NON-TRADITIONAL MACHINING PROCESSES

ULTRASONIC, ELECTRO-DISCHARGE MACHINING (EDM), ELECTRO-CHEMICAL MACHINING (ECM)

A machining process is called non-traditional if its material removal mechanism is basically different than those in the traditional processes, i.e. a different form of energy other than the excessive forces exercised by a tool, which is in physical contact with the work-piece is applied to remove the excess material from the work surface, or to separate the work-piece into smaller parts.

Comparison between traditional and non-traditional processes

1. In traditional processes, the cutting tool and workpiece are always in contact with a relative motion against each other which results in friction and a significant tool wear. In non-traditional processes, here is no physical contact between the tool and workpiece. However in some non-traditional processes, tool wear exists.
2. Material removal rate of the traditional processes (TP) is limited by the mechanical properties of the work material. Non-traditional processes (NTP) easily deal with such difficult-to-cut materials like ceramics and ceramic based tool materials, fiber reinforced material etc
3. In TP, the relative motion between the tool and workpiece is typically rotary or reciprocating. Thus the shape of the work surface is limited to circular or flat shapes. Most NTP were develop to solve this problem.
4. Machining of small cavities, slits, blind or through holes is difficult with traditional processes whereas it is a simple work for NTP.
5. TP are well established, use relatively simple and inexpensive machinery and readily available cutting tools. NTP require expensive equipment and tooling as well as skilled labour which increases significantly the production cost.

From the above, NTP should be employed when there is a need to process some newly developed difficult-to-cut materials, machining of which is accompanied by excessive cutting forces and tool wear. Also when there is need for unusual and complex shapes, which cannot easily be machined or cannot at all be machined by traditional processes.

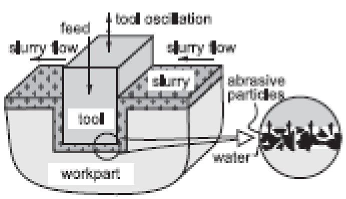
Classification of NTP

1. Mechanical processes: The mechanical energy differs from the action of the conventional cutting tool. Examples include ultrasonic machining and jet machining.
2. Electrochemical processes: Based on electrochemical energy to remove the material. Examples include electrochemical machining and electrochemical deburring and grinding
3. Thermal energy processes: Thermal energy generated by the conversion of electrical energy to shape or cut the workpiece. Examples include electric discharge processes, electron beam machining, laser beam machining and plasma arc cutting
4. Chemical machining: Chemicals selectively remove material from portions of the workpiece, while other portions of the surface are mask protected.

ULTRASONIC MACHINING

It is a non-traditional process in which abrasives contained in slurry are driven against the work by a tool oscillating at low amplitude (25-100 μm) and high frequency (15-30 kHz). The basic process is that a ductile and tough tool is pushed against the work with a constant force. A constant stream of abrasive slurry passes between the tool and the work to provide abrasives and carry away chips. The majority of the cutting action comes from an ultrasonic (cyclic) force applied. The basic components to the cutting action are believed to be brittle fracture caused by impact of abrasive grains due to the tool vibration; cavitation induced erosion and chemical erosion caused by slurry.

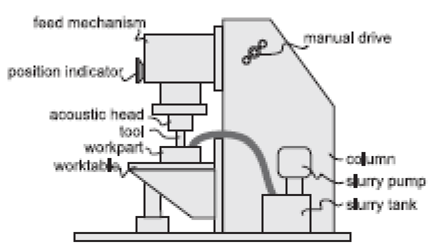
The ultrasonic machining process can be used to cut through and blind holes of round or irregular cross-sections. The process is best suited to poorly conducting, hard and brittle materials like glass, ceramics, carbides, and semiconductors. There is little production of heat and stress in the process but work may chip at exit side of the hole. The critical parameters to control the process are the tool, amplitude and material, abrasive grit size and material, feed force, slurry concentration and viscosity.



Ultrasonic machining.

Limitations of the ultrasonic machining include very low material removal rate, extensive tool wear, small depth of holes and cavities.

The acoustic head is the most complicated part of the machine. It must provide a static constant force, as well as the high frequency vibration. Tools are produced of tough but ductile metals such as soft steel of stainless steel. Abrasive slurry consists of a mixture of liquid (water is the most common but oils or glycerol are also used) and 20% to 60% of abrasives with typical grit sizes of 100 to 800. The common types of abrasive materials are boron carbide, silicon carbide, diamond and corundum (Al_2O_3)).



Principal components of an ultrasonic machine.

JET MACHINING

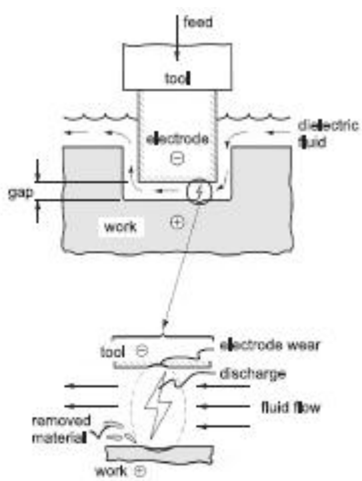
In this method, high velocity stream of water (Water Jet Cutting) or water mixed with abrasive materials (Abrasive Water Jet Cutting) is directed to the workpiece to cut the material. If a mixture of gas and abrasive particles is used, process is referred to as Abrasive Jet Machining and is used not to cut the work but for finishing operations like deburring, cleaning, polishing.

ELECTRIC DISCHARGE MACHINING

In electric discharge processes, the work material is removed by a series of sparks that cause localized melting and evaporation of the material on the work surface. The two main processes in this category are electric discharge machining and wire electric discharge machining.

Electric discharge machining (EDM) is one of the most widely used NTP. An EDM setup and a close-up view of the gap between the tool and the work are shown in the figures below.

A formed electrode produces the shape of the finished work surface. The sparks occurs across a small gap between tool and work surface. The EDM process must take place in the presence of a dielectric fluid, which creates a path for each discharge as the fluid becomes ionized in the gap. The fluid, quite often kerosene-based oil is also used to carry away debris. The discharges are generated by a pulsating direct-current power supply connected to the work and the tool. Electrode materials are high temperature but easy to machine, thus allowing easy manufacture of complex shapes. e.g copper, tungsten and graphite. The process is based on melting temperature, not hardness, so some very hard material can be machined this way.

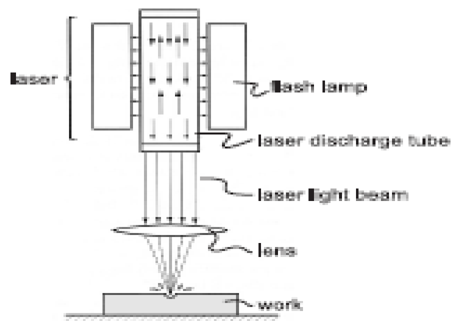


The setup of Electric Discharge Machining (EDM) process and close-up view of gap, showing discharge and metal removal.

Electric Discharge Machine.

LASER BEAM MACHINING (LBM)

It uses the light energy from a laser to remove material by vaporization and ablation. The types of lasers used in LBM are basically the carbon dioxide (CO_2) gas lasers. Lasers produce collimated monochromatic light with constant wavelength. In the laser beam, all of the light rays are parallel, which allows the light not to diffuse quickly lie the normal light. The light produced by laser has significantly less power than a normal white light, but it can be highly focused, thus delivering a significantly higher light intensity and respectively temperature in a very localized area. Lasers are used for variety of industrial applications such as heat treatment, welding and measurement as well as a number of cutting operations such as drilling, slitting, slotting and marking operations. The range of work materials that can be machined by LBM is virtually unlimited including metals with high hardness and strength, soft metals, ceramics, glass, plastics, rubber, cloth and wood. LBM can be used for 2D or 3D workspace. The LBM machines typically have a laser mounted and the beam is directed to the end of the arm using mirrors. Mirrors are often cooled because of high laser powers.

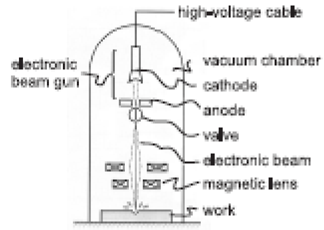


The setup of laser beam machining process.

ELECTRON BEAM MACHINING (EBM)

EBM is one of the several industrial processes that use electron beams. EBM uses a high-velocity stream of electrons focused on the workpiece surface to remove material by melting and vaporization. An electron beam gun generates a continuous stream of electrons that are focused through an electromagnetic lens on the work surface. The electrons are accelerated with high voltages to create velocities over 200000 km/s. The lens is capable of reducing the area of the beam to a diameter as small as 0.035 mm. on impinging the surface, the kinetic energy of the electrons is converted into thermal energy of extremely high density which vaporizes the material in a localized area. EBM must be carried out in a vacuum chamber to eliminate collision of the electrons with gas molecules.

EBM is used for variety of high precision cutting application on any known material. e.g. drilling of extremely small diameter holes, cutting of slots etc. Other applications include heat treating and welding. The process is generally limited to thin parts in the range from 0.2 to 6 mm thick. Other limitations are the need to perform the process in a vacuum, the high energy required and the expensive equipment.



The setup of electron beam machining process.

REVIEW QUESTIONS

1. Explain the term “non-traditional machining”.
2. Differentiate between tradition and non-traditional machining
3. Explain the following:
   i. Ultrasonic machining
   ii. Jet machining
   iii. Electron beam machining
   iv. Laser beam machining
   v. Electric discharge machining