UNIT-II

The audible range human is 20Hz-20kHz

Ultrasonic Machining

Introduction:- (comes in existence in 1950)

In order to meet the challenges ~~posed~~ present by the machining of the hard to machine and brittle materials - whether conductive or non conductive the technique of ultrasonic machining has been developed in the field of machining technology.

The term "ultrasonic" is used to signify a vibratory wave of high frequency above the audible range onto the work surface in the presence of a flowing slurry.

The main reason for using ultrasonic ~~xx~~ frequency during the machining process is to provide a better working performance.

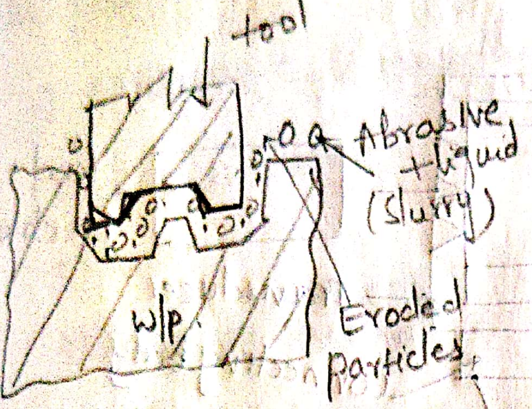
Due to the audible frequencies of high intensities would damage the human ears.

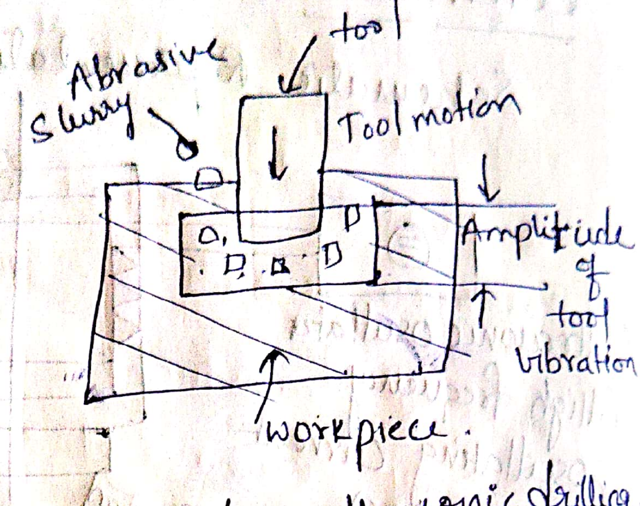
No ~~s~~ heat generation, low cost, effective machining.

Definition:-

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

Working principle :-





The principle of metal removal by ultrasonic drilling

→ The tool is made to vibrate or oscillate at ultrasonic frequency to the order of 20 kilo cycles per sec in a direction normal to the surface being machined.

→ Abrasive particles like boron carbide or silicon oxide are mixed with water and this slurry is fed continuously between the tool and the workpiece.

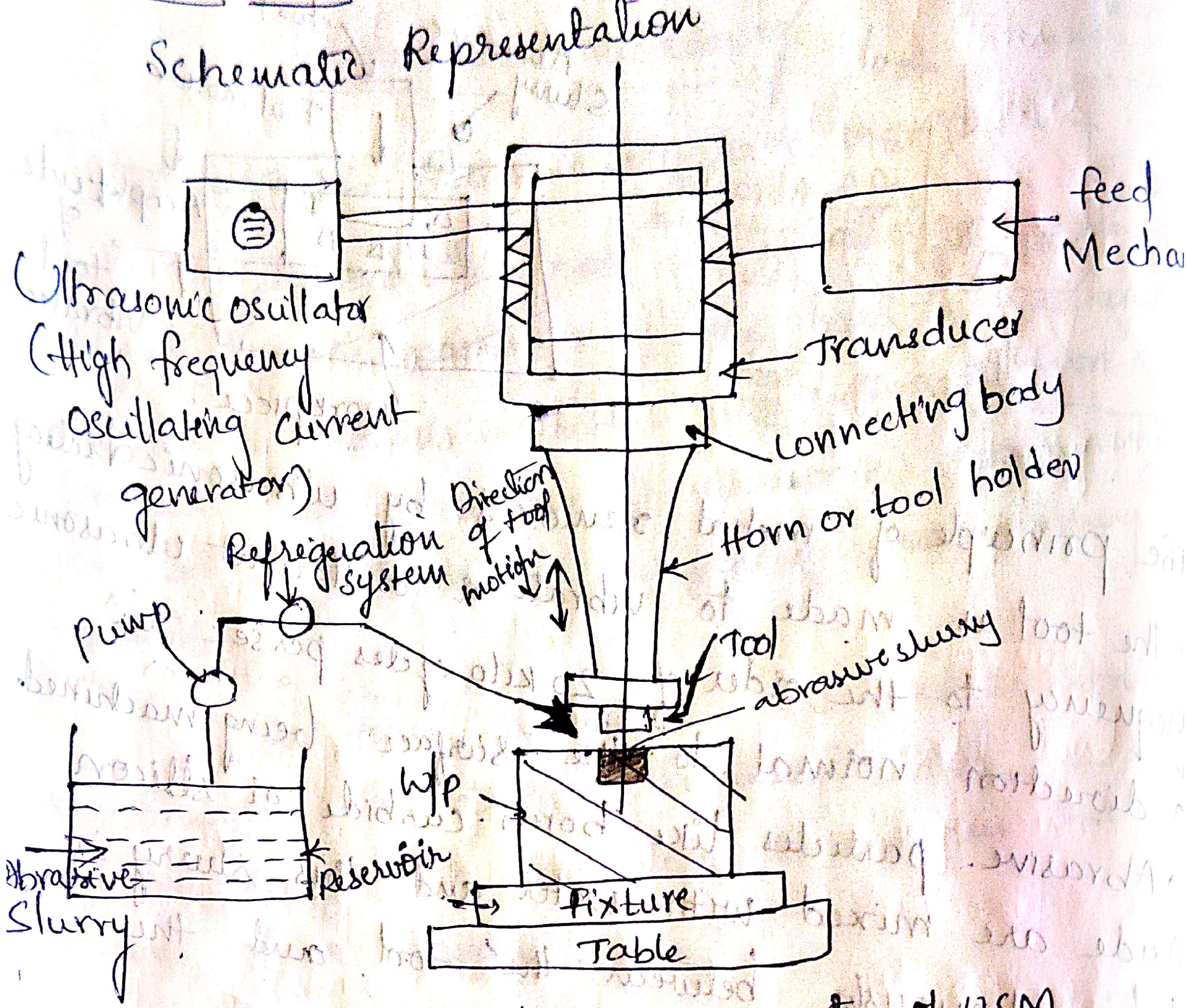
→ The tool hammers upon the abrasive particles which get embedded in the work surface and in turn remove the metal from the workpiece by the process of abrasion in the form of tiny particles.

Note :- 1) Ultrasonic vibration generate sound waves. The sound wave passing through a solid loses energy in the form of heat.

2) The heat raises the temp of the workpiece which in turn reduces its yield strength and hence easier metal removal.

Construction :-

Schematic Representation



The following are the components of USM -

1) Ultrasonic Oscillator
2) Transducer
3) A connecting Body
4) A horn
5) Feed device
6) pump
7) A container for the slurry of abrasive grains holding device.
8) Workpiece

The ultrasonic machining set up consists of the following operating elements.

1) Ultrasonic transducer
2) concentrator
3) Tool
4) Abrasive slurry
5) Abrasive feed mechanism and
6) Tool feed mechanism

Ultrasonic Oscillator :- (It is used to produce an alternating current oscillating at high frequency usually b/w 18 & 40kHz in the ultrasonic range).

→ Usually in Ultrasonic machining tool should be vibrated with Ultrasonic speed (i.e, above 15,000 cycles per sec)

→ To effect this an oscillator is employed to generate high frequency oscillating current.

→ This electrical energy should be converted now into mechanical energy (in the form of high frequency vibration) and it is done with the help of a transducer.

→ There are many ways in which ultrasonic waves could be generated.

→ But the method to be selected depends upon the frequency range to be covered and the power output.

Transducer :- I/P — [Transducer] — O/P

→ Transducer is a device which converts energy from one form to another i.e., it can generate or receive sound wave. electrical energy into sound or vice versa

→ An acoustic (A device transforming) transducer converts electrical, mechanical or Thermal energy to acoustical energy

→ The reversible acoustic transducer will do just opposite of it.

Ex:- In a loud speaker, the sound wave is first converted into electricity, amplified by an amplifier (Kept in the system) and then reconverted to sound waves by another reversible transducer.

Types of Transducers:-

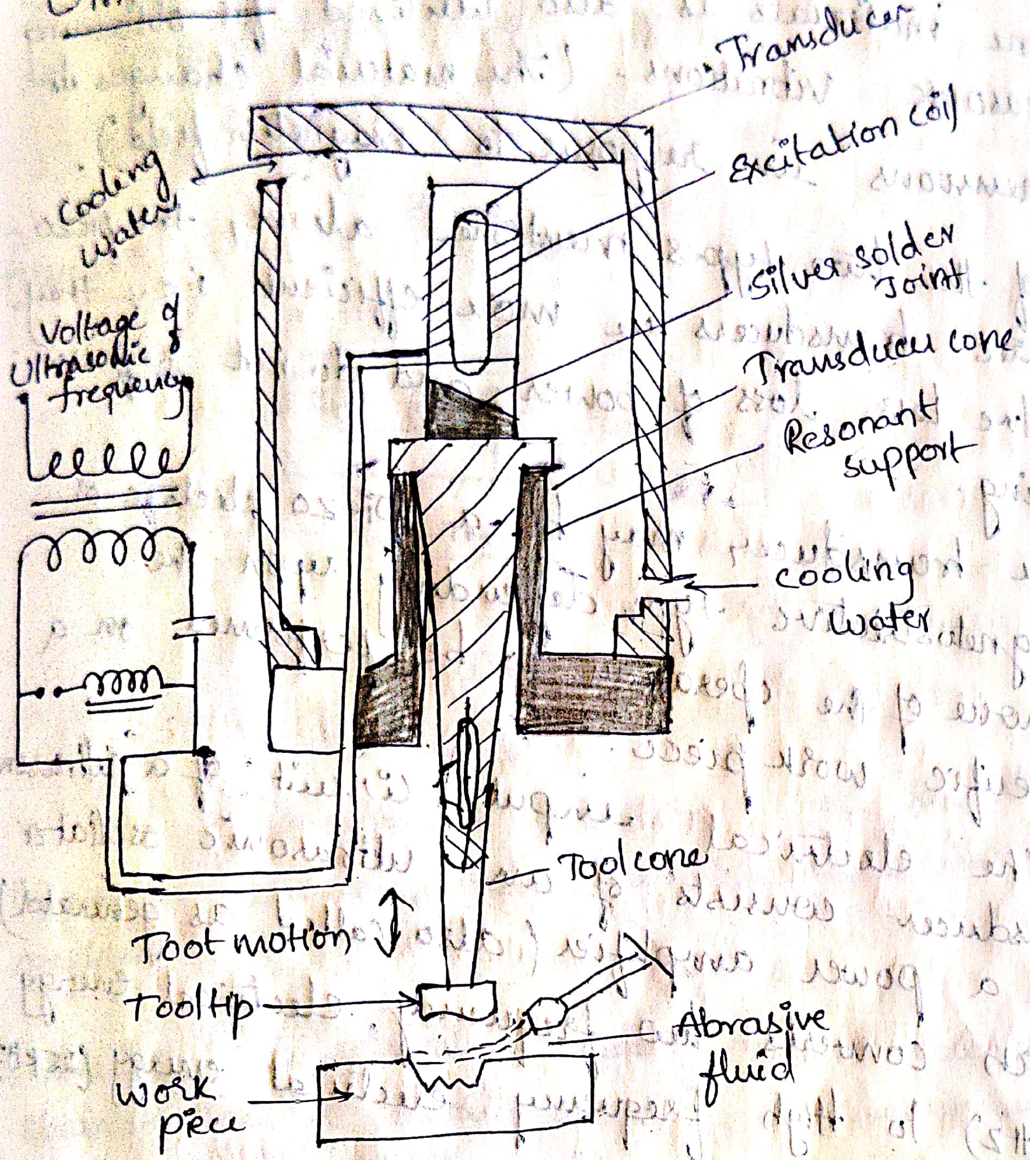
1) purely mechanical Transducers:-
Whistles and siren fall under this category which can produce sound waves of frequencies upto 10,000 C.P.S

2) Electromagnetic Transducers:-
These are used in microphones and loud speakers to generate audiofrequency range.

3) Electrostatic Transducers:-
These are mostly used for internal friction measurement and also aso condenser microphones.

4) Crystal oscillator (or) crystal Transducer:-
→ The word 'crystal' means materials which exhibit piezoelectric effect.
→ These materials divided into too main groups
1) Natural crystals (such as quartz, rochella salt etc)
2) synthetic crystals (such as lithium, ammonium, dihydrogen phosphate etc) ~~and 3) polarised ferroelectric ceramics (such as~~
3) polarised ferroelectric ceramics (such as barium titanate).
→ Such materials are used to generate vibration in the tool.

Ultrasonic Transducer:-



→ The device used for converting any type of energy into ultrasonic waves or vibrations is called ultrasonic transducer

→ The electrical energy is converted into Mechanical vibrations for carrying out the machining operation.

→ Normally piezoelectric crystals are used for inducing ultrasonic vibrations, since they posses the capability of changing their dimensions to the given electrical energy (or) They have the capability of converting electrical energy into mechanical vibrations

→ The magnetostrictive effect exhibited by some materials is also utilized for obtaining ultrasonic vibrations. (The material changes its dimensions in response to magnetic field).

→ Of the two types mentioned above, the piezo-electric transducers are more efficient i.e., they involve less loss of power and do not require cooling.

→ The transducer may be a piezo electric or Magnetostrictive type depending upon the choice of the operation to be performed on a specific work piece.

→ The electrical input circuit of a ultrasonic transducer consists of an ultrasonic oscillator and a power amplifier (also called as generator) which converts low frequency electrical energy (50Hz) to High frequency electrical energy (25KHz)

3) Concentrators :-

→ The concentrator provides the link b/w the tool and the transducer. It is also called as tool cone, horn, wave guide or tool holder.

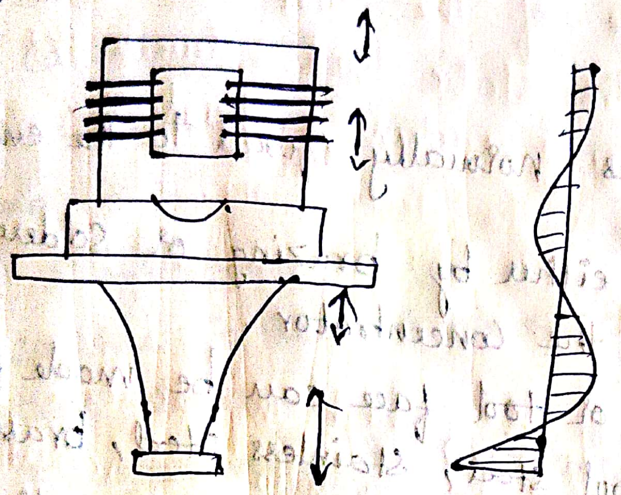
→ The main purpose of the concentrator is to increase the amplitude of vibration obtained from the transducer.

Types of concentrators :-

The different types of concentrators used are

1) Exponential type 
2) conical type and 
3) stepped type 

Function :-



Mode of longitudinal vibration of the transducer Concentrator assembly, indicating how vibrations is amplified.

→ The horn is generally made of monel metal or stainless steel or titanium alloy or aluminium which can be fitted to the transducer either by by brazing or to a connecting body made of monel metal at a fixed nodal point.

→ Among the concentrator materials, titanium has the best acoustical properties but machining to a particular horn shape and brazing becomes difficult.

→ The amplitude of vibration increased by the concentrator is based on the principle of resonance.

→ If a proper length of any material whose natural frequency ω, matches with the excitation frequency ωe, with amplitude a_0, then at resonance, (i.e, at $\omega/\omega_e = 1$) the ratio of x/a_0 increases if it is not critically damped.

where x is the amplitude at the tool connected end.

→ continuation.

4) Tool:-

→ The tool is normally fixed to the end of the Concentrator

→ It is fixed either by brazing or soldering or fastened to the concentrator.

→ The tool tip or tool face can be made from diamond, tool steel, stainless steel, brass or copper

→ It must be ductile and tough rather than being hard.

→ If ratio of workpiece hardness and tool hardness increases the material removal rate decreases.

→ If the mass length of the tool is remarkable it absorbs the ultrasonic energy, thus reducing the efficiency of the machining.

→ In practice the slenderness ratio of the tool should not exceed 20.

→ The area of the tool should not be more than the area of the tool cone or concentrator by 10-15%.

~~Concentrator continuation.~~

The tool holders are available as

1) Non-amplifying type

2) Amplifying type.

Disadvantages:

1) Higher fabrication cost
2) poor surface finish quality
3) Need for frequency tuning to maintain resonance.

5) Abrasive Slurry :-

The abrassive slurry is nothing but a mixture of abrasive grain and the carrier fluid, generally water. Some of the abrasive used are

1) Aluminium oxide (Al_2O_3 Alumina)
2) Boron carbide (B_4C)
3) Silicon Carbide (SiC)
4) Diamond Dust
5) Boron Silicarbide.

→ Boron carbide is the best, most efficient and fastest cutting abrasive

→ But it is expensive and it is used for cutting harder materials like tungsten carbide, ~~tool steel~~ and precious stones.

→ silicon carbide finds maximum applications and is employed for use on glass, Germanium and some ceramics.

→ The cutting time with SiC is about 20-40% more than the B_4C - Alumina is much less efficient & the cutting time is about 3-4 times of that with the B_4C.

6) Abrasive Feed Mechanism :-

→ The abrasive slurry is supplied through a nozzle by a pump.

→ A good method is to keep the tool and workpiece in a bath of slurry.

→ This ensures good supply of slurry and reduces any tendency of the tool to scatter the slurry when the amplitude is large.

→ Another efficient method is to supply the slurry to the cutting zone through a hollow tool or through holes in the w/p.

7) Tool feed Mechanism :-

→ The objective of the tool feed mechanism is to apply the static load between the tool and the w/p, during machining operation.

→ It also brings the tool slowly, close to the w/p surface and provide adequate, constant cutting force.

→ The sensitivity is of high importance.

→ feed may either be given to the acoustic head or to the w/p, but in general the feed motion is given to the acoustic head so as to facilitate positioning of the w/p in X-Y direction.

→ The tool feed mechanism controls the penetration rate and the depth of machining.

Functions:-

1) Bring the tool close to the w/p, given place for abrasive flow

2) To provide the required impact force or cutting force and maintain it throughout the operation as required

Types of feed mechanism :-

1) spring type
2) counter-weight type
3) Motor type
4) Pneumatic and hydraulic type

→ In counter-weight type, the force of impact is the difference between the weight of the acoustic head and that of the counter weight attached.

→ The force in this case can be adjusted by varying the counter weights.

→ This type is insensitive and inconvenient for adjustability during the operation.

→ The spring control system is quite sensitive

→ pneumatic and hydraulic systems may be used for high rating m/c

Work Material :-

→ Material removal method involved in this process is brittle fracture and obviously works only on relatively brittle materials.

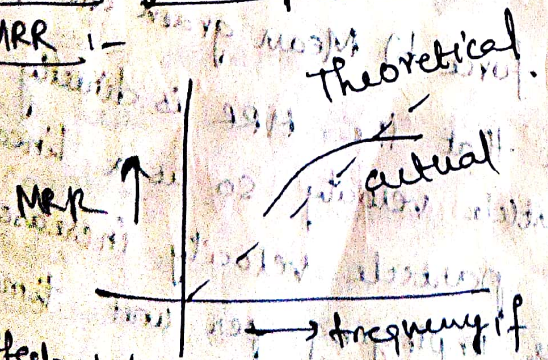
→ Any hard materials ~~et~~ like stones, carbides, ceramics and brittle materials can also be machined.

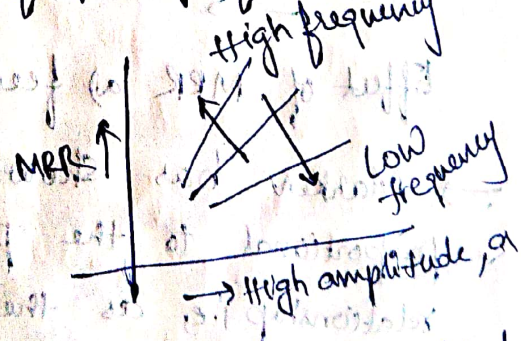
→ Any material having hardness >50 HRC like stainless steel, germanium, glass, ceramic etc can be machined.

→ The abrasive used in USM can be aluminium oxide, boron carbide and silicon carbide.

Mechanics of metal removal process parameters (or) Variables of USM

1) **Effect of Amplitude and frequency of vibration on MRR** :-





Effect of different parameters on MRR a) frequency b) Amplitude

Different researches have different predictions on the effect of amplitude on MRR:

1) Rozenberg found that for a given material, the MRR is proportional to the square of the amplitude.

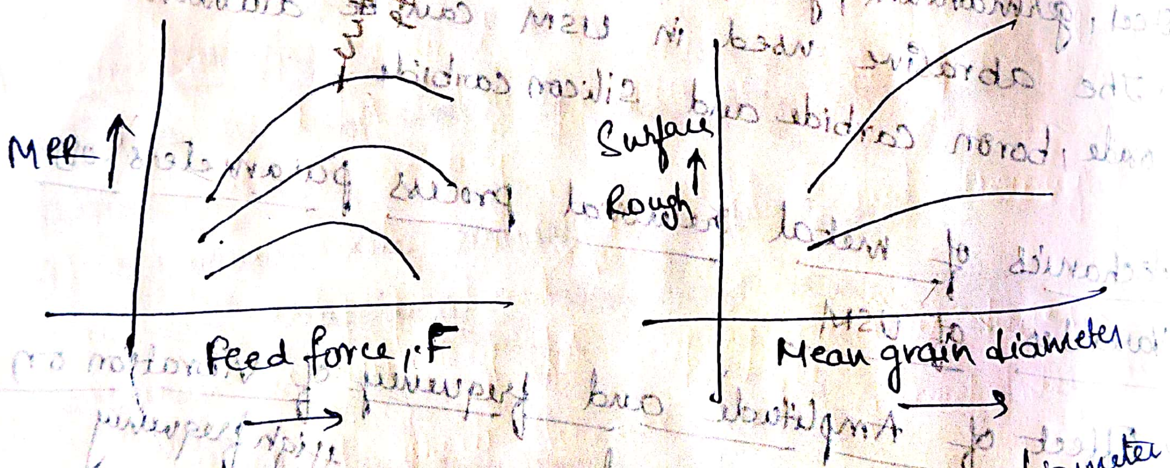
2) Miller has shown that the cutting rate bears a linear relationship with amplitude. According to him the MRR increases linearly with an increase in amplitude and frequency.

3) Miller's Model has shown that scatter of values

4) Shaw showed that MRR is proportional to amplitude $^{3/4}$, He also predicted that the MRR is directly proportional to the first power of frequency for a fixed amplitude. the max extent a vibration

the rate/sec of a vibration (as sound waves)

2) Effect of particle velocity:-



Effect of MRR a) feed force b) Mean grain diameter

Markov has shown that the MRR is directly proportional to the particle velocity so as a linear relationship i.e., as the particle velocity increases the number of particles impinging per unit time and the impact force with which the particles hit the workpiece increases. ~~which~~

3) Effect of static loading or feed force :-

→ The MRR increases with an increase in the feed force.

→ But it tends to decrease beyond a critical value of the force, since the magnitude of the force crushes the abrasive grains thus decreasing its cutting ability and the MRR.

→ If the feed force is more, the surface finish is good, because the grains are crushed to smaller size.

4) Effect of Grain size :-

→ According to the equation for the volume of material removal rate, as the grain size increases, the MRR should also increase proportionaly.

→ As the grain size increases the MRR also increases till the grain size equals the amplitude of vibration.

→ Beyond this, the MRR decreases due to the effect of crushing of abrasive grains.

Advantages :-

1) High accuracy and good surface finish can be easily attained

2) No heat generation during machining

3) Capability of drilling circular and non circular holes in very hard materials like stones, carbides, ceramics and brittle materials.

4) Burless process.

5) Non-conductive materials canbe machined

6) Low cost of metal removal

7) Low material removal

8) High tooling cost

Dis advantages :-

1) Tool wear

2) Frequent tuning is required sometimes

3) Low material removal rate

4) Not economical for soft materials

5) Not suitable for heavy stock removal.

Applications :-

1) Almost all the materials can be machined except some soft materials.

2) Diamond, Tungsten carbide, gem stones can be successfully machined

3) It is used for drilling, grinding, coining, threading and even for welding

4) circular and non circular, blind and through hole can be easily produced.

5) used in jewellery for shaping precious stones

6) Drilling of screw threads, and curved holes in brittle materials.

7) Micro drilling of holes upto 0.08mm onwards.

8) Machining shallow cavities of irregular and complex shapes.

Recent development :-

Production of parts in microscale, especially with brittle materials is challenging. Ultrasonic micromachining has been gaining popularity as a new alternative in fabrication of such parts