively soft material and used to vibrate abrasive slurry to cut the workpiece material. The tool is attached to the arbor (tool holder) by brazing or mechanical means. Sometimes hollow tools are also used which feed the slurry focusing machining zone.

Ultrasonic Oscillator

This operation uses high frequency electric current which passes to an ultrasonic oscillator and ultrasonic transducer. The function of the transducer is to convert electric energy into mechanical energy developing vibrations into the tool.

Feed Mechanism

Tool is fed to the machining zone of workpiece. The tool is shaped as same to the cavity of be produced into the workpiece. The tool is fed to the machining area. The feed rate is maintained equal to the rate of enlargement of the cavity to be produced.

Applications of USM

This process is generally applied for the machining of hard and brittle materials like carbides glass, ceramics, precious stones, titanium, etc. It is used for tool making and punch and die making. The workpeice material is normally removed in the form of very find chips so generated surface quality is extremely good. It is widely used for several machining operations like turning, grinding, trepanning and milling, etc. It can make hole of round shape and other shapes.

Advantages of USM

Advantages of USM process are listed below :

(a) Its main advantage is the workpiece after machining is free from any residual stress as to concentrated force or heat is subject to it during the machining process.

(b) Extremely hard and brittle materials can be machined, their machining is very difficult by conventional methods.

(c) Very good dimensional accuracy and surface finish can be obtained.

(d) Operational cost is low.

(e) The process is environmental friendly as it is noiseless and no chemical and heating is used.

Disadvantages of USM

The process of USM have some disadvantages and limitations as described below :

(a) Its metal removal rate (MRR) is very low and it can not be used for large machining cavities.

(b) Its initial setup cost and cost of tool is very high, frequency tool replacement is required as tool wear takes place in this operation.

(c) Not recommended for soft and ductile material due to their ductility.

(d) Power consumption is quite high.

(e) Slurry may have to be replaced frequently.

5.7 CHEMICAL MACHINING PROCESSES (CHM)

Chemical machining is one of the non-conventional machining processes where material is removed by bringing it in contact of a strong chemical enchant. There are different chemical machining methods base on this like chemical milling, chemical blanking, photochemical machining, etc.

Working Principle of CHM

The main working principle of chemical machining is chemical etching. The part of the workpiece whose material is to be removed, is brought into the contact of chemical called enchant. The metal is removed by the chemical attack of enchant. The method of making contact of metal with the enchant is masking. The portion of workpiece where no material is to be removed, is mashed before chemical etching.

Process Details of CHM

Following steps are normally followed in the process of CHM :

Cleaning

The first step of the process is a cleaning of workpiece, this is required to ensure that material will be removed uniformly from the surfaces to be processed.

Masking

Masking is similar to masking action is any machining operation. This is the action of selecting material that is to be removed and another that is not to be removed. The material which is not to be removed is applied with a protective coating called maskant. This is made of a materials are neoprene, polyvinylchloride, polyethylene or any other polymer. Thinkers of maskent is maintained upto 0.125 mm. The portion of workpiece having no application of maskent is etched during the process of etching.

Etching

In this step the material is finally removed. The workpiece is immersed in the enchant where the material of workpiece having no protective coating is removed by the chemical action of enchant. Enchant is selected depending on the workpiece material and rate of material removal; and surface finish required. There is a necessity to ensure that maskant and enchant should be chemically in active. Common enchants are H_2SO_4, $FeCL_3$, HNO_3. Selection of enchant also affects MRR. As in CHM process, MRR is indicated as penetration rates (mm/min).

Demasking

After the process is completed demasking is done. Demasking is an act of removing maskent after machining.

Application of CHM

The application and working of CHM process are indicated in Figure 5.4, various applications of CHM are discussed below.

Chemical Milling

It is widely used in aircraft industry. It is the preparation of complicated geometry on the workpiece using CHM process.

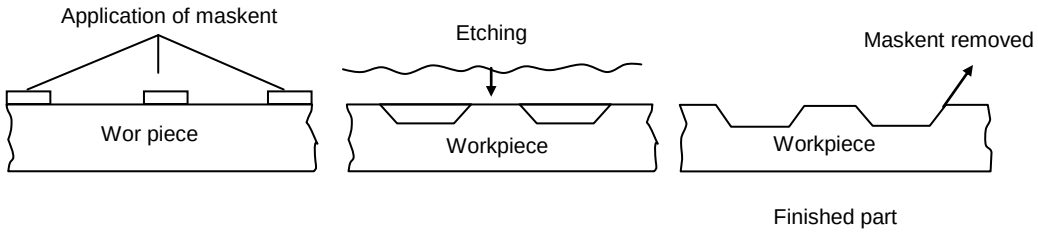

Figure 5.4 : Application and Working of CHM

Chemical Blanking

In this application cutting is done on sheet metal workpieces. Metal blanks can be cut from very thin sheet metal, this cutting may not be possible by conventional methods.

Photochemical Machining

It is used in metal working when close (tight) tolerances and intricate patterns are to be made. This is used to produce intricate circuit designs on semiconductor wafers.

Advantages of CHM

Advantages of CHM process are listed below :

(a) Low tooling cost.

(b) Multiple machining can be done on a workpiece simultaneously.

(c) No application of force so on risk of damage to delicate or low strength workpiece.

(d) Complicated shapes/patterns can be machined.

(e) Machining of hard and brittle material is possible.

Disadvantages and Limitations of CHM

(a) Slower process, very low MRR so high cost of operation.

(b) Small thickness of metal can be removed.

(c) Sharp corners cannot be prepared.

(d) Requires skilled operators.

5.8 ELECTROCHEMICAL MACHINING (ECM)

Electrochemical machining (ECM) process uses electrical energy in combination with chemical energy to remove the material of workpiece. This works on the principle of reverse of electroplating.

Working Principle of ECM

Electrochemical machining removes material of electrically conductor workpiece. The workpiece is made anode of the setup and material is removed by anodic dissolution. Tool is made cathode and kept in close proximity to the workpiece and current is passed through the circuit. Both electrodes are immersed into the electrolyte solution. The working principle and process details are shown in the Figure 5.5. This works on the basis of Faraday's law of electrolysis. The cavity machined is the mirror image of the tool. MRR in this process can easily be calculated according to Faraday's law.

Process Details

Process details of ECM are shown in Figure 5.5 and described as below :

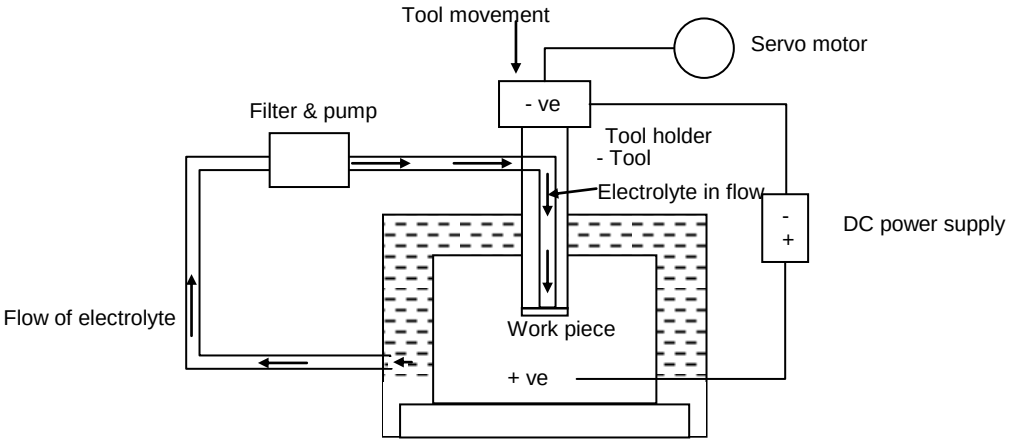

Figure 5.5 : Working Principle and Process Details of ECM

Workpiece

Workpiece is made anode, electrolyte is pumped between workpiece and the tool. Material of workpiece is removed by anodic dissolution. Only electrically conducting materials can be processed by ECM.

Tool

A specially designed and shaped tool is used for ECM, which forms cathode in the ECM setup. The tool is usually made of copper, brass, stainless steel, and it is a mirror image of the desired machined cavity. Proper allowances are given in the tool size to get the dimensional accuracy of the machined surface.

Power Supply

DC power source should be used to supply the current. Tool is connected with the negative terminal and workpiece with the positive terminal of the power source. Power supply supplies low voltage (3 to 4 volts) and high current to the circuit.

Electrolyte

Water is used as base of electrolyte in ECM. Normally water soluble NaCl and $NaNO_3$ are used as electrolyte. Electrolyte facilitates are carrier of dissolved workpiece material. It is recycled by a pump after filtration.

Tool Feed Mechanism

Servo motor is used to feed the tool to the machining zone. It is necessary to maintain a constant gap between the workpiece and tool so tool feed rate is kept accordingly while machining.

In addition to the above whole process is carried out in a tank filled with electrolyte. The tank is made of transparent plastic which should be non-reactive to the electrolyte. Connecting wires are required to connect electrodes to the power supply.

Applications of ECM Process

There are large number of applications of ECMs some other related machining and finishing processes as described below :

(a) *Electrochemical Grinding* : This can also be named as electrochemical debrruing. This is used for anodic dissolution of burrs or roughness a surface to make it smooth. Any conducting material can be machined by this process. The quality of finish largely depends on the quality of finish of the tool.

(b) This is applied in internal finishing of surgical needles and also for their sharpening.

(c) Machining of hard, brittle, heat resistant materials without any problem.

(d) Drilling of small and deeper holes with very good quality of internal surface finish.

(e) Machining of cavities and holes of complicated and irregular shapes.

(f) It is used for making inclined and blind holes and finishing of conventionally machined surfaces.

Advantages of ECM Process

Following are the advantages of ECM process :

(a) Machining of hard and brittle material is possible with good quality of surface finish and dimensional accuracy.

(b) Complex shapes can also be easily machined.

(c) There is almost negligible tool wear so cost of tool making is only one time investment for mass production.

(d) There is no application of force, no direct contact between tool and work and no application of heat so there is no scope of mechanical and thermal residual stresses in the workpiece.

(e) Very close tolerances can be obtained.

Disadvantages and Limitations of ECM

There are some disadvantages and limitations of ECM process as listed below :

(a) All electricity non-conducting materials can not be machined.

(b) Total material and workpiece material should be chemically stable with the electrolyte solution.

(c) Designing and making tool is difficult but its life is long so recommended only for mass production.

(d) Accurate feed rate of tool is required to be maintained.

5.9 LASER BEAM MACHINING (LBM)

Laser beam have wide industrial applications including some of the machining processes. A laser is an optical transducer that converts electrical energy into a highly coherent light beak. One must know the full name of laser, it stands for “light amplification of stimulated emission of radiation”. Laser being coherent in nature has a specific property, if it is focused by conventional optical lenses can generate high power density.

Working Principle of LBM

LBM uses the light energy of a laser beam to remove material by vaporization and ablation. The working principle and the process details (setup) are indicated in Figure 5.6. In this process the energy of coherent light beam is focused optically for predecided longer period of time. The beam is pulsed so that the released energy results in an impulse against the work surface that does melting and evaporation. Here the way of metal removing is same as that of EDM process but method of generation of heat is different. The application of heat is very finely focused in case of LBM as compared to EDM.

Process Details of LBM

Process details of LBM are shown in line diagram shown in Figure 5.6, description of the details is given below.

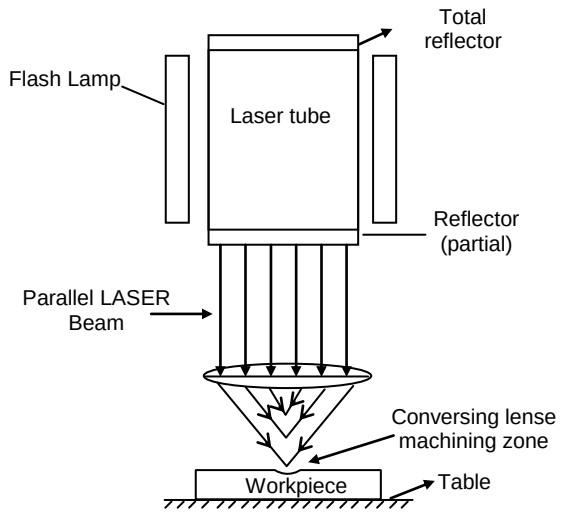

Figure 5.6 : Working Principle and Process Details of LBM

Laser Tube and Lamp Assembly

This is the main part of LBM setup. It consists of a laser tube, a pair of reflectors, one at each end of the tube, a flash tube or lamp, an amplification source, a power supply unit and a cooling system. This whole setup is fitted inside a enclosure, which carries good quality reflecting surfaces inside. In this setup the flash lamp goes to laser tube, that excites the atoms of the inside media, which absorb the radiation of incoming light energy. This enables the light to travel to and fro between two reflecting mirrors. The partial reflecting mirror does not reflect the total light back and apart of it goes out in the form of a coherent stream of monochromatic light. This highly amplified stream of light is focused on the workpiece with the help of converging lense. The converging lense is also the part of this assembly.

Workpiece

The range of workpiece material that can be machined by LBM includes high hardness and strength materials like ceramics, glass to softer materials like plastics, rubber wood, etc. A good workpiece material high light energy absorption power, poor reflectivity, poor thermal conductivity, low specific heat, low melting point and low lotent heat.

Cooling Mechanism

A cooling mechanism circulates coolant in the laser tube assembly to avoid its over heating in long continuous operation.

Tool Feed Mechanism

There is no tool used in the LBM process. Focusing laser beam at a pre-decided point in the workpiece serve the purpose of tool. As the requirement of being focused shifts during the operation, its focus point can also be shifted gradually and accordingly by moving the converging lense in a controlled manner. This movement of the converging lense is the tool feed mechanism in LBM process.

Applications of LBM

LBM is used to perform different machining operations like drilling, slitting, slotting, scribing operations. It is used for drilling holes of small diameter of the order of 0.025 mm. It is used for very thin stocks. Other applications are listed below :

(a) Making complex profiles in thin and hard materials like integrated circuits and printed circuit boards (PCBS).

(b) Machining of mechanical components of watches.

(c) Smaller machining of very hard material parts.

Advantages of LBM

(a) Materials which cannot be machined by conventional methods are machined by LBM.

(b) There is no tool so no tool wear.

(c) Application of heat is very much focused so rest of the workpiece is least affected by the heat.

(d) Drills very find and precise holes and cavities.

Disadvantages of LBM

Major disadvantages of LBM process are given below :

(a) High capital investment is involved. Operating cost is also high.

(b) Recommended for some specific operations only as production rate is very slow.

(c) Cannot be used comfortably for high heat conductivity materials light reflecting materials.

(d) Skilled operators are required.

5.10 PLASMA ARC MACHINING (PAM)

It is also one of the thermal machining processes. Here the method of heat generation is different than EDM and LBM.

Working Principle of PAM

In this process gases are heated and charged to plasma state. Plasma state is the superheated and electrically ionized gases at approximately 5000°C. These gases are directed on the workpiece in the form of high velocity stream. Working principle and process details are shown in Figure 5.7.

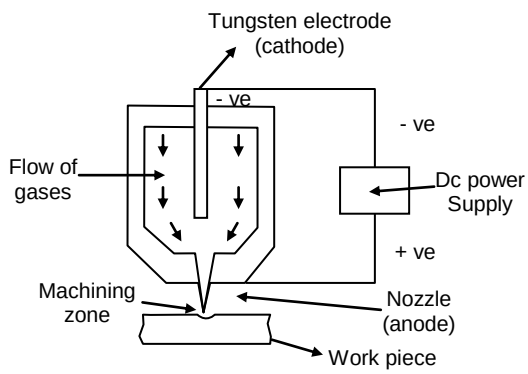

Figure 5.7 : Working Principle and Process Details of PAM

Process Details of PAM

Details of PAM are described below.

Plasma Gun

Gases are used to create plasma like, nitrogen, argon, hydrogen or mixture of these gases. The plasma gun consists of a tungsten electrode fitted in the chamber. The electrode is given negative polarity and nozzle of the gun is given positive polarity. Supply of gases is maintained into the gun. A strong

arc is established between the two terminals anode and cathode. There is a collision between molecules of gas and electrons of the established arc. As a result of this collision gas molecules get ionized and heat is evolved. This hot and ionized gas called plasma is directed to the workpiece with high velocity. The established arc is controlled by the supply rate of gases.

Power Supply and Terminals

Power supply (DC) is used to develop two terminals in the plasma gun. A tungsten electrode is inserted to the gun and made cathode and nozzle of the gun is made anode. Heavy potential difference is applied across the electrodes to develop plasma state of gases.

Cooling Mechanism

As we know that hot gases continuously comes out of nozzle so there are chances of its over heating. A water jacket is used to surround the nozzle to avoid its overheating.

Tooling

There is no direct visible tool used in PAM. Focused spray of ho0t, plasma state gases works as a cutting tool.

Workpiece

Workpiece of different materials can be processed by PAM process. These materials are aluminium, magnesium, stainless steels and carbon and alloy steels. All those material which can be processed by LBM can also be processed by PAM process.

Applications of PAM

The chief application of this process is profile cutting as controlling movement of spray focus point is easy in case of PAM process. This is also recommended for smaller machining of difficult to machining materials.

Advantages of PAM Process

Advantages of PAM are given below :

(a) It gives faster production rate.

(b) Very hard and brittle metals can be machined.

(c) Small cavities can be machined with good dimensional accuracy.

Disadvantages of PAM Process

(a) Its initial cost is very high.

(b) The process requires over safety precautions which further enhance the initial cost of the setup.

(c) Some of the workpiece materials are very much prone to metallurgical changes on excessive heating so this fact imposes limitations to this process.

(d) It is uneconomical for bigger cavities to be machined.

5.11 SUMMARY

Modern machining methods are alternate machining methods to conventional machining. These methods do not use sharp cutting edge tool for the machining of workpiece materials. These methods are mainly categorized into different types depending upon the type of energy used in the process of machining.

The unit covers the thermal energy based machining processes as electric discharge machining, laser beam machining, plasma arc machining processes, in these processes concentrated heat is focused at a point on the workpiece where machining is to done. The application of concentrated heat melts the material and evaporates the same. These methods have their relative advantages, disadvantages and limitations and so applications. Control of focusing the heat application is much better in case of LBM than followed by PAM and then EDM. So applications are decided on this base.

USM is a process in which mechanical abrasive action of hard spray particles is used to remove the material of workpiece. The cutting principle of this process resembles with the conventional cutting upto some extent. Surface quality given by this process is better than conventional machining process as material is removed in the form of very tiny chips. On the basis of specific characteristics of the process its application area, advantages and disadvantages are covered in detail in this unit.

Non-conventional machining also uses chemical reactivity to remove material of workpiece. Electrochemical machining and chemical machining works on this principle. This machining processes remove workpiece material by dissolving it atom by atom. So these give excellent quality of surface finish due to smallest possible chip size. These methods are also capable to produce very complicated geometries and cavities with ultra accuracy in the workpiece. These processes have limitations that the workpiece material which are insensitive to chemicals cannot be machined. Process details, their applications, advantages and disadvantages are also described in this unit.

5.12 ANSWERS TO SAQs

Refer the preceding text for all the Answers to SAQs.