NON-TRADITIONAL MANUFACTURING PROCESSES(1)

INTRODUCTION AND ULTRASONIC MACHINING

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MATERIAL REMOVAL PROCESSES

The material removal processes are a family of shaping operations in which excess material is removed from a starting work part so that what remains is the desired final geometry. The ‘‘family tree’’ is shown in Fig.1. The term nontraditional machining refers to this group that removes excess material by various techniques involving mechanical, thermal, electrical, or chemical energy (or combinations of these energies). They do not use a sharp cutting tool in the conventional sense. The nontraditional processes have been developed since World War II largely in response to new and unusual machining requirements that could not be satisfied by conventional methods.

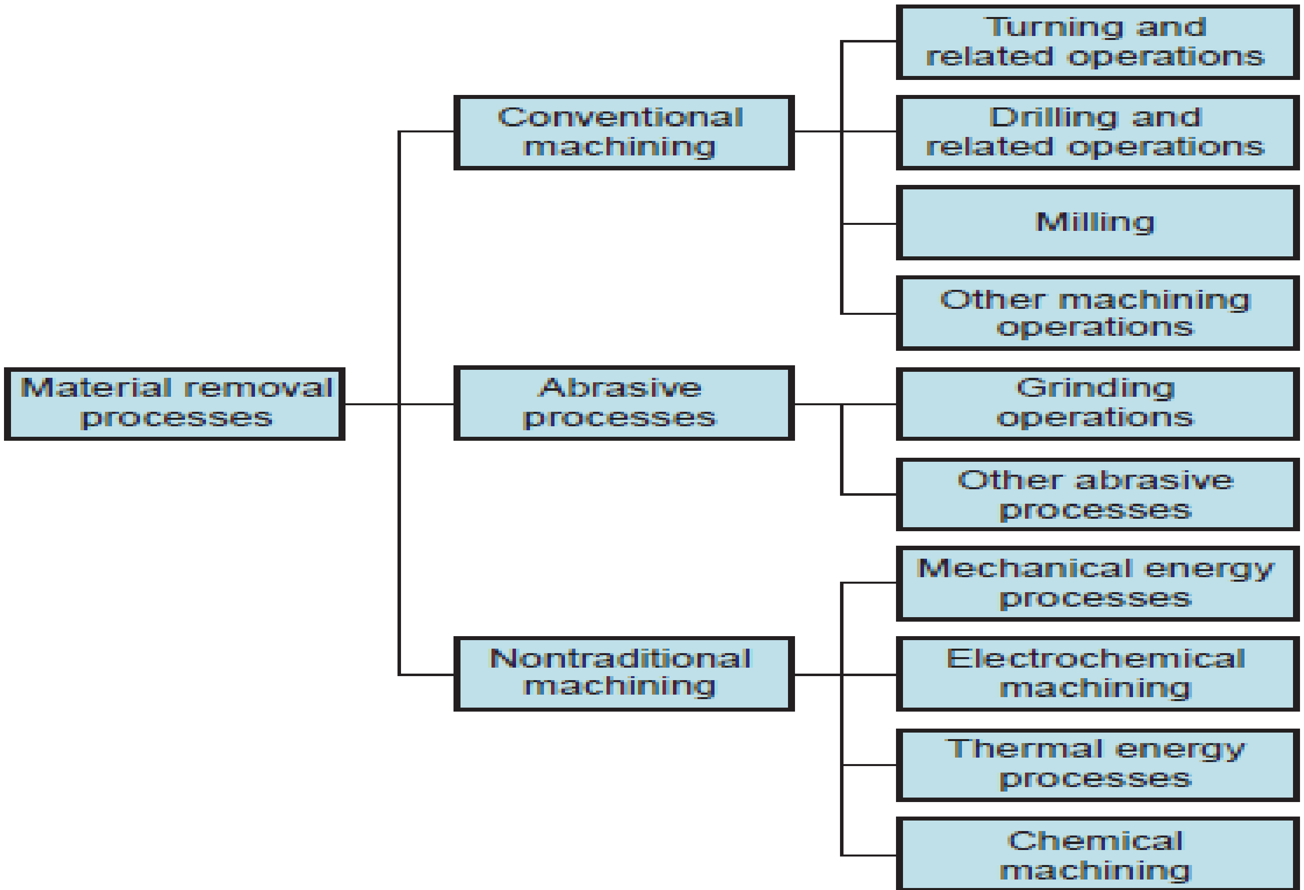


Fig.1
Classification of material removal processes

NON TRADITIONAL MACHINING (NTM) PROCESSES ARE CHARACTERISED AS FOLLOWS:

- 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.

- In NTM, there may not be a physical tool present. For example in laser jet machining, machining is carried out by laser beam. However in Electrochemical Machining there is a physical tool that is very much required for machining.

- In NTM, the tool need not be harder than the work piece material. For example, in EDM, copper is used as the tool material to machine hardened steels

- Mostly NTM processes do not necessarily use mechanical energy to provide material removal. They use different energy domains to provide machining. For example, in USM, AJM, WJM mechanical energy is used to machine material.

Why NTMP is important?

Extremely hard and brittle materials are difficult to machine by traditional machining processes such as turning, drilling, shaping and milling. Non traditional 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.

1-Technologically advanced industries like aerospace, nuclear power, ,wafer fabrication, automobiles has ever increasing, use of High –strength temperature resistant (HSTR) alloys (having high strength to weight ratio) and other difficult to machine materials like titanium, SST, nimonics, tungsten, molybdenum, columbium, ceramics and semiconductors. It is no longer possible to use conventional process to machine these alloys.

2-The workpiece material is too brittle to be machined without damage to the workpiece .this is typically the case with highly heat treated alloys,glass ,ceramics and powder –metallurgy parts.

3-Very hard fragile materials difficult to clamp When the workpiece is too flexible or slender for traditional machining.

4-Production and processing parts of complicated shapes (in HSTR and other hard to machine alloys) is difficult , time consuming an uneconomical by conventional methods of machining.

5-Special surface finish and dimensional tolerance requirements cannot be produced economically by conventional machining.

6-Temperature rise during processing and residual stresses developed in the workpiece are not desirable or acceptable.

Differences between Conventional and Non conventional machining processes.

Sl No.	Conventional Process	Non Conventional Process
1.	The cutting tool and work piece are always in physical contact with relative motion with each other, which results in friction and tool wear.	There is no physical contact between the tool and work piece, In some non traditional process tool wear exists.
2.	Material removal rate is limited by mechanical properties of work material.	NTM can machine difficult to cut and hard to cut materials like titanium, ceramics, nimonics, SST,c omposites, semiconducting materials.
3.	Relative motion between the tool and work is typically rotary or reciprocating. Thus the shape of work is limited to circular or flat shapes. In spite of CNC systems, production of 3D surfaces is still a difficult task.	Many NTM are capable of producing complex 3D shapes and cavities.

4.	Machining of small cavities , slits , blind holes or through holes are difficult	Machining of small cavities, slits and Production of non-circular, micro sized, large aspect ratio, shall entry angle holes are easy using NTM
5.	Use relative simple and inexpensive machinery and readily available cutting tools	Non traditional processes requires expensive tools and equipment as well as skilled labour, which increase the production cost significantly
6.	Capital cost and maintenance cost is low	Capital cost and maintenance cost is high
7.	Traditional processes are well established and physics of process is well understood	Mechanics of Material removal of Some of NTM process are still under research
8.	Conventional process mostly uses mechanical energy	Most NTM uses energy in direct form For example : laser, Electron beam in its direct forms are used in LBM and EBM respectively
9.	Surface finish and tolerances are limited by machining inaccuracies	High surface finish(up to 0.1 micron) and tolerances (25 Microns)can be achieved
10.	High metal removal rate.	Low material removal rate.

THE NONTRADITIONAL PROCESSES ARE OFTEN CLASSIFIED ACCORDING TO PRINCIPAL FORM OF ENERGY USED TO EFFECT MATERIAL REMOVAL. BY THIS CLASSIFICATION, THERE ARE FOUR TYPES:

1. Mechanical. Mechanical energy in some form other than the action of a conventional cutting tool is used in these nontraditional processes. Erosion of the work material by a high velocity stream of abrasives or fluid (or both) is a typical form of mechanical action in these processes.

2. Electrical. These nontraditional processes use electrochemical energy to remove material; the mechanism is the reverse of electroplating.

3. Thermal. These processes use thermal energy to cut or shape the workpart. The thermal energy is generally applied to a very small portion of the work surface, causing that portion to be removed by fusion and/or vaporization. The thermal energy is generated by the conversion of electrical energy.

4. Chemical. Most materials (metals particularly) are susceptible to chemical attack by certain acids or other etchants. In chemical machining, chemicals selectively remove material from portions of the workpart, whereas other portions of the surface are protected by a mask.

Classification of NTM processes is carried out depending on the nature of energy used for material removal.

The broad classification is given as follows:

- **Mechanical Processes**

➢ Abrasive Jet Machining (AJM)

➢ Ultrasonic Machining (USM)

➢ Water Jet Machining (WJM)

- **Electrochemical Processes**

➢ Electrochemical Machining (ECM)

➢ Electro Chemical Grinding (ECG)

➢ Electrochemical deburring (ECD)

- **Electro-Thermal Processes**

➢ Electro-discharge machining (EDM)

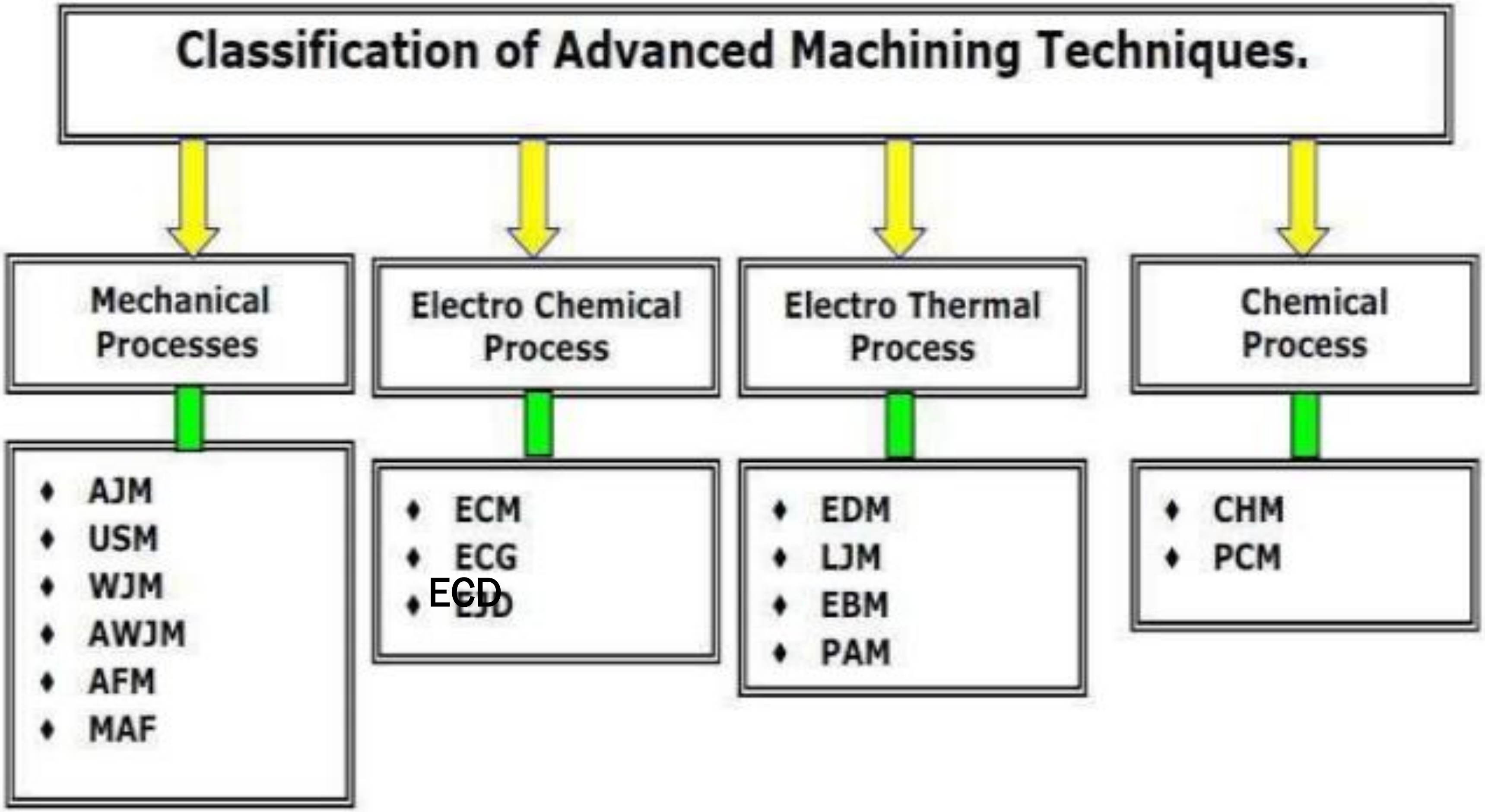
➢ Laser Jet Machining (LJM)

➢ Electron Beam Machining (EBM)

- **Chemical Processes**

➢ Chemical Milling (CHM)

➢ Photochemical Milling (PCM)


Classification of Advanced Machining Techniques.
Mechanical Processes
Electro Chemical Process
Electro Thermal Process
Chemical Process
AJM
USM
WJM
AWJM
AFM
MAF
ECM
ECG
ECD
EDM
LJM
EBM
PAM
CHM
PCM

SELECTION OF PROCESS

The correct selection of the non-traditional machining methods must be based on the following aspects.

i) Physical parameters of the process

ii) Shape to be machined

iii) Process capability

iv) Economics of the processes.

1. MECHANICAL ENERGY PROCESSES

In this section we examine several of the nontraditional processes that use mechanical energy other than a sharp cutting tool: (1) ultrasonic machining, (2) water jet processes, (3) AWJM (4) AJM (5) A FM.

1.1 ULTRASONIC MACHINING

Ultrasonic machining (USM) is a nontraditional machining process in which abrasives contained in a slurry are driven at high velocity against the work by a tool vibrating at low amplitude and high frequency. The amplitudes are around 0.075 mm , and the frequencies are approximately 20,000 Hz. The tool oscillates in a direction perpendicular to the work surface, and is fed slowly into the work, so that the shape of the tool is formed in the part. However, it is the action of the abrasives, impinging against the work surface, that performs the cutting. The general arrangement of the USM process is depicted in Fig.2 and 3. Common tool materials used in USM include soft steel and stainless steel. Abrasive materials in USM include boron nitride, boron carbide, aluminum oxide, silicon carbide and diamond.

The slurry in USM consists of a mixture of water and abrasive particles. Concentration of abrasives in water ranges from 20% to 60%. The development of ultrasonic machining was motivated by the need to machine hard, brittle work materials, such as ceramics, glass, and carbides. It is also successfully used on certain metals, such as stainless steel and titanium. This process used for increasing complex operations to provide intricate shapes and workpiece profile

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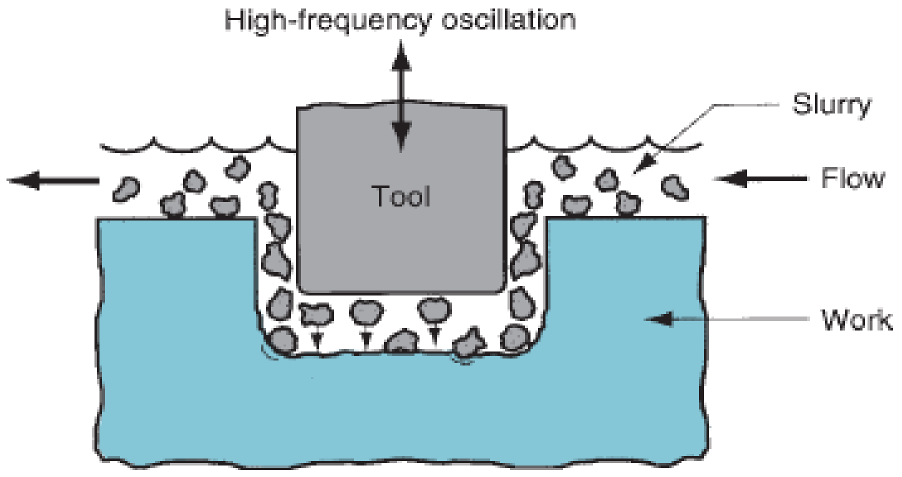

Fig.2 Ultrasonic machining

WORKING PRINCIPLE

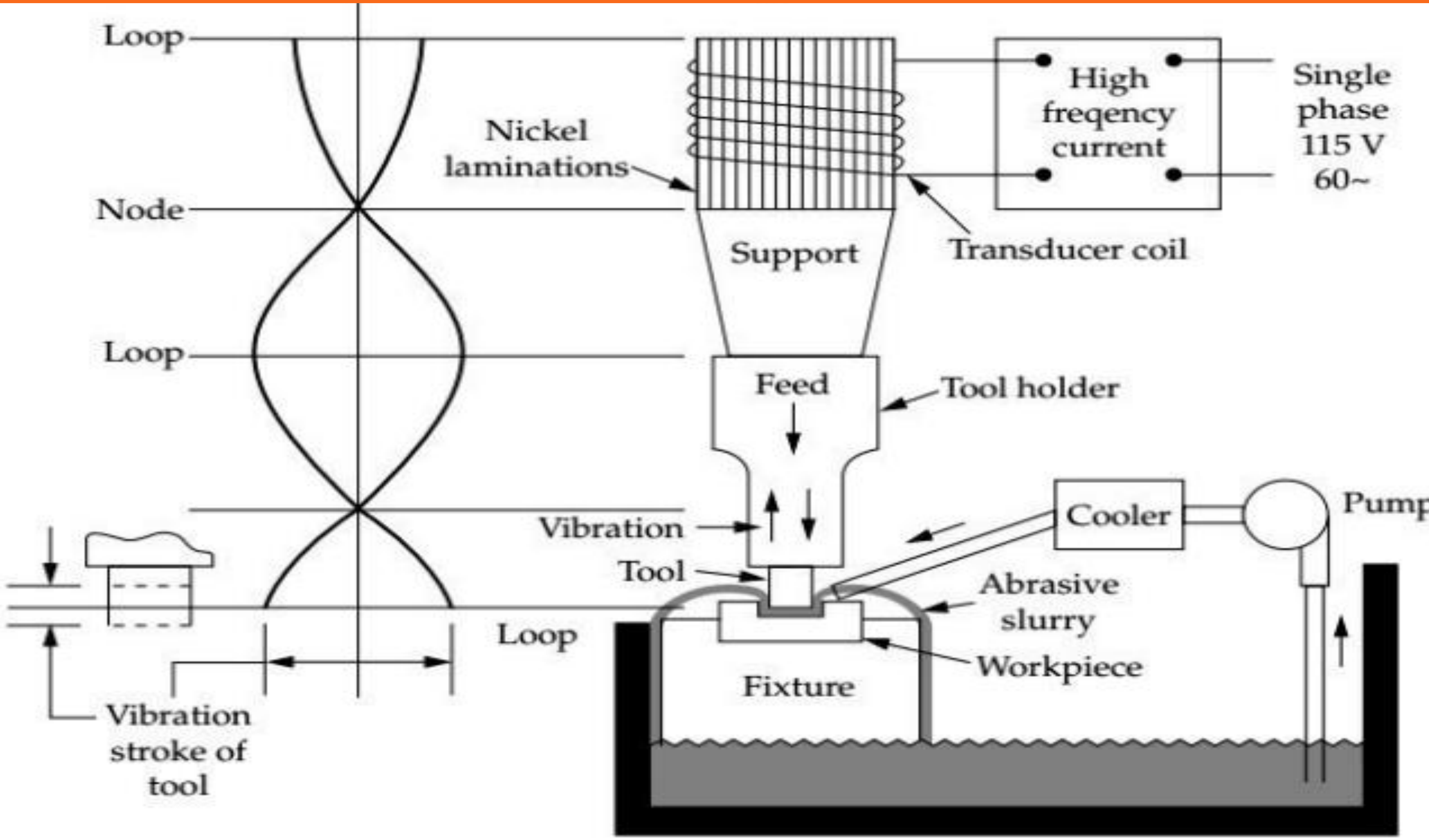

Fig.3 Arrangement of USM

IMPORTANT PARAMETERS

The important parameters which affect the process are the:

1. Frequency,
2. Amplitude,
3. Static loading (feed force),
4. Hardness ratio of the tool and the workpiece,
5. Grain size,
6. Concentration of the abrasive in the slurry

USM Equipment

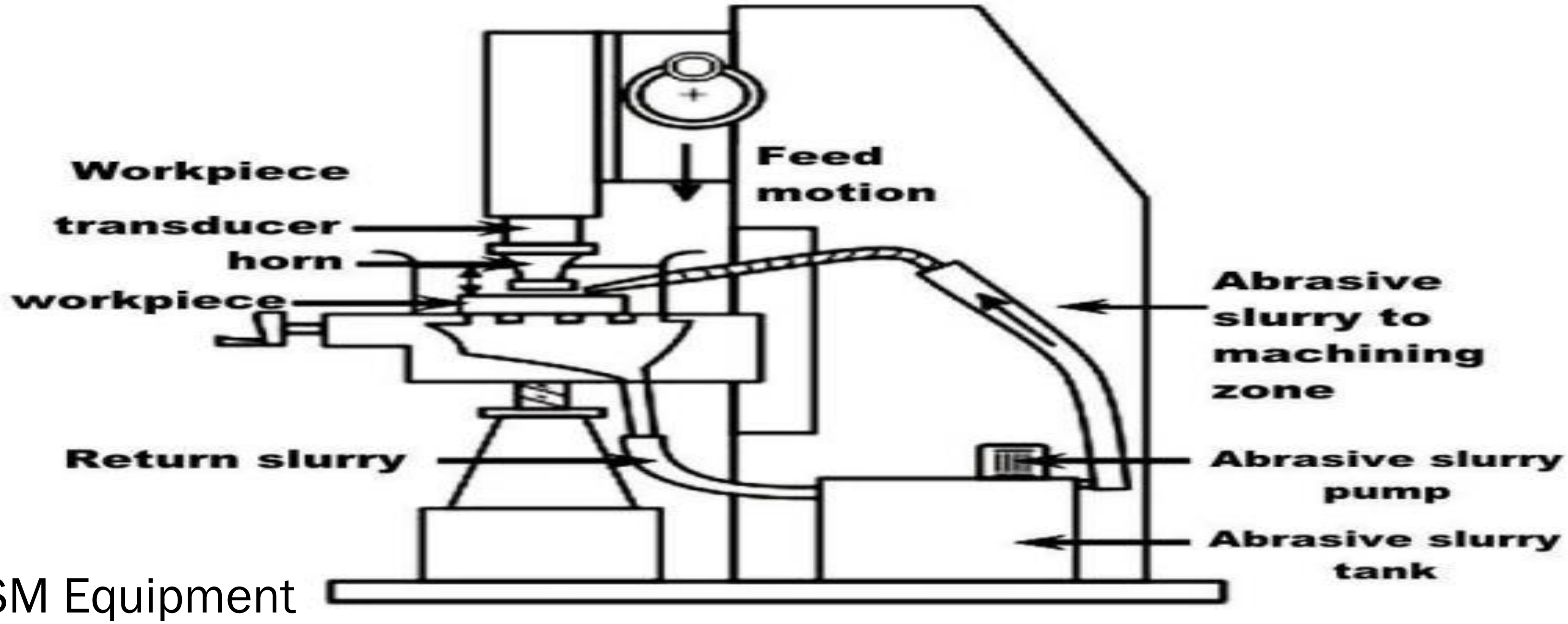

Fig.4 USM Equipment

The basic mechanical structure of an USM is very similar to a drill press. However, it has additional features to carry out USM of brittle work material. The work piece 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 lowered or raised to accommodate work of different thickness as in fig 4.

The typical elements of an USM are

- Slurry delivery and return system.
- Feed mechanism to provide a downward feed force on the tool during machining.
- The transducer, which generates the ultrasonic vibration.
- The horn or concentrator, which mechanically amplifies the vibration to the required amplitude of 15 – 50 µm and accommodates the tool at its tip.

The vibration amplitude should be set approximately equal to the grit size, and the gap size should be maintained at about two times grit size. To a significant degree, grit size determines the surface finish on the new work surface. In addition to surface finish, material removal rate is an important performance variable in ultrasonic machining. For a given work material, the removal rate in USM increases with increasing frequency and amplitude of vibration

Shapes obtained by USM include non-round holes, holes along a curved axis, and coining operations, in which an image pattern on the tool is imparted to a flat work surface.

The basic components to the cutting action (The reasons for material removal) are believed to be:

- brittle fracture caused by impact of abrasive grains due to the tool vibration;
- cavitation induced erosion;
- chemical erosion caused by slurry.

APPLICATIONS OF USM

- Used for machining hard and brittle metallic alloys, semiconductors, glass, ceramics, carbides etc.
- Used for machining round, square, irregular shaped holes and surface impressions.
- Machining, wire drawing, punching or small blanking dies.
- Drilling and machining cavities or holes in conductive and non-conductive materials like glass, ceramics etc.
- Used to machine hard materials like tool steel, tungsten and hard carbides. ☐ Threading of various glass and ceramic materials.
- Used for making tools and dies.
- Soft materials like non-ferrous metals and alloys and brittle materials can be machined.
- Removing flash and parting lines from injection moulded parts.
- Deburring and polishing plastic, nylon and Teflon components.
- To produce high quality surface.
- Hard materials and precious stones such as synthetic ruby for the preparation of jewels for watch and timer movements are successfully machined by this method.

ADVANTAGES 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. The main advantages are;
- 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.
- No burrs and no distortion of workpiece.
- Hard and brittle metals can be machined.
- Stresses are minimum.
- Thin sheets can be machined.
- Investment cost is low.

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.
- Depth of holes and cavities produced are small. Usually the depth of hole is limited to 2.5 times the diameter of the tool. There is a tendency for holes to break out at the bottom owing to high amplitude of vibrations of the tool.
- Not suitable for soft workpiece material.
- Machining accuracy is poor.
- Nozzle wear rate is high.
- Suitable only for small workpieces. matrial.