Study of Parameters of Ultrasonic machining

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CERTIFICATE

This is to certify that the report entitled “**Study Of Parameters of Ultrasonic Machining**” submitted by Sri Sumit Kumar Samal in the fulfillment of the requirements for the award of Bachelor of Technology Degree in Mechanical Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

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ABSTRACT

The recent development of modern hi-tech industries has given rise to the creation of a whole range of new materials. These include high strength, stainless and heat resistant steels and alloys, titanium, ceramics, composites, and other nonmetallic materials. These materials may not be suitable for traditional methods of machining due to the chipping or fracturing of the surface layer, or even the whole component, and results in a poor product quality.

Similarly, the creation of new materials often highlights some problems unsolvable in a framework of traditional technologies. In certain cases these problems are caused by the construction of the object and the requirements particular to it. As an example, in microelectronics, its often necessary to connect some components without heating them or adding any intermediate layers. This forbids the use of traditional methods such as soldering or welding.

Many of these and similar problems can be successfully solved using ultrasonic technologies. The USD (Ultrasonic Drilling Machine) uses a novel drive mechanism to transform the ultrasonic or vibrations of the tip of a horn into a sonic hammering of a drill bit through an intermediate free-flying mass.

INTRODUCTION:

The use of ultrasonic for machining processes of hard and brittle materials is known since early 1950s .The working process of an ultrasonic machine is performed by subjecting its tool to a combination of two motions. A driving motion is required to shape the w/p. A high frequency (ultrasonic) vibration of specific direction, frequency and intensity is then superimposed. Ultrasonic machines belong to the general class of vibration machines, but they form a special group for the following reasons.

The first reason is determined by the peculiarities in the behavior of materials and media in an ultrasonic field. Among these peculiarities is the drastic change in elastic – plastic characteristics that include fragility, plasticity and viscosity. The second reason is due to the peculiarities in the construction of major parts of the machine. The main components are usually formed using vibrating bar systems consisting of heterogeneous sections and using waveguides. The tool-work piece interaction leads to a nonlinearity in the vibration system in its operating conditions.

In the following literature we have tried to consider the physical foundations of ultrasonic processes among which we are laying focus on the ultrasonic machining of brittle materials. The construction of the machine and its elements depends critically on the process being performed by the tool. Therefore the optimum parameters those are required for a specified set of operations are needed to be studied in order to produce required quality of machining within the permissible time and resources.

Chapter

1

GENERAL INTRODUCTION

1.1 ULTRASONIC PROCESS:-

Ultrasonic machining (USM) is the removal of material by the abrading action of grit-loaded liquid slurry circulating between the workpiece and a tool vibrating perpendicular to the workface at a frequency above the audible range. Ultrasonic machining, also known as ultrasonic impact grinding, is a machining operation in which an abrasive slurry freely flows between the workpiece and a vibrating tool. It differs from most other machining operations because very little heat is produced. The tool never contacts the workpiece and as a result the grinding pressure is rarely more, which makes this operation perfect for machining extremely hard and brittle materials, such as glass, sapphire, ruby, diamond, and ceramics.

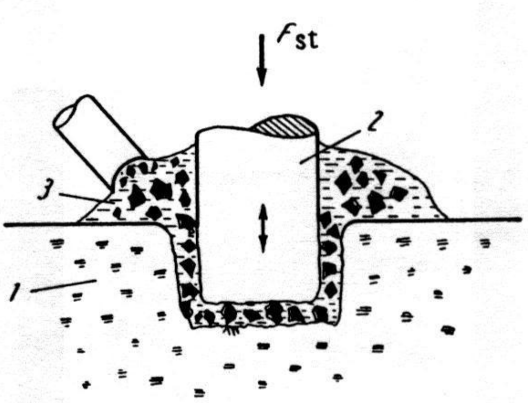


Diagram of ultrasonic cutting process. 1) Workpiece; 2) tool; 3) abrasive suspension.

Fig 1.1

The working process of an ultrasonic machine is performed when its tool interacts with the workpiece or the medium to be treated. The tool is subjected to vibration in a specific direction, frequency and intensity. The vibration is produced by a transducer and is transmitted to the tool using a vibration system, often with a change in direction and amplitude. The construction of the machine is dependent on the process being performed by its tool.

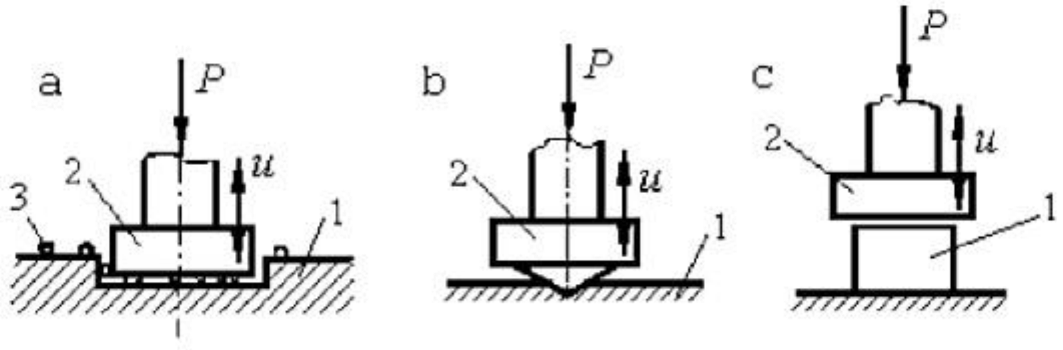
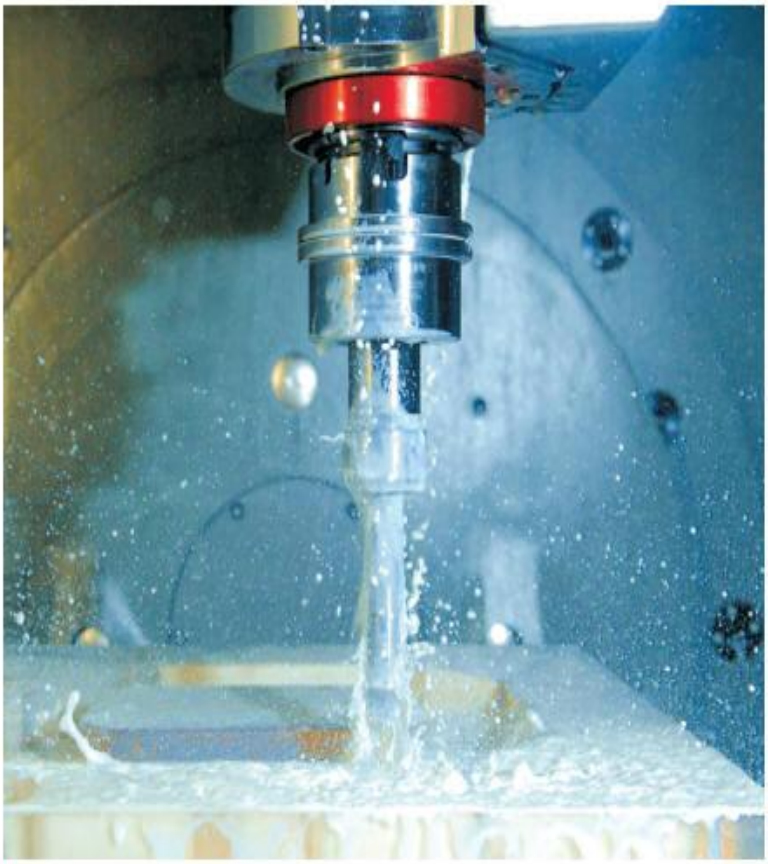


Fig 1.2

The above figure shows the ultrasonic erosion process used to machine hard, brittle materials. The workpiece 1 is placed under the face of the tool 2 which is subjected to high frequency vibration perpendicular to the surface being machined. Abrasive slurry is conveyed to the working zone between the face of the tool and the surface being machined. The tool moves towards the workpiece and is subjected to a static driving force P. repetitive impact of the tool on the grains of the abrasive material, falling from the slurry onto the surface to be treated , lead to the fracture of the workpiece material and to the creation of a cavity with the shape mirror formed of the tool. The abrasive particles are propelled or hammered against the workpiece by the transmitted vibrations of the tool. The particles then microscopically erode or "chip away" at the workpiece.

Generally the tool oscillates at a high frequency (about 20,000 cps) in an abrasive slurry. The high speed oscillations of the tool drive the abrasive grain across a small gap of about 0.02-0.10 mm against the workpiece.



Since Zerodur is one of the most expensive materials in the world, technologies, such as ultrasonic machining, are used to prevent a part from turning into scrap by loose tolerances

Fig 1.2 **Zerodur** is a glass-ceramic that has an amorphous (vitreous) component and a crystalline component.

1.2 Machining unit for Ultrasonic machining :-

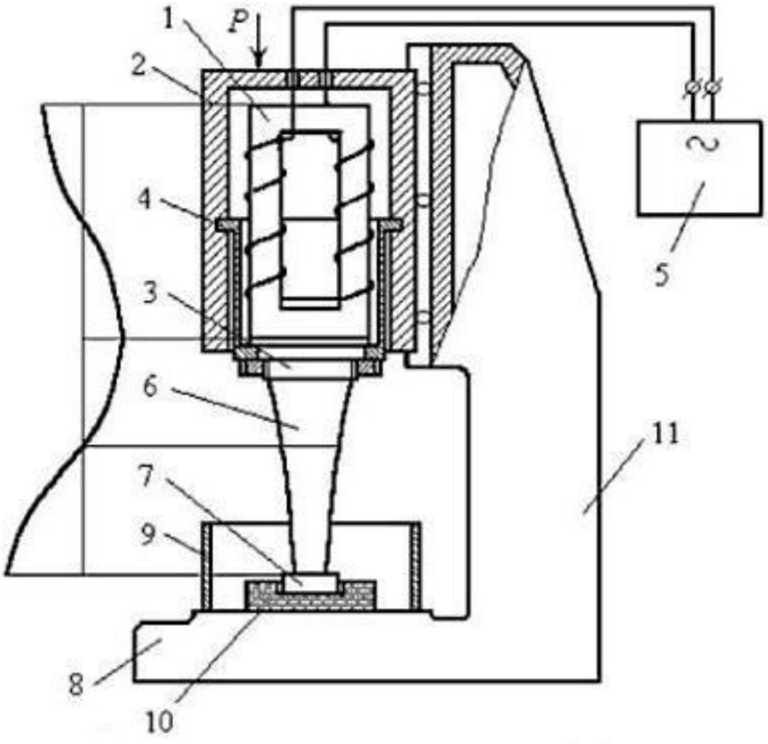


Fig 1.3

The above figure schematically depicts the major components of a typical ultrasonic machining setup. The vibration exciter, a magnetostrictive transducer 1, is fixed to the body 2 of the acoustic head using the shoulder 3 and the thin walled cup 4. The winding of the transducer is supplied with an alternating current, at ultrasonic frequency, by the generator 5. The alternating magnetic field induced by the current in the core of the transducer, which is made from magnetostrictive material, is transformed into mechanical vibration in the core. Its main elements are an electromagnet and a stack of nickel plates. The high frequency power supply activates the stack of magnetostrictive material which produces the vibratory motion of the tool. The tool amplitude of this vibration is usually inadequate for cutting purposes, and hence the tool is connected to the transducer by means of a concentrator which is simply a convergent wave guide to produce the desired amplitude at the tool end. The waveguide or concentrator 6 transmits this vibration to the tool 7. The concentrator takes the form of a bar with a variable cross section. It is specially designed to transmit vibration from the transducer, to the tool, with an increase in the amplitude. The selection of frequency and amplitude is governed by practical considerations.

The workpiece 10 is placed under the tool, on a plate 8, in a tray 9, within an abrasive slurry. The body of the acoustic head is adjusted to the base’s guides 11 and is subjected to a static force P which drives the tool in the direction necessary to machine the workpiece.

The magnetostrictive material is brazed to a connecting body of monel metal. A removable tool holder is fastened to the connecting body and is made of monel metal or stainless steel. All these parts, including the tool, act as one elastic body, transmitting the vibrations to the tip of the tool.

The abrasive slurry is circulated by pumping, and it requires cooling to remove the generated heat to prevent it from boiling in the gap and causing the undesirable cavitation effect caused by high temperature.

Tool holder

The tool holder transfers the vibrations and, therefore, it must have adequate fatigue strength. With a good tool design, an amplitude gain of 6 over the stack can be obtained. Generally, the shape of tool holder is cylindrical, or a modified cone with the centre of mass of the tool on the centre line of the tool holder. It should be free from nicks, scratches and tool marks to reduce fatigue failures caused by the reversal of stresses.

Tool materials and tool size

The tool material employed in USM should be tough and ductile. However, metals like aluminum, give very short life. Low-carbon steel and stainless steels give superior performance. The figure below shows a qualitative relationship between the material removal rate and lambda i.e. workpiece/tool hardness.

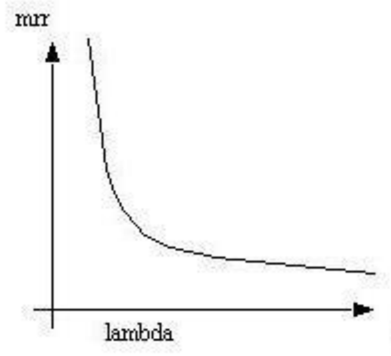


Fig 1.4

The mass length of the tool is very important. Too great a mass absorbs much of the ultrasonic energy, reducing the efficiency of machining. Long tool causes overstressing of the tool. Most of the USM tools are less than 25 mm long. In practice the slenderness ratio of the tool should not exceed 20. The under sizing of the tool depends coupon the grain size of the abrasive. It is sufficient if the tool size is equal to the hole size minus twice the size of the abrasives.

Abrasive slurry

Boron carbide is by far the fastest cutting abrasive and it is quite commonly used. Aluminium oxide and silicon carbide are also employed. Boron carbide is very costly and its about 29 times higher than that of aluminium oxide or silicon carbide. The abrasive is carried in a slurry of water with 30-60% by volume of the abrasives. When using large-area tools, the concentration is held low to avoid circulation difficulties.

The most important characteristic of the abrasive that highly influences the material removal rate and surface finish of the machining is the grit size or grain size of the abrasive. It has been experimentally determined that a maximum rate of machining is achieved when the grain size becomes comparable to the tool amplitude. Grit sizes of 200-400 are used for roughing operations and a grit size of 800-1000 for finishing.

TRANSDUCERS

The ultrasonic vibrations are produced by the transducer. The transducer is driven by suitable signal generator followed by power amplifier. The transducer for USM works on the following principle

- Piezoelectric effect
- Magnetostrictive effect
- Electrostrictive effect

Among all the above types of transducers Magnetostrictive transducers are most popular and robust amongst all.

HORN OR CONCENTRATOR

The horn or concentrator is a wave-guide, which amplifies and concentrates the vibration to the tool from the transducer. The horn or concentrator can be of different shape like

- Tapered or conical
- Exponential
- Stepped

Machining of tapered or stepped horn is much easier as compared to the exponential one.

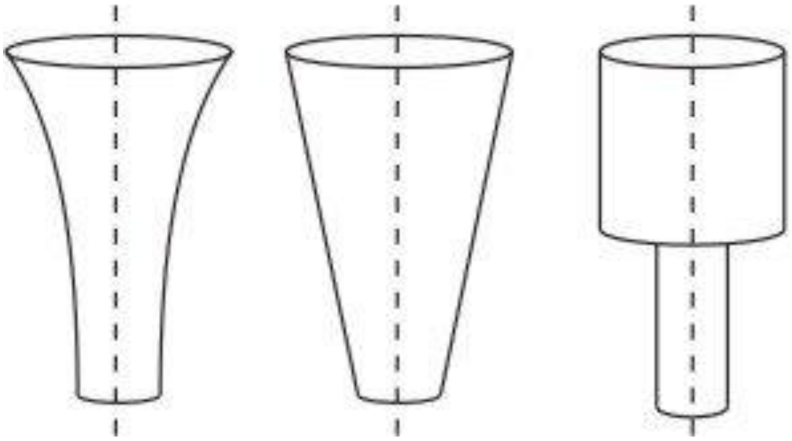


Fig 1.5
Different Horns used in USM

SALIENT FEATURES OF THE ULTRASONIC MACHINING SETUP:-

- The machines have a power rating of 0.2-2.5 kW
- The amplitude of vibration is of the order of 0.01 to 0.06 mm
- Frequency varies from a lower limit of 15,000 Hz (hearing range) to an upper limit of about 25,000 Hz (imposed by the requirement of cooling of the transducer)
- The transducer amplitude is limited by the strength of the magnetostrictive material.
- A refrigerating cooling system is used to cool the abrasive slurry to a temperature of 5-6^{0}C
- The tool is smaller than the size of the cavity by a few hundredths of a millimeter and made of low-carbon or stainless steel to the shape of the desired cavity.
- Tool size = Hole size – 2*(Size of the abrasives)
- Grit size 200-400 for roughing & 800- 1000 for finishing
- Slenderness ratio of the tool should not exceed 20

1.3 Parameters of Ultrasonic Machining:-

The ultrasonic vibration machining method is an efficient cutting technique for difficult-to-machine materials. It is found that the USM mechanism is influenced by these important parameters.

- Amplitude of tool oscillation(a_0)
- Frequency of tool oscillation(f)
- Tool material
- Type of abrasive
- Grain size or grit size of the abrasives – d_0
- Feed force - F
- Contact area of the tool – A
- Volume concentration of abrasive in water slurry – C
- Ratio of workpiece hardness to tool hardness; $\lambda=\sigma_w/\sigma_t$

Physical parameters	
Abrasive	Boron carbide, aluminium oxide and silicon carbide
Grit size(d_0)	100 – 800
Frequency of vibration (f)	19 – 25 kHz
Amplitude of vibration (a)	15 - 50 µm
Tool material	Soft steel titanium alloy
Wear ratio	Tungsten 1.5:1 and glass 100:1
Gap overcut	0.02-0.1 mm

Table 1.1

Material removal rate

USM can be applied to machine nearly all materials; however it is not economical to use USM for materials of hardness less than 50 HRC. Generally the workpiece materials are of stainless steel, cobalt-base heat-resistant steels, germanium, glass, ceramic, carbide, quartz and semiconductors. It is highly useful in the machining of materials that cannot be machined by any conventional machining process that are ceramic and glass.

Material removal rate is inversely proportional to the cutting area of the tool. Tool vibrations also affect the removal rate. The type of abrasive, its size and concentration also directly affect the MRR

Material removal in USM appears to proceed by a complex mechanism involving both fracture and plastic deformation to varying degrees, depending on several process variables.

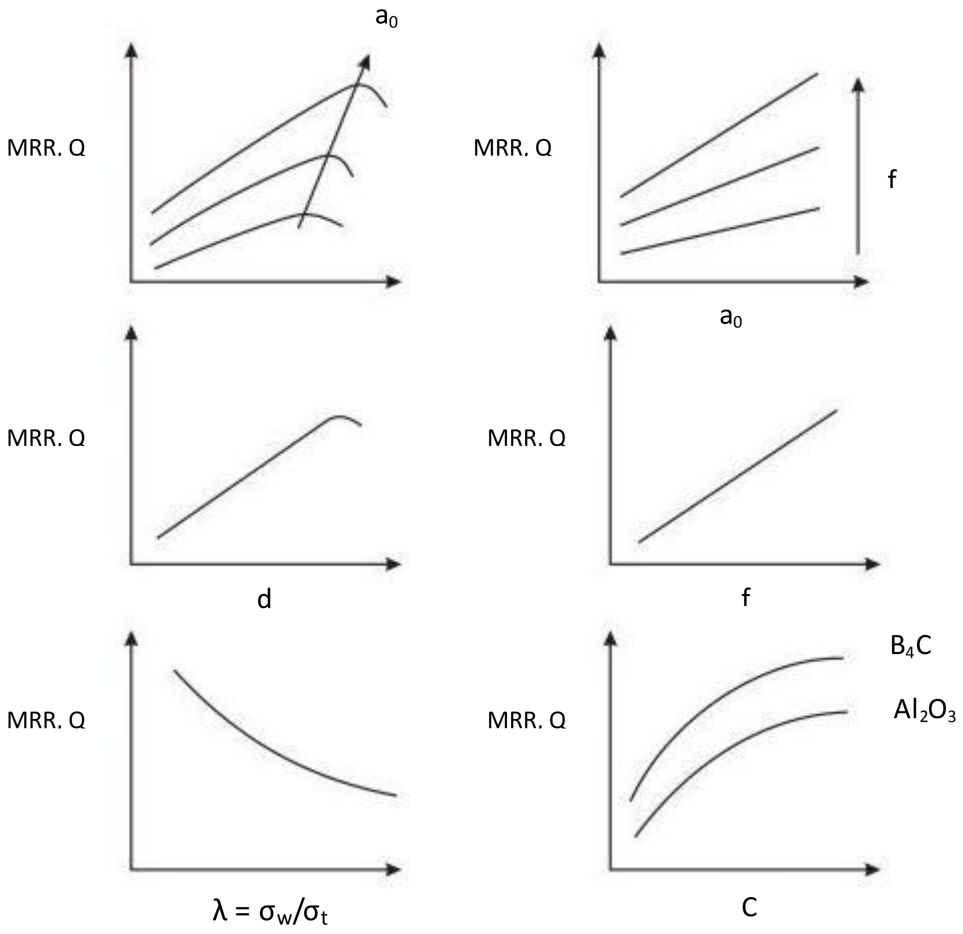


Fig 1.6
Effect of machining parameters on MRR

1.4 Advantages:-

- UM effectively machines precise features in hard, brittle materials such as
  - glass
  - engineered ceramics
  - CVD SiC- Chemical Vapor Deposition Silicon Carbide
  - quartz
  - single crystal materials
  - PCD - Polycrystalline diamond
  - ferrite
  - graphite
  - glassy carbon
  - composites
  - piezoceramics

Square cavities, round through holes and crossing beams in a 4-in. borosilicate wafer.

Fig 1.7

- A nearly limitless number of feature shapes—including round, square and odd-shaped thru-holes and cavities of varying depths, as well as OD-ID features—can be machined with high quality and consistency.
- Aspect ratios as high as 25-to-1 are possible, depending on the material type and feature size.
- The machining of parts with preexisting machined features or metallization is possible without affecting the integrity of the preexisting features or surface finish of the workpiece.
- USM machined surfaces exhibit a good surface integrity and the compressive stress induced in the top layer enhances the fatigue strength of the workpiece.
- The quality of an ultrasonic cut provides reduced stress and a lower likelihood of fractures that might lead to device or application failure over the life of the product.
- Unlike other non-traditional processes such as laser beam, and electrical discharge machining, etc., ultrasonic machining does not thermally damage the workpiece or appear to introduce significant levels of residual stress, which is important for the survival of brittle materials in service.

Fig 1.8 A UM-machined square hole in 0.0175-in. thick glass. The machined feature exhibits a clean edge, and the natural corner radius is < 0.005 in.

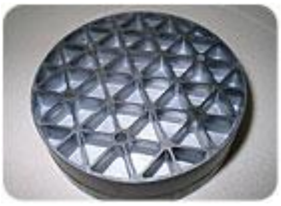


Fig 1.9 Honeycomb structure machined on the back of a silicon mirror for NASA.

- Unlike conventional machining methods, ultrasonic machining produces little or no sub-surface damage and no heat-affected zone.
- This machining process is nonthermal, nonchemical, and nonelectrical. It does not change the metallurgical, chemical or physical properties of the workpiece.

1.5 DISADVANTAGES

- Ultrasonic machines have a relatively **low mrr.** Material removal rates are quite low, usually less than 50 mm3/min.
- The abrasive slurry also "machines" the tool itself, thus causing **high rate of tool wear** , which in turn makes it very difficult to hold close tolerances.
- The slurry may wear the wall of the machined hole as it passes back towards the surface, which limits the accuracy, particularly for small holes.
- The machining area and the depth of cut are quite restricted

1.6 APPLICATIONS

- Ultrasonic machining is ideal for certain kinds of materials and applications. Brittle materials, particularly ceramics and glass, are typical candidates for ultrasonic machining. Ultrasonic machining is capable of machining complex, highly detailed shapes and can be machined to very close tolerances (±0.01 mm routinely) with properly designed machines and generators. Complex geometric shapes and 3-D contours can be machined with relative ease in brittle materials. Multiple holes, sometimes hundreds, can be drilled simultaneously into very hard materials with great accuracy.

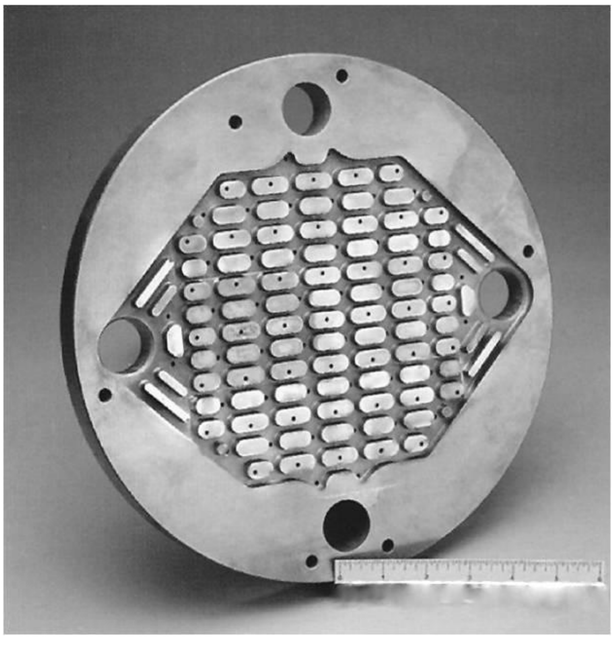


Fig 1.10

Channels and holes ultrasonically machined in a polycrystalline silicon wafer.

- Coining operations for materials like glass ,ceramics, etc.

Fig 1.11
Coin with grooving carried out with USM

- Threading by appropriately rotating and translating the workpiece/tool.
- Rotary ultrasonic machining uses an abrasive surfaced tool that is rotated and vibrated simultaneously. The combination of rotating and vibrating action of the tool makes rotary ultrasonic machining ideal for drilling holes and performing ultrasonic profile milling in ceramics and brittle engineered materials that are difficult to machine with traditional processes.
- Ultrasonic machining can be used to form and redress graphite electrodes for electrical discharge machining. It is especially suited to the forming and redressing of intricately shaped and detailed configurations requiring sharp internal corners and excellent surface finishes.
- It is particularly useful in microdrilling holes of upto 0.1 mm.

Fig 1.12 SEM of a 0.64mm hole ultrasonically machined in an alumina substrate

Chapter

2

LITERATURE REVIEW

2.1 History and background of Ultrasonic Machining

Hard solids are invariably stiff, strength and wear resistant. On the other hand, hard solids typically exhibit statistically variable brittle fracture and high sensitivity to machining damage. When loaded with tensile stresses, hard solids pass from elastic to fracture behavior and invariably fail by crack extension. Thus, hard solids are usually brittle, i.e., they have small capacity to convert elastic energy into plastic deformation at room temperature (Dieter, 1981).

Brittle and hard solids can be classified in four groups: minerals, polycrystalline ceramic aggregates (traditional and advanced), single crystals and amorphous glasses. Minerals are frequently used as raw materials in the production of a large range of products such as abrasives, gemstones, metals and alloys, single crystals synthetically produced on a commercial scale, etc. Traditional ceramics and glasses are extensively used to manufacture many products currently used in daily life. Advanced ceramics have been widely adopted as functional as well as structural engineering materials (Chiang et al. 1997). Functional ceramics and single crystals are extensively used in the production of electric, electronic, magnetic and optical components for high performance systems such as transducers, resonators, actuators and sensors (Fraden, 1996). The past twodecades have seen a tremendous resurgence in the use of advanced ceramics in structural applications such as roller and sliding bearings, adiabatic diesel engines, cutting tools, etc. Conventional forming and sintering processes of ceramic powders do not necessarily give the high dimensional accuracy and the good surface quality required for functional and structural components. Thus, precision machining technologies have been developed for the manufacture of cost-effective and quality-assured precision parts produced by brittle and hard solids.

Ultrasonic machining offers a solution to the expanding need for machining brittle materials such as single crystals, glasses and polycrystalline ceramics, and for increasing complex operations to provide intricate shapes and workpiece profiles. This machining process is non-thermal, non-chemical, creates no change in the microstructure, chemical or physical properties of the workpiece and offers virtually stress-free machined surfaces. It is therefore used extensively in manufacturing hard and brittle materials that are difficult to cut by other conventional methods. The actual cutting is performed either by abrasive particles suspended in a fluid, or by a rotating diamond-plated tool. These variants are known respectively as stationary ultrasonic machining and rotary ultrasonic machining (RUM).

Rotary ultrasonic machining (RUM) is a hybrid machining process that combines the material removal mechanisms of diamond grinding with ultrasonic machining (USM), resulting in higher material removal rates (MRR) than those obtained by either diamond grinding or USM alone. Experiments with calcium aluminum silicate and magnesia-stabilized zirconia have shown that the MRR obtained with RUM is six to 10 times higher than that of a conventional grinding process under similar conditions, and it is about 10 times faster than USM. It is also easier to drill deep holes with RUM than with USM, and the hole accuracy is improved. Other advantages of this process include a superior surface finish and low tool pressure.

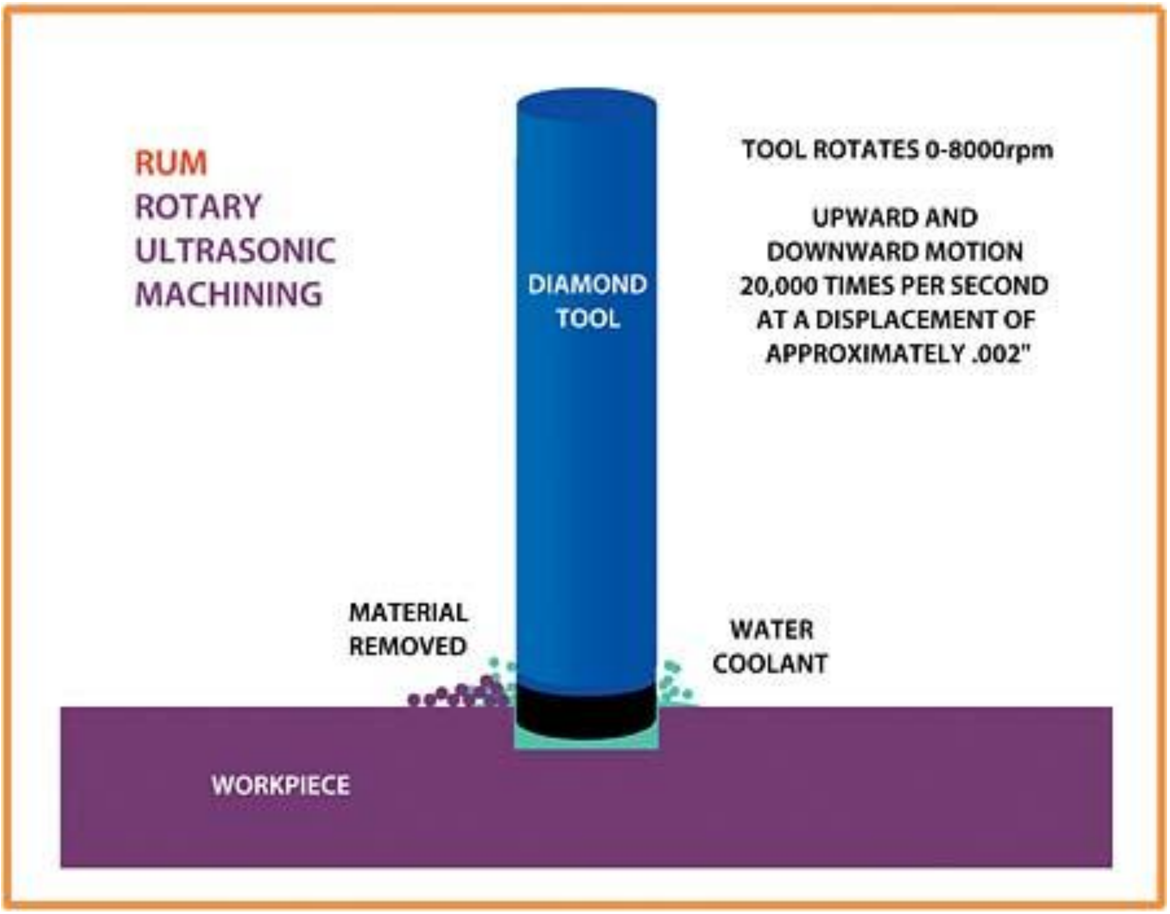


Fig 2.1

In rotary ultrasonic machining, a rotating core drill with metal-bonded diamond abrasives is ultrasonically vibrated in the axial direction while the spindle is fed toward the workpiece at a constant pressure.

Stationary (or conventional) ultrasonic machining (USM) accomplishes the removal of material by the abrading action of a grit-loaded slurry, circulating between the workpiece and a tool that is vibrated at small amplitude. The form tool itself does not abrade the workpiece; the vibrating tool excites the abrasive grains in the flushing fluid, causing them to gently and uniformly wear away the material, leaving a precise reverse form of the tool shape. The uniformity of the sonotrode-tool vibration limits the process to forming small shapes typically under 100 mm in diameter.

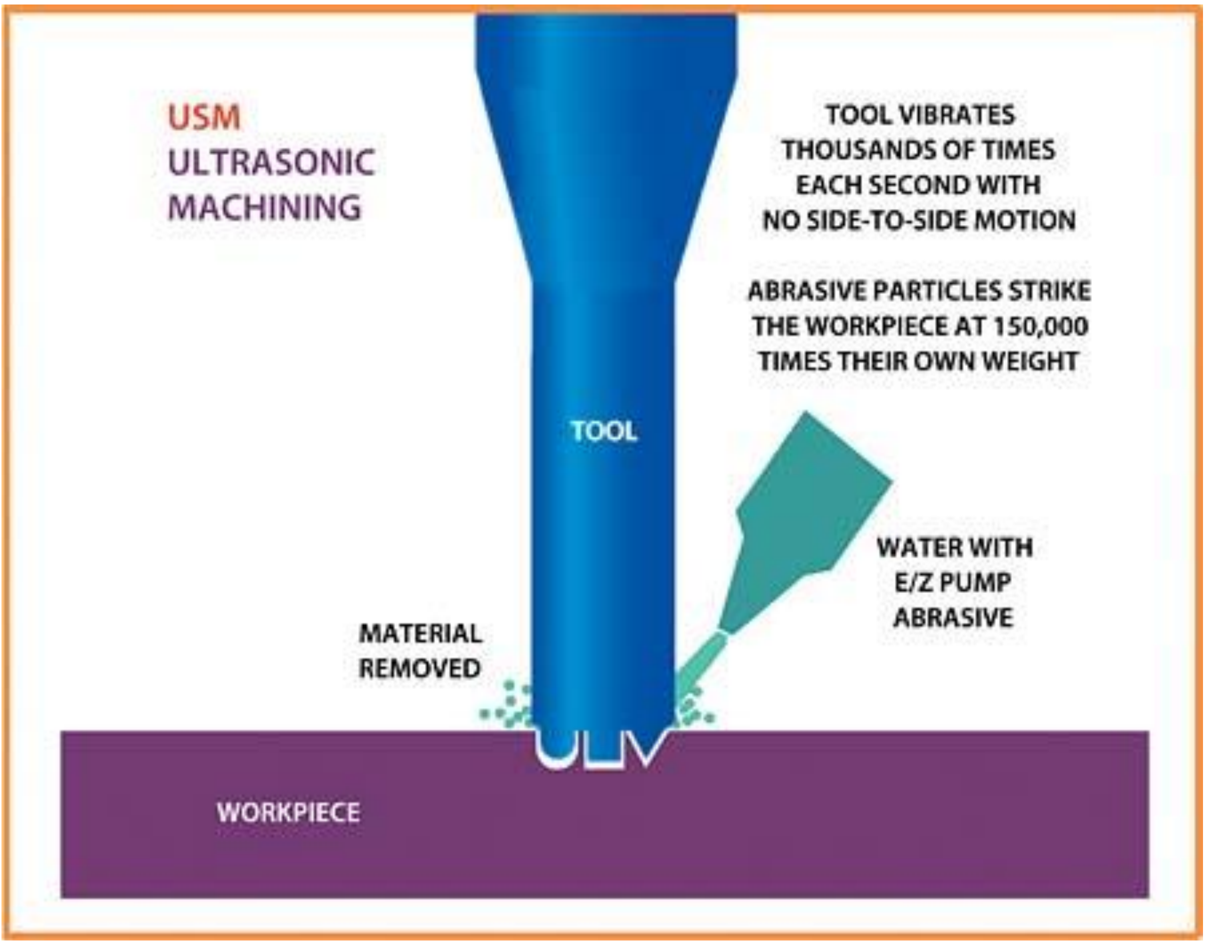


Fig 2.2

In ultrasonic machining, the tool, which is shaped conversely to the desired hole or cavity, oscillates at high frequency, typically 20 kHz, and is fed into the workpiece by a constant force.

The USM system includes the sonotrode-toll assembly, the generator, the grit system and the operator controls. A schematic representation of the USM set-up is shown in Fig. The sonotrodetool assembly consists of a transducer, a booster and a sonotrode. The electronic generator powers the transducer, creating impulses that occur at a range of 19.5 to 20.5 kHz, and automatically adjusts the output frequency to mach the resonant frequency of the tool, which varies according to the sonotrode shape and material. The transducer converts the electrical pulses into vertical stroke. This vertical stroke is transferred to the booster, which may amplify or suppress the stroke amount. The modified stroke is then relayed to the sonotrode-tool assembly. The amplitude along the face of the tool typically falls in a 20 to 50 µm range. The vibration amplitude is usually equal to the diameter of the abrasive grit used.

The grit system supplies a slurry of water and abrasive grit, usually silicon or boron carbide, to the cutting area. In addition to providing abrasive particles to the cut, the slurry also cools the sonotrode and removes particles and debris from the cutting area. The overcut produced with USM is a function of the abrasive particle size, as are the surface finish and the material removal rates (Komaraiah et al. 1988, Thoe et al. 1998). The operator controls provide inputs for manual or automatic sequencing of operations. Controls include variable cutting force, ram position, speed control of the ram movement, cycle timing, retract distance and flush timing.

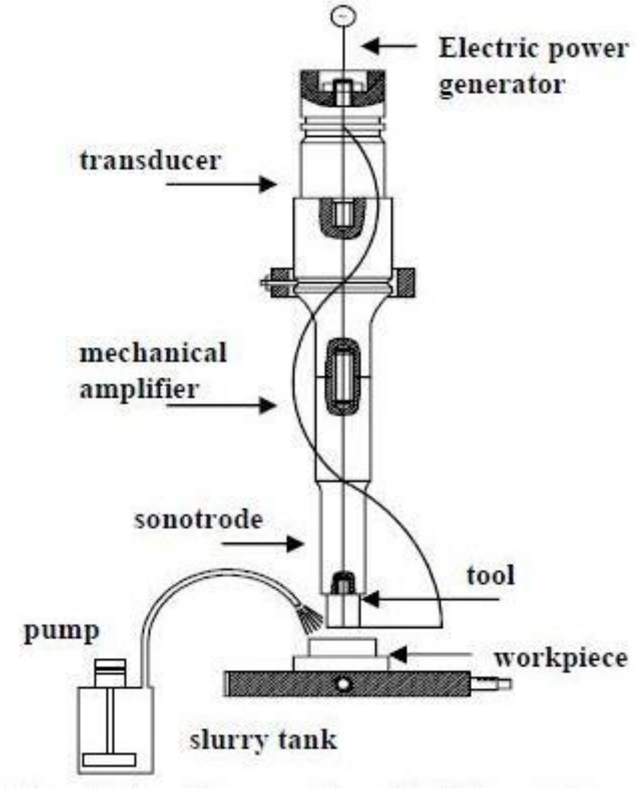


Fig 2.3

Schematic representation of the USM apparatus

From the tribological point of view, USM can be classified as a three-body abrasive wear. The material removal is assured by direct hammering and impact action of the abrasive particles against the surface of the workpiece (Shawn, 1956; Kainth et al., 1979). Soundararajan and Radhakrishnan (1986) showed that direct hammering of the abrasive particles on the workpiece by the tool, resulting in material removal and particle crushing, may contributes up to 80 % of the stock removal in brittle solids such as glass. Cavitation effects from the abrasive slurry and chemical action associated with the fluid employed have been reported as minor material removal mechanisms. Material removal rate, surface finish and machining accuracy are influenced by various operational parameters such as amplitude and frequency of ultrasonic oscillations, static load applied on the sonotrode, tool design, hardness and size of abrasive particles.

2.2 FUTURE OF ULTRASONIC MACHINING:

Unlike applications in medicine, inspection and parts cleaning where ultrasonic (high frequency sound) waves are applied directly, ultrasonic machining is a metalcutting process that is facilitated by ultrasonic technology. The result is a system that can machine brittle materials such as ceramics, glass, silicon, graphite, composite materials and precious stones. Increasingly, workpieces made from these "advanced materials" are being specified in the medical, automotive, aerospace and optics industries. It is the properties of these materials—low weight, chemical and thermal stability and wear resistance—that make them attractive for design engineers. But the very properties that make the composition of these materials attractive for selected applications make them a bear to machine with conventional metal cutting processes.

Engineered ceramic materials exhibit a host of very attractive properties for today's scientists, design engineers and R&D engineers. Properties of interest include high hardness, high thermal resistance, chemical inertness, tailored electrical conductivity, high strength-to-weight ratio and longer life expectancy. Ultrasonic machining (USM) is of particular interest in the machining of both conductive and non-conductive, brittle, complicated shape materials such as diamonds, titanium and engineering ceramics. Rupinder and Aspinwall [1,2] introduced a review for the fundamental principles of steady-state ultrasonic machining. The material removal mechanisms involved the effects of operating parameters on material removal rate, tool wear rate, and work piece surface finish of titanium and its alloys for application in manufacturing industry.

Inventions been done that relates primarily to ultrasonic machining which involves vibrating the part to be machined rather than a tool of the machine. To impart vibrations to the part to be machined it is secured to a metallic part for transmitting vibrations which is in turn connected to a transducer for converting electrical oscillations into mechanical vibrations. An abrasive is supplied to the space between the opposed operative faces of the tool and the part to be machined. The invention also relates to an installation for carrying out the method which includes a machining enclosure and a recycling assembly for recycling the abrasive liquid mixture which is used during the process.

A new method for micro ultrasonic machining (MUSM) has been developed. In order to obtain high-precision tool rotation, the spindle mechanism employed in micro-EDM machines was introduced. Since the mechanism does not allow the vibration of tools, the workpiece was vibrated during machining. This setup has been successfully used in machining micro holes as small as 5pm in diameter in quartz glass and silicon. In this machining range, high tool wear posed a problem. To solve this problem, a sintered diamond (SD) tool was tested and was proven to be effective.

Chapter

3

EXPERIMENTAL WORK

3.1 Machine setup in Laboratory:-

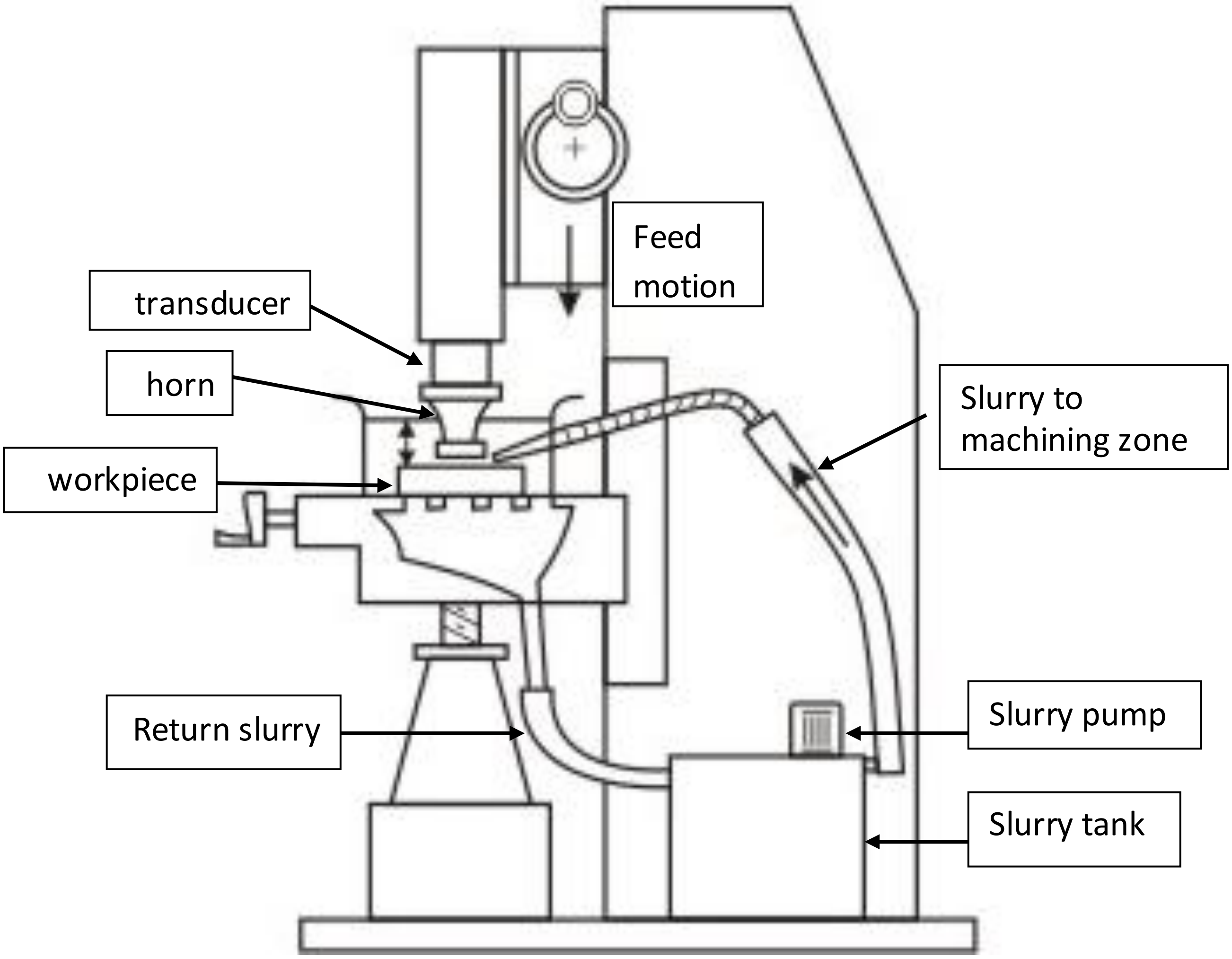


Fig 3.1

Schematic view of an Ultrasonic Machine

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 workpiece is mounted on a plate where it is clamped to the plate by the help of two side plates that can be secured by allen bolts. The plate is situated inside a basin that has a supply for the abrasive slurry and a drainage that clears completes the circulation of the slurry into the slurry tank below. The table or the plate where the workpiece is fixed is fixed and cannot be moved. However the tool holder along with the cabinet that holds the transducer can be manually lowered or raised to accommodate workpieces of different sizes.

The typical elements of an USM are (Fig. 3.1)

- 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.
- HMI-Human Computer Interface; that displays the several options and modes of operations.
- Amplitude regulating power system to control the generator for the amplitude.

Fig 3.2

USM in the labratory

GENERATOR CONTROLLER

Fig 3.3

Generator controller

The unit shown above is required to change and regulate the parameters like frequency and amplitude of the USM. Along with that it also monitors the powerload of the machine while the machining process. As it shows above there is an option for tuning the concentrator in two frequencies that are 20 kHz and 36 kHz. The amplitude can be varied from 70 % to a 100% of the total permissible amplitude. The rightmost panel shows the power load on the machine that varies from 0% to 100% of the total power capacity. As is shown in the above figure the machine has power wattage of 3000W.

TRANSDUCER AND CONCENTRATOR with TOOL HOLDER AND TOOL

Fig 3.4

The above figure shows the assembly of the transducer, concentrator, tool holder and the tool. The titanium alloy transducer is connected to the concentrator that is made up of aluminium. The titanium alloy transducer is advantageous because of being corrosion resistance and due to its high resistance to electrical and mechanical noise of pumps etc. The concentrator is under constant mechanical force that causes it to be heated up quite quickly. Here comes the application of aluminium as the right material for a concentrator. A cooling system is placed near the transducer to prevent excessive heating by supplying pressurized air around the transducer cabinet.

SLURRY TANK AND MOTOR ASSEMBLY

Fig 3.5

Some initial problems were faced in the circulation system, caused due to the entrance of the chips from the workpiece into the slurry tank through the drainage system, connected to the basin that houses the workpiece table or plate.

The above problem was taken care of by adjusting the pipe from the basin to the tank and fastening a net of hole size of about 2mm to the delivery pipe of the tank. The slurry was then filtered and replaced in the tank for usage.

HMI-HUMAN COMPUTER INTERFACE

As the name suggests the HMI is the interface for operations on the ultrasonic machine. It has got a graphics user interface that displays the various options and modes that carry out and tweak the operations on the machine.

3.2 OPERATION OF MACHINE

Basically the machine is designed to drill into ceramic or glass plate.

The machine employs a Panasonic make Ac servo motor (Model: MSM042P1G) and driver (Model: MSD043P1E) for very fine motion.

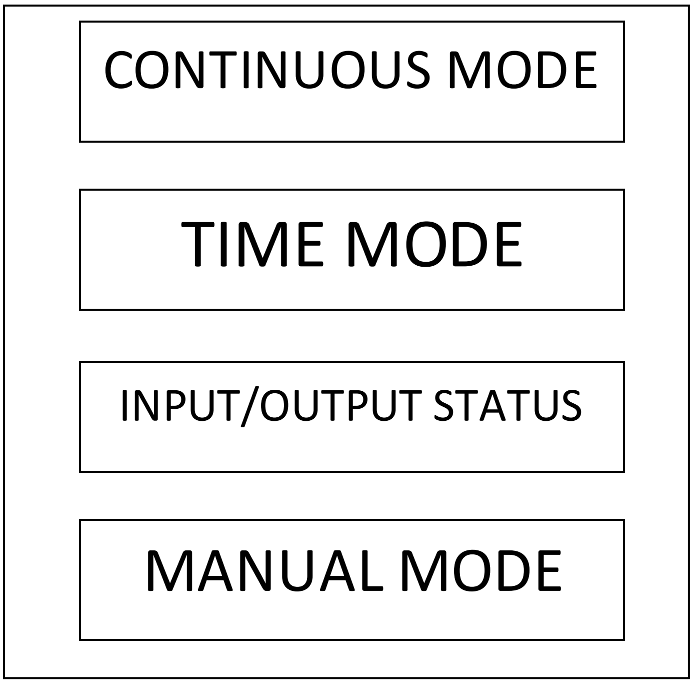


Fig 3.6

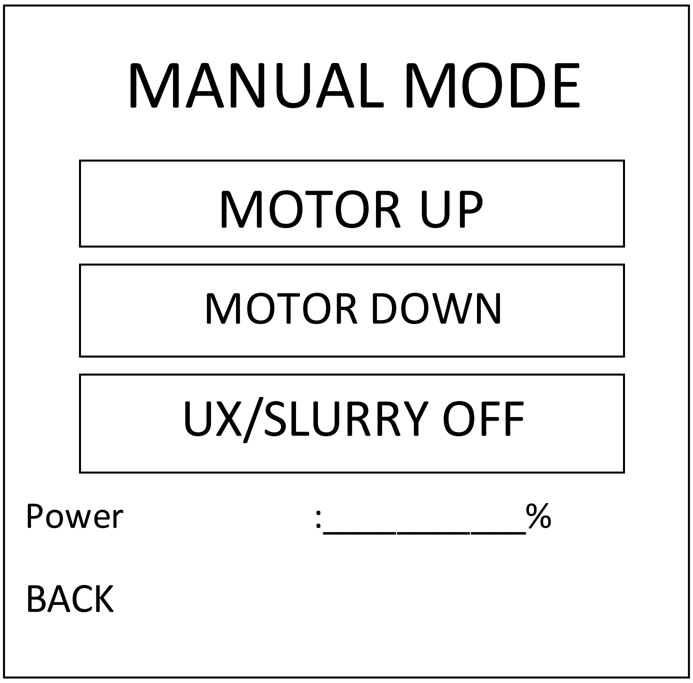
Main screen

Machine can be operated in two modes namely

1. Auto mode
2. Manual mode

1. Manual mode :

The following screen appears by pressing the manual mode button



MANUAL MODE

MOTOR UP

MOTOR DOWN

UX/SLURRY OFF

Power :__________%

BACK

Fig 3.7

Manual mode screen

In this mode motor can be moved manually up or down by up and down buttons respectively provided in the screen. The point to be noted here is that the switches are inch type and therefore to keep the motor **ON** user has to continuously press this key.

Motor can move down till lower sensor turns on. If lower sensor is on then motor will not come down. Similarly for the upward movement. Also we can switch on and off ultrasonic power in this mode. Once this key is pressed ultrasonic and cooling coil will turn on and on pressing again it switches it off.

3.3 MATERIAL SELECTION

Tool material	Titanium alloy
Workpiece material	Ceramic tiles
Composition of w/p	Stoneware
Workpiece thickness	8.30 mm
Abrasive slurry used	Aluminum oxide-Al_2O_3
Concentration	20% by volume in water
Grit size	200
Frequency	20 kHz
Parameter varied	Amplitude

Table 3.1

The tool is attached to the transducer through the concentrator that acts as a wave guide to produce the desired amplitude at the tool end. Achieving the maximum amplitude of tool vibration is necessary for the ultrasonic process to be effective. For this reason the vibration system is adjusted to operate within its resonant range. The system is excited at a frequency that coincides with one of its resonant frequencies. Adjustment of the system's parameters is usually made under idle conditions; it is assumed that the influence of the working loads on the resonant frequency of the system is negligible.

- The vibrating system is thereby preset to a frequency of 20 kHz.
- The slurry is cleaned from any type of impurities and fed into the slurry tank along with water. The mixture is prepared such that we get a concentration of 20% by volume of the abrasive.
- The workpiece is selected and weighed before fixing it to the table with the help of plates and allen screws.
- The compressor motor is turned on to collect the air for the cooling of the transducer.
- The machine is started in the manual mode and operated on the workpiece for one minute with varying amplitudes. The results found are tabulated in the following table.

3.4 OBSERVATION

Initial mass of w/p in grams	Final mass of w/p in grams	Amplitude %	Mass of material removed(in grams)
40.035	40.022	70	00.013
40.076	40.035	80	00.041
40.022	39.785	90	00.037
39.785	39.770	100	0.015

Table 3.2

A graph is plotted according to the above readings.

The machined part is shown as below:

Fig 3.8

Workpiece after being machined

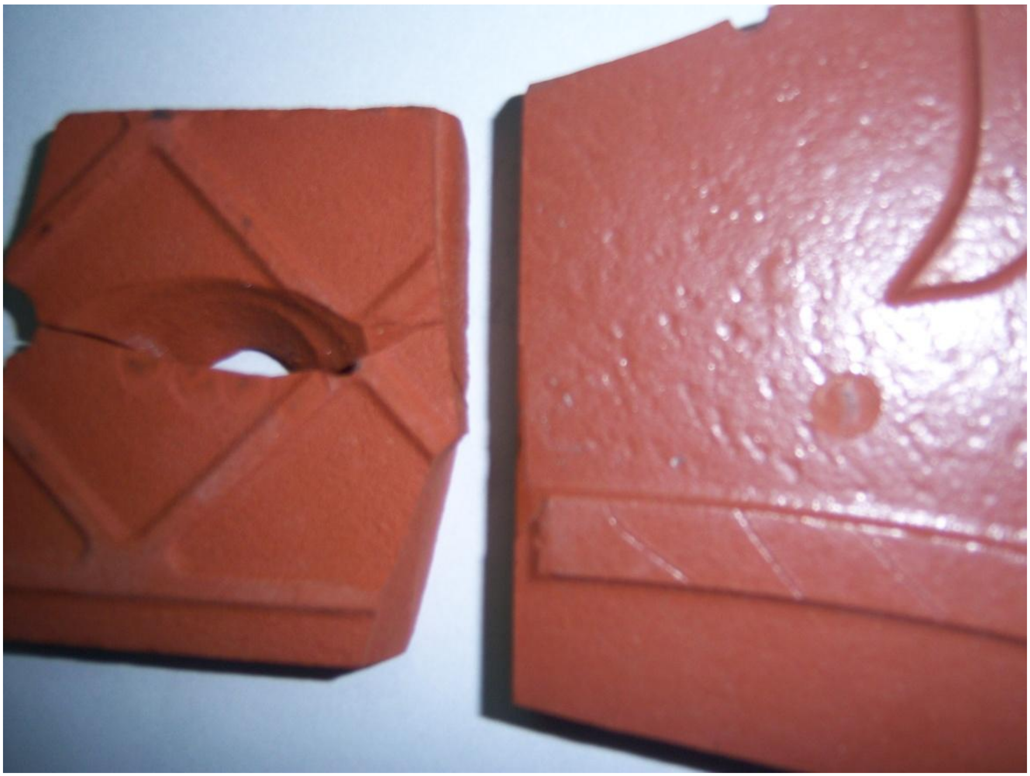


Fig 3.9

Chapter

4

RESULTS AND CONCLUSION

4.1 RESULT

From the plotted graph we can see that the results are highly erratic whereas actual practice the MRR should be increasing with the increase in the amplitude for a given set of other constant parameters. The workpiece finally cracked after taking 6 readings.

We can also see a certain degree of tool vibration. The vibration was found to be of the order of 1.09 mm.

Fig 4.1

Cracked workpiece

DISCUSSION

The following may be the reasons for the above inconsistent readings:

- The ceramic tiles used were not having an even surface and contained ridges. When the tool landed on those ridges, the **surface area of impact** was less and therefore the material removal was much lower.
- During the machining process the extremely high impact load produced by the tool caused the **chips** to break away from the periphery of the workpiece that were in contact with the worktable. This further reduces the final weight of the workpiece that affects the reading for the **material removed**.

4.2 SUGGESTION

- The workpiece used should be of plain area of impact without any discontinuity. It helps in distributing the load thereby acting as a suitable experimental material without breaking.
- The allen screws should be secured so that they are just sufficient to hold the workpiece in place without any vibration. This ensures the workpiece is intact and doesn’t break due to excessive tightening.
- The boundaries of the workpiece can be treated with certain resins or adhesives that prevent the chipping away of the workpiece from the boundaries where no machining takes place.

4.3 CONCLUSION

In the above literature an effort has been made to familiarize with the basic layouts of the common Ultrasonic Machining setup, the various elements that constitute the overall build, and the basic parameters on which the machining characteristics depend.

Preliminary USM experiments carried out pointed out the various regions of improvement in the experimental setup. Absence of any feed force measuring device and the necessity to tune the vibrating system rules out the possibility of any further experiments upon them. The slurry concentration could be varied to find out the effect on the parameter. Different materials can be used for a given abrasive of varying size to find out the best option for machining a given workpiece. The effects of tool vibration frequency, tool vibration amplitude and feed force along with the other process parameters in the USM method were studied theoretically. Also it was observed that care has to be taken to treat the w/p before machining for accurate readings and the slurry tank must be cleaned along with the slurry to keep it free from impurities that may jam the slurry circulation system.

The overall ultrasonic machining process is studied and an effort is made to carry out rigorous experiments in order to reach at the optimal values that could result in the required improvement in machining characteristics mandatory for smooth operation of the setup and satisfactory results.

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