INTRODUCTION

Unconventional manufacturing processes is defined as a group of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for traditional manufacturing processes.

Extremely hard and brittle materials are difficult to machine by traditional machining processes such as turning, drilling, shaping and milling. Nontraditional machining processes, also called advanced manufacturing processes, are employed where traditional machining processes are not feasible, satisfactory or economical due to special reasons as outlined below.

- Very hard fragile materials difficult to clamp for traditional machining
- When the work piece is too flexible or slender
- When the shape of the part is too complex

Several types of non-traditional machining processes have been developed to meet extra required machining conditions. When these processes are employed properly, they offer many advantages over non-traditional machining processes. The common non- traditional machining processes are described in this section.

Manufacturing processes can be broadly divided into two groups)

a) Primary manufacturing processes: Provide basic shape and size

b) Secondary manufacturing processes: Provide final shape and size with tighter control on dimension, surface characteristics

Material Removal Processes Once Again Can Be Divided Into Two Groups

1. Conventional Machining Processes

2. Non-Traditional Manufacturing Processes or Unconventional Machining processes

Conventional Machining Processes mostly remove material in the form of chips by applying forces on the work material with a wedge shaped cutting tool that is harder than the work material under machining condition.

THE MAJOR CHARACTERISTICS OF CONVENTIONAL MACHINING ARE:

- Generally macroscopic chip formation by shear deformation
- Material removal takes place due to application of cutting forces – energy domain can be Classified as mechanical
- Cutting tool is harder than work piece at room temperature as well as under machining Conditions

Non-conventional manufacturing processes is defined as a group of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for traditional manufacturing processes. Material removal may occur with chip formation or even no chip formation may take place. For example in AJM, chips are of microscopic size and in case of Electrochemical machining material removal occurs due to electrochemical dissolution at atomic level.

2 NEED FOR UNCONVENTIONAL MACHINING PROCESSES

• Extremely hard and brittle materials or Difficult to machine material are difficult to Machine by traditional machining processes.

• When the work piece is too flexible or slender to support the cutting or grinding Forces when the shape of the part is too complex.

3 CLASSIFICATION OF UCM PROCESSES:

1. Mechanical Processes

Abrasive Jet Machining (AJM)

Abrasive Water Jet Machining (AWJM)

Water Jet Machining

Ultrasonic Machining (USM)

2. Electrochemical Processes

Electrochemical Machining (ECM)

Electro Chemical Grinding (ECG)

Electro Jet Drilling (EJD)

3. Electro-Thermal Processes

Electro-discharge machining (EDM)

Laser Jet Machining (LJM)

Electron Beam Machining (EBM)

4. Chemical Processes

Chemical Milling (CHM)

Photochemical Milling (PCM)

4 BRIEF OVERVIEW

1 ULTRA SONIC MACHINING

USM is a mechanical material removal process in which the material is removed by repetitive impact of abrasive particles carried in liquid medium on to the work surface, by a shaped tool, vibrating at ultrasonic frequency.

2 ABRASIVE JET MACHINING

It is the material removal process where the material is removed or machined by the impact erosion of the high velocity stream of air or gas and abrasive mixture, which is focused on to the work piece.

3. LASER BEAM MACHINING

Laser-beam machining is a thermal material-removal process that utilizes a high- Energy, Coherent light beam to melt and vaporize particles on the surface of metallic and non- Metallic work pieces. Lasers can be used to cut, drill, weld and mark. LBM is particularly suitable for making accurately placed holes

4. ELECTRON EAM MACHINING

It is the thermo-electrical material removal process on which the material is removed by the high velocity electron beam emitted from the tungsten filament made to impinge on the work surface, where kinetic energy of the beam is transferred to the work piece material, producing intense heat, which makes the material to melt or vaporize it locally.

5. ELECTRO CHEMICAL MACHINING

It is the controlled removal of metals by the anodic dissolution in an electrolytic medium, where the work piece (anode) and the tool (cathode) are connected to the electrolytic circuit, which is kept, immersed in the electrolytic medium

6. ELECTO CHEMICAL GRINDING

ECG is the material removal process in which the material is removed by the combination of Electro-Chemical decomposition as in ECM process and abrasive due to grinding.

7. PLASMA ARC MACHINING

Plasma is defined as the gas, which has been heated to a sufficiently high temperature to Become ionized.

8. WATER JET MACHINING

Water jet cutting can reduce the costs and speed up the processes by eliminating or reducing expensive secondary machining process. Since no heat is applied on the materials, cut edges are clean with minimal burr. Problems such as cracked edge defects, crystallization, hardening, reduced wealdability and machinability are reduced in this process.

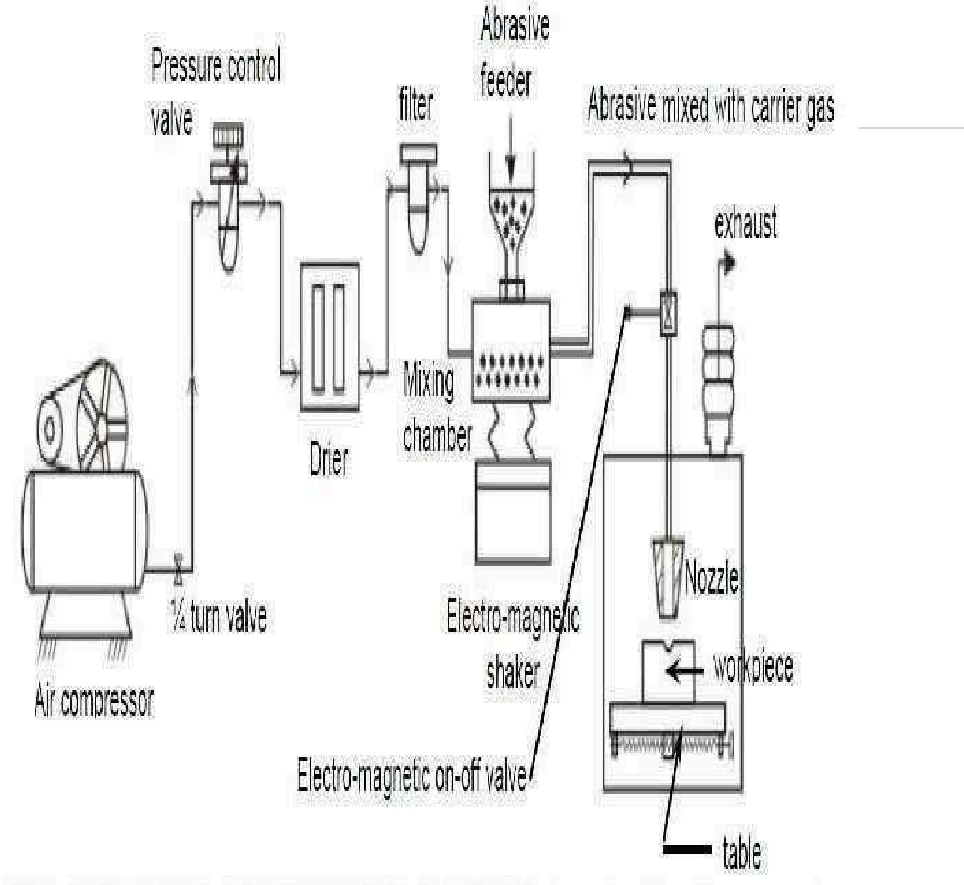
9. ELECTRICAL DISCHARGE MACHINING

EDM is the controlled erosion of electrically conductive materials by the Initiation of rapid and repetitive spark discharge between the electrode tool to the cathode and work to anode separated by a small gap kept in the path of dielectric medium. This Process also called spark erosion.

ABRASIVE JET MACHINING (AJM)

In Abrasive Jet Machining (AJM), abrasive particles are made to impinge on the work material at a high velocity. The high velocity abrasive particles remove the material by micro-cutting action as well as brittle fracture of the work material.

In AJM, generally, the abrasive particles of around 50 μm grit size would impinge on the work material at velocity of 200 m/s from a nozzle of I.D. of 0.5 mm with a standoff distance of around 2 mm. The kinetic energy of the abrasive particles would be sufficient to provide material removal due to brittle fracture of the work piece or even micro cutting by the abrasives.



SCHEMATIC ARRANGEMENT OF AJM

Process Parameters and Machining Characteristics

Abrasive: Material – Al2O3 / SiC / glass

beads Shape – irregular / spherical

Size – 10 ~ 50 μm

Mass flow rate – 2 ~ 20 gm/min

Carrier gas : Composition – Air, CO2, N2 Density – Air

~ 1.3kg/m3

Velocity – 500 ~ 700m/s

Pressure – 2 ~ 10 bar Flow rate – 5 ~ 30 lpm

Abrasive Jet : Velocity – 100 ~ 300 m/s

Mixing ratio – mass flow ratio of abrasive to gas Stand-off distance – 0.5~ 5 mm

Impingement Angle – 60^0 ~ 90^0 Nozzle : Material

– WC Diameter –(Internal) 0.2 ~ 0.8 mm

Life–10~300hours Modelling of material removal

Material removal in AJM takes place due to brittle fracture of the work material due to impact of high velocity abrasive particles.

Modeling has been done with the following assumptions:

a) Abrasives are spherical in shape and rigid. The particles are characterized by the mean grit diameter
b) The kinetic energy of the abrasives are fully utilized in removing material
c) Brittlematerialsareconsideredtofailduetobrittlefractureandthefracturevolumeis considered to be hemispherical with diameter equal to choral length of the indentation
d) For ductile material, removal volume is assumed to be equal to the indentation volume due to particulate impact.

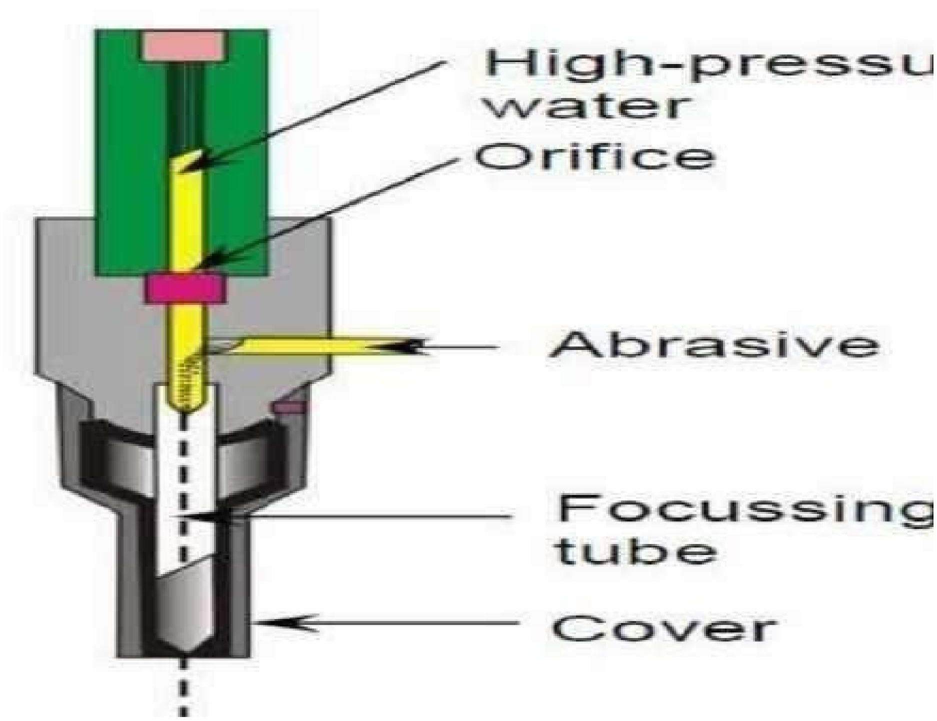
Water Jet Machining (WJM)

Introduction

Water jet cutting can reduce the costs and speed up the processes by eliminating or reducing expensive secondary machining process. Since no heat is applied on the materials, cut edges are clean with minimal burr. Problems such as cracked edge defects, crystalisation, hardening, reduced wealdability and machinability are reduced in this process.

Water jet technology uses the principle of pressurizing water to extremely high pressures, and allowing the water to escape through a very small opening called "orifice" or "jewel". Water jet cutting uses the beam of water exiting the orifice to cut soft materials. This method is not suitable for cutting hard materials. The inlet water is typically pressurized between

1300 – 4000 bars. This high pressure is forced through a tiny hole in which is typically to 0.4 mm in diameter. A picture of water jet machiningprocess



Applications

Water jet cutting is mostly used to cut lower strength materials such as wood, plastics and aluminum. When abrasives are added, (abrasive water jet cutting) stronger materials such as steel and tool steel.

Advantages of water jet cutting

a) There is no heat generated in water jet cutting; which is especially useful for cutting tool steel and other metals where excessive heat may change the properties of the material.

b) Unlike machining or grinding, water jet cutting does not produce any dust or particles that are harmful if inhaled.

c) Other advantages are similar to abrasive water jet cutting

Disadvantages of water jet cutting

a) One of the main disadvantages of water jet cutting is that a limited number of materials can be cut economically.

b) Thick parts cannot be cut by this process economically and accurately

c) Taper is also a problem with water jet cutting in very thick materials. Taper is when the jet exits the part at different angle than it enters the part, and cause dimensional inaccuracy.

ABRASIVE WATER-JETMACHINING (AWJM)

Introduction

Abrasive water jet cutting is an extended version of water jet cutting; in which the water jet contains abrasive particles such as silicon carbide or aluminum oxide in order to increase the material removal rate above that of water jet machining. Almost any type of material ranging from hard brittle materials such as ceramics, metals and glass to extremely soft materials such as foam and rubbers can be cut by abrasive water jet cutting. The narrow cutting stream and computer controlled movement enables this process to produce parts accurately and efficiently. This machining process is especially ideal for cutting materials that cannot be cut by laser or thermal cut. Metallic, non-metallic and advanced composite materials of various thicknesses can be cut by this process. This process is particularly suitable for heat sensitive materials that cannot be machined by processes that produce heat while machining.

The schematic of abrasive water jet cutting is shown in Figure 15 which is similar to water jet cutting apart from some more features underneath the jewel; namely abrasive, guard and mixing tube. In this process, high velocity water exiting the jewel creates a vacuum which sucks abrasive from the abrasive line, which mixes with the water in the mixing tube to form a high velocity beam of abrasives.

Applications

Abrasive water jet cutting is highly used in aerospace, automotive and electronics industries. In aerospace industries, parts such as titanium bodies for military aircrafts, engine components (aluminium, titanium, and heat resistant alloys), aluminium body parts and interior cabin parts are made using abrasive water jet cutting.

In automotive industries, parts like interior trim (head liners, trunk liners, door panels) and fibre glass body components and bumpers are made by this process. Similarly, in electronics industries, circuit boards and cable stripping are made by abrasive water jet cutting.

Advantages of abrasive water jet cutting

In most of the cases, no secondary finishing required

a) No cutter induced distortion
b) Low cutting forces on work pieces

c) Limited tooling requirements

d) Little to no cutting burr

e) Typical finish 125-250microns

f) Smaller kerf size reduces material wastages

g) No heat affected zone

h) Localizes structural changes

i) No cutter induced metal contamination

j) Eliminates thermal distortion

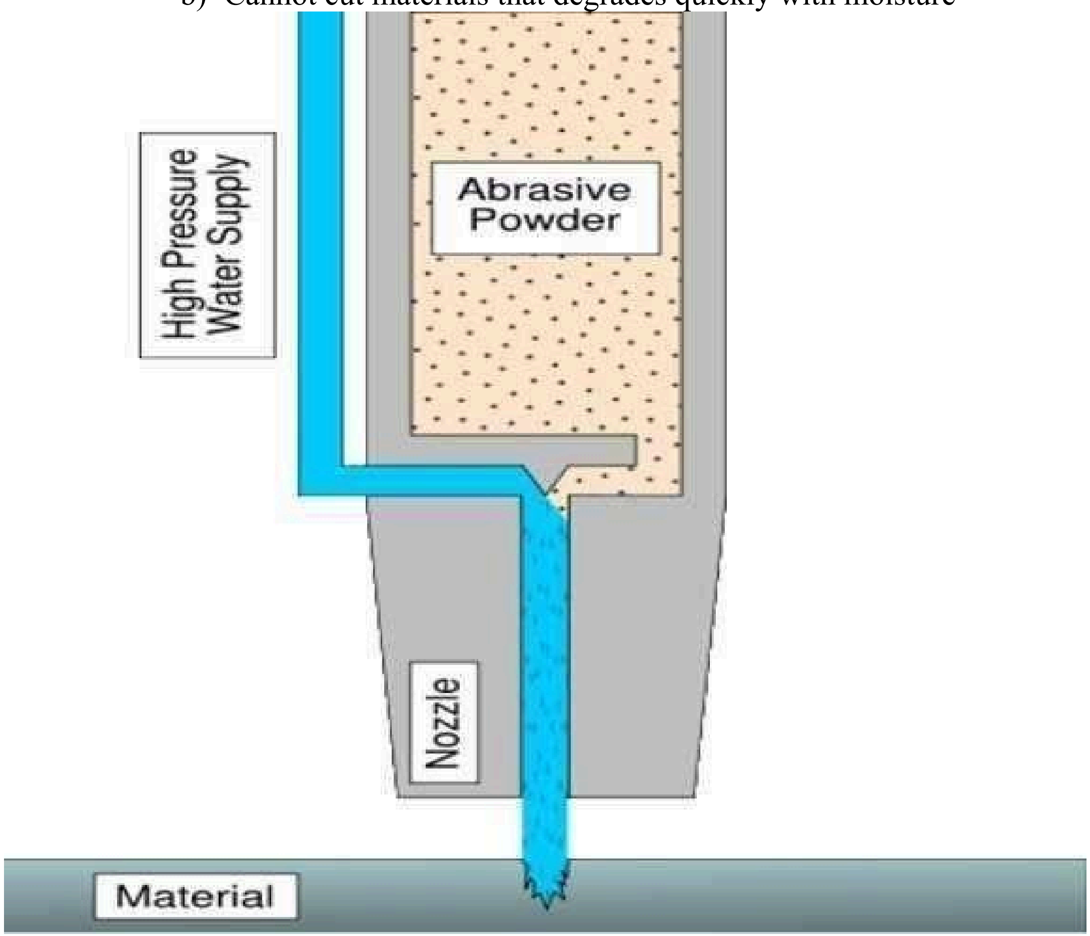
k) No slag or cutting dross

l) Precise, multi plane cutting of contours, shapes, and bevels of any angle.

Limitations of abrasive water jet cutting

a) Cannot drill flat bottom

b) Cannot cut materials that degrades quickly with moisture

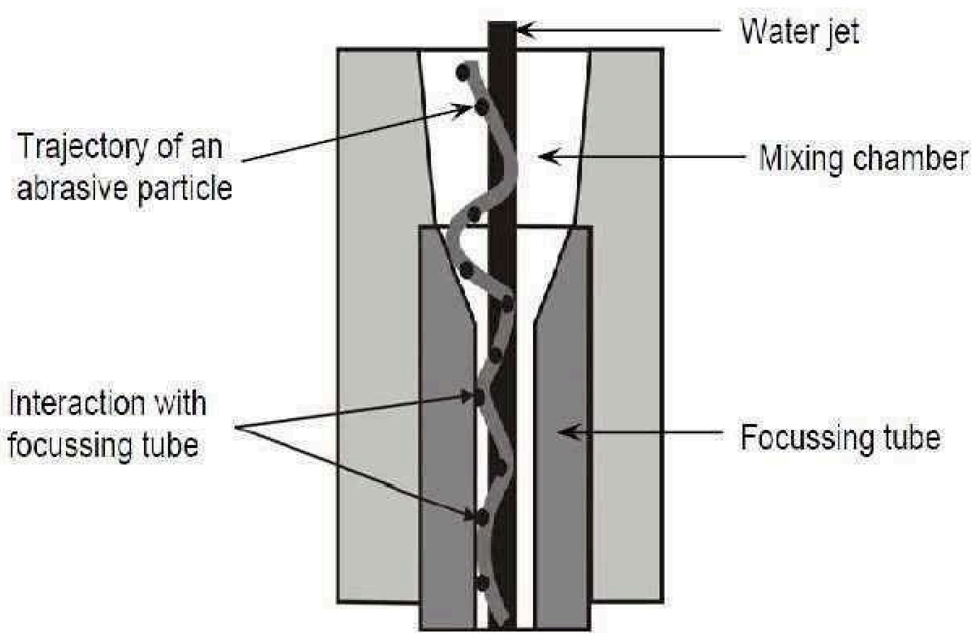


The major disadvantages of abrasive water jet cutting are high capital cost and high noise levels during operation.

A component cut by abrasive water jet cutting is shown in Figure 16. As it can be seen, large parts can but cut with very narrow kerf which reduces material wastages. The complex shape part made by abrasive water jet cutting

Abrasive water jet cutting

a) WJM -Pure
b) WJM – with stabilizer
c) AWJM – entrained – three phase–abrasive, water and air
d) AWJM – suspended – two phase– abrasive and water
e) Direct pumping
   i. Indirect pumping
   ii. Bypass pumping



Components of ABRASIVE WATERJET MACHINING

ULTRASONIC MACHINING (USM)

Introduction

USM is mechanical material removal process or an abrasive process used to erode holes or cavities on hard or brittle work piece by using shaped tools, high frequency mechanical motion and an abrasive slurry. USM offers a solution to the expanding need for machining brittle materials such as single crystals, glasses and polycrystalline ceramics, and increasing complex operations to provide intricate shapes and work piece profiles. It is therefore used extensively in machining hard and brittle materials that are difficult to machine by traditional manufacturing processes. The hard particles in slurry are accelerated toward the surface of the work piece by a tool oscillating at a frequency up to 100 KHz - through repeated abrasions, the tool machines a cavity of a cross section identical to its own.

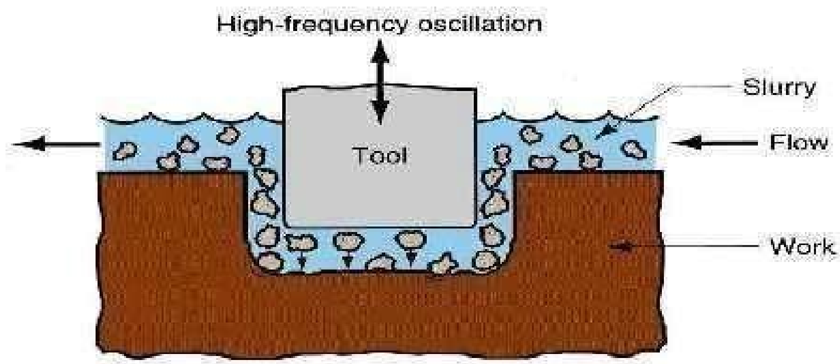


Figure 10: Schematic of ultrasonic machine tool

USM is primarily targeted for the machining of hard and brittle materials (dielectric or conductive) such as boron carbide, ceramics, titanium carbides, rubies, quartz etc. USM is a versatile machining process as far as properties of materials are concerned. This process is able to effectively machine all materials whether they are electrically conductive or insulator.

For an effective cutting operation, the following parameters need to be carefully considered:

- Themachiningtoolmustbeselectedtobehighlywearresistant,suchashigh-ca rbon steels.
- The abrasives (25-60 µm in dia.) in the (water-based, up to 40% solid volume) slurry includes: Boron carbide, silicon carbide and aluminum oxide.

Applications

The beauty of USM is that it can make non round shapes in hard and brittle materials. Ultrasonically machined non round-hole part is shown in Figure 11.

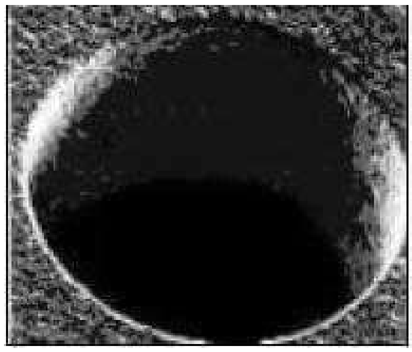


Figure 11: A non-round hole made by USM

Advantage of USM

USM process is a non-thermal, non-chemical, creates no changes in the microstructures, chemical or physical properties of the workpiece and offers virtually stress free machined surfaces.

- Any materials can be machined regardless of their electrical conductivity
- Especially suitable for machining of brittle materials
- Machined parts by USM possess better surface finish and higher structural integrity.
- USM does not produce thermal, electrical and chemical abnormal surface

Some disadvantages of USM

- USM has higher power consumption and lower material-removal rates than traditional fabrication processes.
- Tool wears fast in USM.
- Machining area and depth is restraint in USM.