Comparison with traditional Machining :-

Traditional Machining / Conventional Machining	Non-traditional Machining / Non-conventional Machining
* Only Mechanical Energy (power) is utilized to gradually remove excess material from workpiece.	* Various forms of energy like (electrical, Mechanical, thermal, chemical, light etc.) are directly utilized to remove excess material.
* Materials are removed in the form of tiny sharp chips.	* So called 'chip' is not produced here. Material is removed in various forms, such as tiny metal particles, ions, molten or vapor etc.
* A sharp wedge shaped cutting tool having specific geometry, material and properties is required for cutting action. It has a paticular shape and size.	* So called cutting tool does not exist here. In few cases tool is required and its profile & property must match with the requirement.
* Physical contact betn cutting tool and workpiece and also relative velocity in betn them are necessary in order to remove materials.	* No physical contact occurs betn cutting tool and workpiece.
* Skilled labors are also readily available at comparatively cheaper cost.	* Most of these processes are developing. Labor cost is also high due to less number of skilled labors available in this field.
* Surface finish is very less.	* Surface finish is very high.
* Material removal rate is very high.	* Material removal rate is very less.

Abrasive Jet Machining (AJM) :-

→ In AJM abrasive particles are made to impinged on the work material at a very high speed.

→ The jet of abrasive particles is carried by carrier gas.

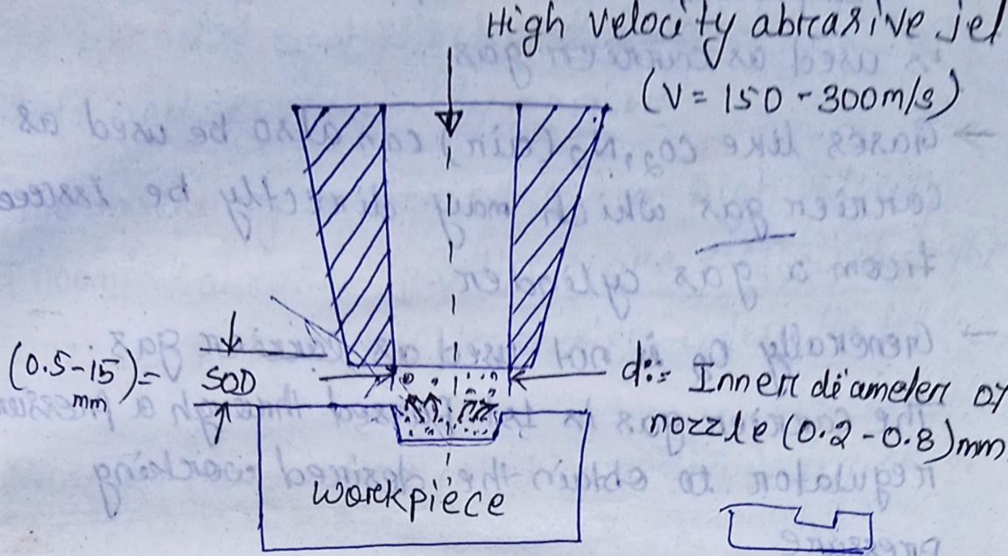
→ The high velocity stream of abrasive is generated by converting the pressure energy of the carrier gas to its KE and hence high velocity jet. (Device used Nozzle). (Drop in KE & increase pressure - Diffuser).

→ The nozzle directs the abrasive jet in a controlled manner on to the work material (velocity & angle maintain)
So that the distance betⁿ the nozzle tip and the w/p and the impingement angle can be set disereably. (stand of distance) (SOD)

→ The high velocity abrasive particles remove the material by micro cutting action as will as brittle fracture of the work material.

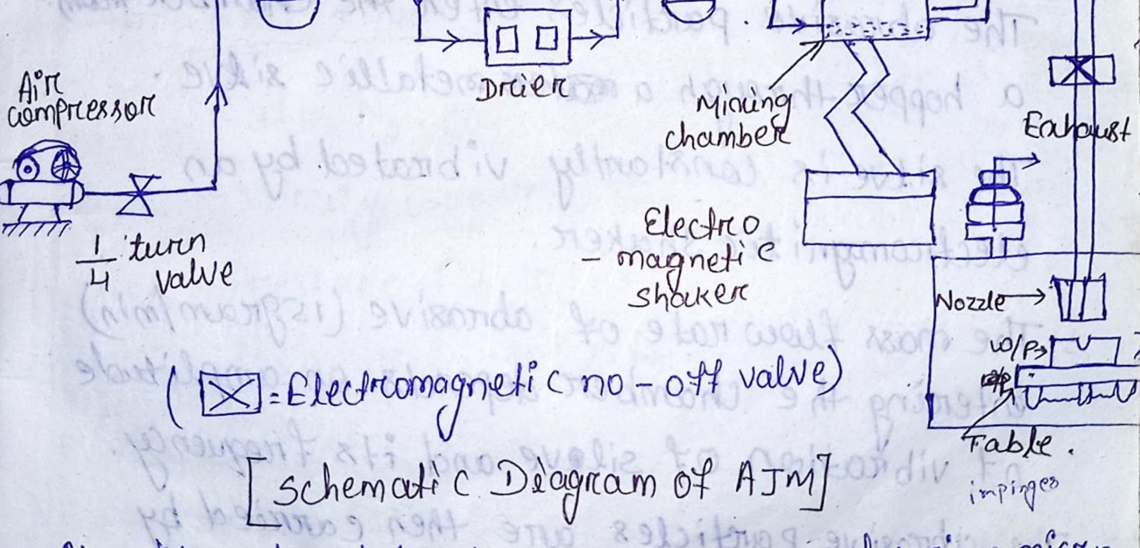
→ In AJM finner abrasive grits are used and the parameters can be controlled more effectively providing better control over Product quality.

In AJM generally the abrasive particle of around 50 μm greit size would impenge on work material at a velocity of 200 m/s from a nozzle of inner diameter 0.5 mm with a SOD of around 2mm.



→ The KE of abrasive particles would be sufficient to provide material removal due to brittle fracture of w/p or even micro cutting by the abrasives.

Equipment:-



[Schematic Diagram of AJM]

impinges

* Abrasive Jet machining is a also known as abrasive micro blasting process.

→ In AJM air is compressed in an air compressor and compressed air at a pr. of around 5bar is used as carrier gas.

→ Gases like CO_2, N_2 (air) can also be used as carrier gas which may directly be issued from a gas cylinder.

→ Generally O_2 is not used as carrier gas.

The carrier gas is 1st passed through a pressure regulator to obtain the desired working pressure.

The gas is then passed through an air drier to remove any residual water vapour.

The remove any oil vapour or particulate contaminant the same is passed through a series of filters.

Then the carrier gas enters a closed chamber known as mixing chamber.

The abrasive particles enter the chamber from a hopper through a metallic sieve.

The sieve is constantly vibrated by an electromagnetic shaker.

The mass flow rate of abrasive (15gram/min) entering the chamber depends on amplitude of vibration of sieve and its frequency.

The abrasive particles are then carried by carrier gas to the machining chamber via an electromagnetic on-off valve.

The machining enclosere is essential to contain the abrasive and machined particles in a safe and ecofriendly manner.

The machining is carried out as high velocity (200m/s) abrasive particles are issued from the nozzle on to a w/p traversing under the jet.

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Process Parameters / Machining characteristics:-

a) Abrasive

- Material - Al_2O_3, SiC, glass beads, diamond dust, sodium bicarbonate.
- Shape - Irregular, spherical
- Size - (10-50) μm.
- Mass flow rate - (2-20) gm/min.

> AJM is a metal removal process by the abrasive particles with high pressure gas or air impacting through a nozzle on to the workpiece.

b) Carrier gas

- Air, N_2, CO_2
- Velocity (500-700) m/s.
- Pressure - (2-10) bar
- flow rate (5-30) lt/min

c) Abrasive jet

- velocity (100-300) m/s
- Mixing ratio - (mass flow ratio of abrasive to gas) ~~mixing ratio~~

$$= \frac{M_{abrasive}}{M_{gas}}$$

~~d) Impingement angle (angle at~~

d) Stand off distance – (0.5 – 15) mm.

e) Impingement angle (angle at which abrasives are impacted to w/p) (60 – 90°)

f) Nozzle

- Material – Tungsten carbide, sapphire(WC)
- Internal dia – (0.2 – 0.8) mm.
- Life – (10 – 300) hrs.

Machining characteristics:–

i) The important machining characteristics in AJM is MRR $\left(\frac{\text{vol Removed}}{\text{time}} \text{ or } \frac{\text{mass removed}}{\text{time}} \right)$

ii) → Machining accuracy

iii) → Nozzle life.

Modeling of material Removal:–

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

→ Modeling has been done with the following assumptions.

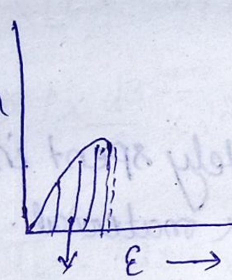
a) Abrasives are spherical in shape and rigid.

b) The KE of abrasives are fully utilized in removing of material.

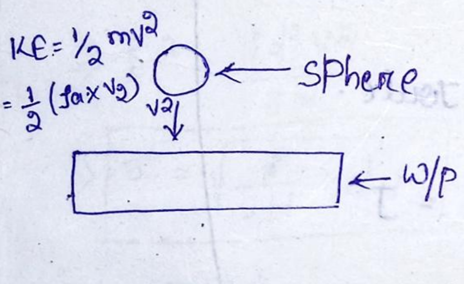
c) Brittle materials are considered to fail due to brittle fracture and the fracture volume is considered to be hemispherical with dia = the chordal length of the indentation.

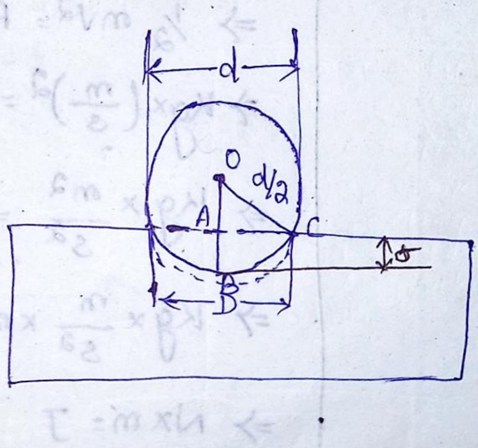
MRR = ?

[KE of abrasive jet = Material removal]



Strain energy = $\frac{1}{2}\sigma \times \varepsilon$





$$OC^2 = OA^2 + AC^2$$

$$\Rightarrow \frac{d^2}{4} = \left(\frac{d}{2} - \delta\right)^2 + \left(\frac{D}{2}\right)^2$$

$$\Rightarrow \frac{d^2}{4} = \frac{d^2}{4} + \delta^2 - d\delta + \frac{D^2}{4}$$

($\delta^2 \to 0$ (very less))

Application :-

a) This is used for abrading and frosting glass more economically as compared to etching and grinding.

b) Cleaning of metallic smear (mark made by smearing by the help of greasing or sticky substance) on ceramics, oxides on metals, resistive coating

c) It is useful in drilling of glases ~~with~~ wafers (a thin piece of something circuit produced), deburing of plastics, cutting of titanium foils, engraving resistration number on toughen glass used for car windows.

d) Cutting thin fragile component like Si, Ge at c......

e) Trimming and micromodule frabrication for electrical contact, semiconductors processing can also be done effectivity.

f) Used for drilling, cutting, deburring, itching, Cleaning, polishing of hard and brittle materials.

g) Most suitable for machining brittle and heat sensitive mtrs. like glass, quartz, sapphire, mica, Ceramics, Si, Gallium, Be, Ge etc-----

h) It is a good method for deburring brittle holes like in hypodermic needles and for mall milled slots in hard metalline components.

Advantages :-

i) High surface finish can be obtained depending upon grain size.

ii) Depth of damage is very low. (0.5 micron)

iii) It provides cool cutting action so it can machine delicate and heat sensitive material.

iv) Process is free from Chatter (free from vibration) of vibration as there is no. contact bet' tools & w/p.

v) Capital cost is low.

vi) Easy to operate and maintain.

Disadvantages:-

i) Ductile & soft material can not be machined.

ii) MRR is low (ex:- for glass = 40gm/min)

iii) Nozzle life is limited (300 hrs).

Ultrasonic Machining (USM)

Defn USM is a non-traditional process in which abrasives contained in a slurry are driven against the work by a tool oscillating at a very low amplitude and high frequency.
(25-100 μ)
(20 - 25 KHz)

20 - 25 KHz = Sonic range

> 20 KHz = Ultra-sonic
greater than

< 20 Hz = Infrasonic.
less than

→ Speed of sound in dry air = 343 m/s

- Supersonic - > speed of sound.

Subsonic - < speed of sound.

Process:-

→ It is a mechanical type NTM process which is employed to machine hard and brittle materials (both electrically conductive & non-conductive materials.

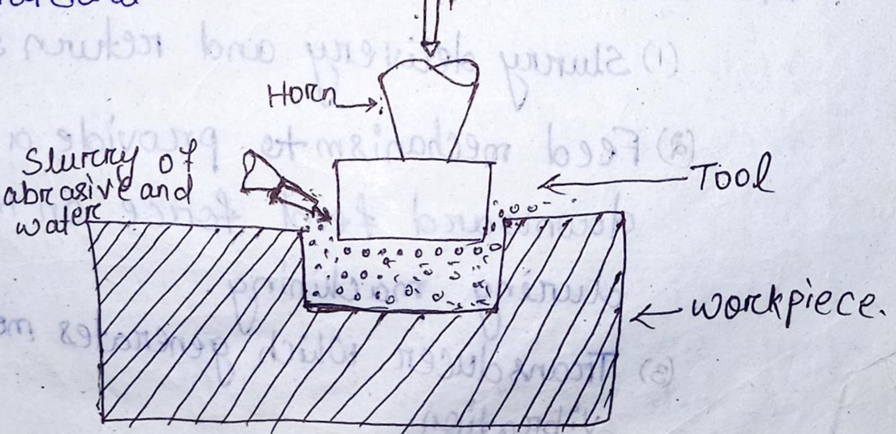
→ In USM, a tool of desired shape vibrates at an ultrasonic frequency with an amplitude of around (15-50) μm) over the workpiece.

→ Generally the tool is pressed downward with a feed force (F) between the tool and w/p, the machining zone is flooded with hard abrasive particles generally in the form of water based slurry.

→ As the tool vibrates over the w/p, the abrasive particles act as the indentors and indents both the work material and the Tool.

→ The abrasive particles, as they indent the work material would remove the same perticularly if the work material is brittle due to crack initiation propagation and brittle fracture of the material.

→



Feed force is required to maintain the gap after machining betn tool & w/p.

Horn also known as concentrator, which is used to hold tool and convert the mechanical vibration and amplifies (focus) it and provide to tool. Horn is connected with transducer.

Energy → Transducer → Horn → Tool
↓
abrasive
↓
fracture.

Equipments :-

The basic mechanical structure of an USM is very similar to drill press.
The w/p is mounted on a vice which can be located at the desired position under the tool using a 2-axis table.
The table can further be raised or lowered to accomadate ~~be raised as~~ work of diff thickness.

The main elements of an USM are :-

(1) Slurry delivery and return system
(2) Feed mechanism to provide a downward feed force on the tool during machining.
(3) Transducer which generates mechanical vibration.

B) Transducer :-

The ultrasonic vibrations are produced by the transducer, the transducer is driven by suitable signalgenerator, followed by Power amplifier.

The transducer for USM works on the following principle:-

(a) Piezoelectric effect
(b) magnetostrictive effect
(c) Electrostrictive effect

a) Piezoelectric effect :-

→ These transducer generate a small electric current when they are compressed.

→ Also when the electric current is passed through the crystal it expands.

→ When the current is removed crystal attains its original shape and size. Such transducer are available up to 900 watt.

→ Piezoelectric crystal have high conversion efficiency (95%).

b) <u>Magnetostrictive Transducer</u>:-

→ These also changes its length when subjected to strong magnetic field.

→ These transducer are made of Nickel, <u>Nickel alloy sheet</u>.

→ Conversion efficiency = (20 - 30)%.

→ Such transducers are available upto 2000 watt.

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Imp 4) <u>Tool holder / Horn / Concentrator</u>:-

→ The tool holder holds and connecte the tool with the transducer.

→ It virtually transmitts the vibrational energy and is some cases amplifies and focuses the vibration (mechanical energy).

→ It is simply a velocity transformer with the enception than half of the wave-length.

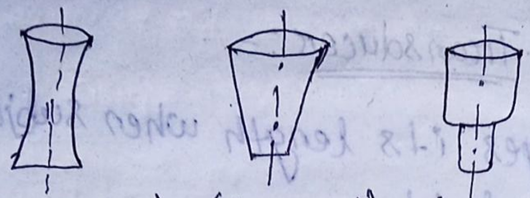
→ The horn mechanically modifies the vibrational energy to give required force- amplifiers ratio.

Horn / concentrator can be of diff. shape

(i) tappered or conical.

(ii) Exponential.

(iii) stepped



(Exponential) (tappered) (stepped)

Tool

→ Tools are made of relatively ductily materials like brass, stainless steel or mild steel ductille metallic alloys. so that Tool wear Rate can be minimised.

(If brittle tool used may be a chance of brittle fracture due to very hard abrasive particle).

Abrasive Slurry :-

→ Abrasive used as Al_2O_3, B_4C, SiC, diamond dust.

→ Boron is suitable for cutting tungsten carbide (WC), tool steel and precious stones.

→ Al_2O_3 is best for cutting glass, germanium and ceramics.

→ Diamond powder is used for cutting diamond and rubies.

→ Size varies from (200 - 2000) grit.

→ Liquid - Benzene
- Vegetable oils
- Glycerin
- Water.

* **Functions of Abrasive Slurry:-**

→ It acts as an acoustic bond betn w/p and vibrating tool. (absorb maxm energy)

→ Helps efficient transfer of energy betn w/p and tool.

→ Acts as a coolant.

→ Provides a medium to carry the abrasive to the cutting zone.

→ Helps to carry away the worn abrasive and debris (swarf).

Characteristics of Liquid:-

→ Density (approx. equal to density of abrasives).

→ Good wetting properties to wet the tool, w/p, and abrasives.

→ High thermal conductivity and specific heat for effective removal of heat from cutting zone.

→ Low viscous and high fluidity to carry the abrasive down the sides of the hole betn tool and w/p.

Advantages :-

→ Can be used for machining hard brittle, fragile and non-conductive material.

→ No thermal stress is produced becoz no heat generation.

→ Burr less and distortion less process.

→ Little or no sub surface damage.

→ No heat affecting zone (HAZ).

Disadvantages :-

→ Low MRR usually less than 50 mm^3/min.

→ Tool wear occurs.

→ can only be used when hardness of work is more than 45 HRC.

Applications :-

→ Machining of cavities in electrically non-conducting ceramics.

→ Used for multi-step processing for fabricating silicon nitrite (SC_3N_4) turbine blades.

→ Large no. of holes of small diameter.

Ex :- In 1973, Benedict performed 930 holes of 0.32mm has been reported using hypodermic needle.

→ Used for grinding Quartz glass.

LASER BEAM MACHINING (LBM)

Introduction

Laser beam Maching is a technology that uses a laser beam (narrow beam of intense Monochromatic light) to cut required shapes or profile or pattern in almost all types of Materials.

- In this process, the output of a high power laser beam is directed in a programmed manner towards the material required to be cut. The high amount of heat thus generated either Melts, burns or vaporizes away the material at the focused region.
- LBM process is carried out utilizing the energy of co-herent photons or Laser beam, which is mostly converted into thermal energy upon interaction with most of the materials. Laser beam can very easily be focused using optical unses as their wavelength ranges from half micron to around 70 microns.
- Focused Laser beam can have power density in excess of 1MW/mm^2.
- As Laser interacts with the material, the energy of the photon is absorbed by the work material leading to rapid substantial rise in local temperature. This in turn results in Melting and vapourization of the work material and finally material is removed.

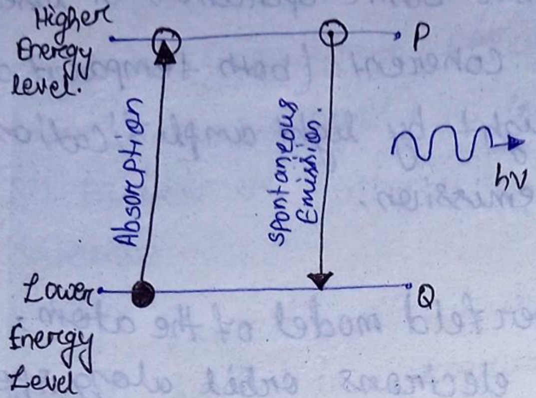
Principle of Laser :-

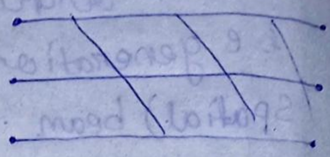
→ The word laser is an acronym for light Amplification by the Stimulated Emission of Radiation. Lasing process describes the basic operation of laser, i.e generation of coherent (both temporal and spatial) beam of light by light amplification using "Stimulated emission.

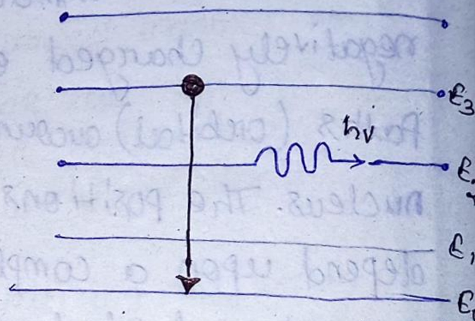
→ In the Bohr-Sommerfeld model of the atom, negatively charged electrons orbit along specific paths (orbital) around a ~~posit~~ positively change nucleus. The positions of the discrete orbitals depend upon a complex set of conditions, such as the number of electrons surrounding the nucleus the existance of nearby atoms and their electron structure, and the presence of electric and magnetic fields.

→ Each of the orbital electrons is associated with unique energy levels.
(Stationary energy state in the atom).

→ The atom is said to be in its ground state when all the electrons occupy orbitals that have lowest potential energies. At absolute ~~at ze~~ zero (0 K) all electrons are in ground state. The electrons at ground state can be excited to higher state of energy by absorbing energy from external sources like increase in electronic vibration at elevated temperature, through chemical reaction or well as via absorbing energy of the photon.







The above fig. depicts schematically the absorbption of a photon by an electron. The electron moves from a lower energy level to a higher energy level.

Spontaneous & Stimulated Emission:-

By the absorption of photon when the electrons are excited to higher state, they will almost immediately decay back to the ground state in about 10 ns. and happens spontoneously. spontaneous decay oftem results in spontaneous emission of photons having exactly the same frequency as the exciting photons. Light created from atoms may be in random direction but at well-defined wavelengths called "emission lines". These emission lines can intensity when more electrons are pumped (excited) to the higher energy state.

However, sometimes the excited atoms may be trapped in an energy state forbidding it for any downward transition. So the atom can linger in this so-called Metastable state from Micro to milliseconds range before decaying to a lower energy state.

→ The existence of metastable states can upset the thermodynamic equillibrium which normally prevail in atomic system. If enough ~~equillibrium~~ ~~which~~ ~~normally~~ ~~pr~~ electrons get hung up in a metastable state. Thus creating a condition for "Population Invertion", which is thermodynamically unstable.

→ Such electrons, at higher energy meta stable state in the form can return to the ~~groo~~ ground of an avalanche provided stimulated by a photon of suitable freqvency or energy. Like stimulated absorption and spontaneous emission. Einstein proposed the powerfol thermodynamic argument for he third kind of transition, which is called stimulated emission.