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USM FOR HARD OR BRITTLE MATERIAL & EFFECT OF PROCESS PARAMETERS: A REVIEW

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ABSTRACT

In the previous years, we have seen that it is very difficult to machine hard and brittle material. Machining of this type of material is done by Ultrasonic Machining (USM) which is more preferable method. Due to hardness and brittleness it is a poor conductor of electricity so it can be done only by mechanical process so ultrasonic machining is used because it consist of high frequency vibrating tools with mechanical motion. There is slurry of abrasive is used and finally a cut or hole in the work piece eroded. In this paper the recent progress is summarize mainly of glass, titanium or ceramics. The properties of these materials are low coefficient of thermal expansion and high level of hardness. The process parameter on material removal rate (MRR), tool wear rate or surface finishing of glass, ceramics, and titanium and also for further application in manufacturing area is also summarised.

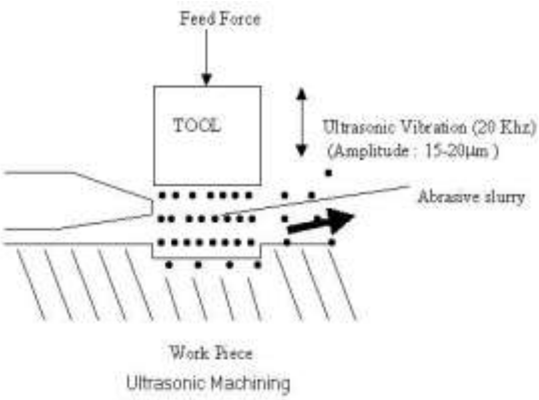
Keywords: Ultrasonic machining; USM for ceramics; USM for glass; USM for Titanium; USM MRR; USM Surface Roughness

I INTRODUCTION

Due to the excellent properties of materials such as silicon, titanium, glass, ceramics are using in a widely now a days in industries. These materials are of hard and brittle type having Hardness Rockwell C (HRC) 40 or above but the material may not good electric conductor. It consists of mainly four category i.e polycrystalline ceramics aggregate, minerals, single crystal and amorphous. Glass is an amorphous solid material. From centuries glass is used in window and drinking vessel, in soda lime glass, that composed of several additives and about 75% silica (SiO_2). Ultrasonic machining is a non-traditional process and it is applicable in non-conductive material like-ceramics due to the difficulty in machining by conventional process [1]. Advanced Ceramics are mainly used for making roller and sliding bearing and also in adiabatic diesel engine. Due to this there is a need for development of non-conventional machining for brittle material [2]. These brittle material consist of high strength, low thermal conductivity, low friction and corrosion resistance.

[3].The hard material can convert elastic energy into plastic deformation easily at room temperature because of its low thermal conductivity [4]. USM is a manufacturing process of chipless which is based upon a magnetostrictive or piezoelectric transducer through which a tool s attached by the support of concentrator which helps to erode a hole in the work piece as shown in fig.1.

The frequency range of USM is above the hearing range of a Human ear i.e. (20--20,000Hz) so it is considered as noiseless process [5]. In traditional the shape and size of work piece is depend upon the geometry of the tool. The abrasive slurry and grit size of the particle is affect the MRR and also improves the quality of surface. The flow behaviour of slurry is studied by simulation and it is found that if place of nozzle is at a distance of around 10mm from the cutting zone, then nozzle posses maximum efficiency [6].



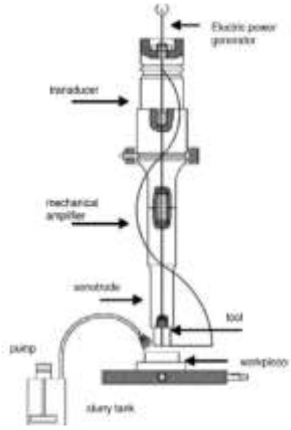
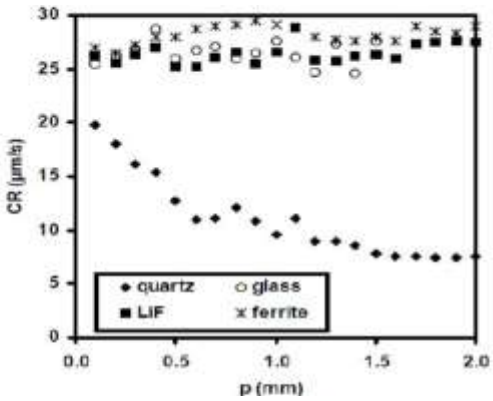


Fig.1USM material removal mechanism [4] **Fig.2 Basic Element of USM [4]**

USM machines are also called ultrasonic vibration cutting (UVC) only two parameters are involved in this like- tool vibration amplitude and vibration frequency, are considered in the UVC system which increases the surface finishing and stability in cutting process [7].

II INVOLVEMENT OF HARD AND BRITTLE MATERIAL IN USM

For last 200 years Titanium (symbol Ti, Atomic no.22, Atomic w.t 47.9). It is mainly efficient and is used in metal for high performance of aircraft, such as engine. A rotary ultrasonic machining which is having a core drill with abrasive particles with high frequency towards the work piece mainly for glass, ceramics [3]. Experiments are conducted by using rectangular cutting tool and SiC particles having mean grit size of 15 microns. In this study of different hard material alumina, quartz, glass, ferrite or Lif and shows that the rate of MRR constant as per machining. In this it takes study of 5mm thick block of glass or other material. The hardness and fracture toughness of glass value is defined using Vickers indenter [4]. After investigation it is found that the rate of cutting rate is decreased with p(depth) in the first half part of machining process as shown in fig.3.. This problem takes place due to the slurry turbulence effect increases or by recycling capacity effect the hammering and impact act between tool and the work piece [4].



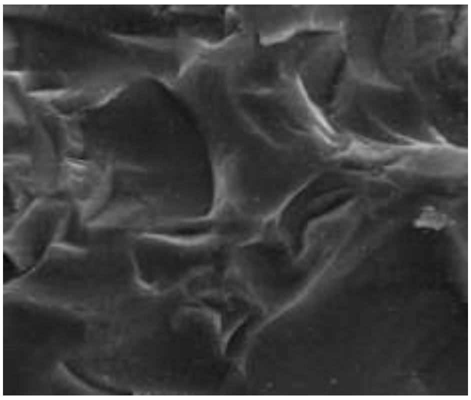


Fig.3 Variation of cutting rate (CR) as a function of cutting depth(p) [4] & Fig.4 SEM micrographs of ultrasonic machined surface i.e glass with SiC grit size 15micron

Glass have less value of hardness (5.8+/- .5) GPA and toughness is approx. .48 which is less than the other material but its value of roughness is high shown by micrograph with SiC grit of 15 microns which is shown in fig.4 shows the reason that glass have no effect on MRR.

Rotational ultrasonic machining is best is best for machining process of advanced ceramics [8]. To increase the hardness and toughness of advanced ceramics the Alumina and lanthanum is helpful. For precise machining of ceramics or glass material with less time consuming using hydrofluoric acid solution is added with abrasive particles i.e. alumina . Ultrasonic machine which is chemically assisted the propagation of impact energy in the lateral direction is limited because the link between the molecules is weakened. Also the deep medium crack produced is due to increase of transmission energy [9]. USM history was begun from 1927 by R.W. Loomis and firstly the patent was granted in 1945 and from 1950 it is commonly used for machining purpose [10]. For conducting micro-machining process viscoelastic thermoplastic material is used as tooling [11].

III. RATE OF MATERIAL REMOVAL (RMM) AND SURFACE MODIFICATION USING ULTRASONIC MACHINING

Input variable (feed rate, vibration amplitude, spindle speed, abrasive size and area of core drill end face).In Rotational ultrasonic machining(RUM) it is seen that the spindle speed and feed rate have significant effect on cutting, but ultrasonic vibration amplitude, abrasive size and abrasive concentration have less effect on cutting force. It indicates that if cutting force increase as abrasive particle and feed rate increase and if cutting force is decreased then abrasive size, vibration amplitude, and spindle speed increases [3]. The tool life or wear out the tool in Ultrasonic vibration machining might be reduced due to the deformation mechanism of work material in the cutting zone. In this a single cutting tool with 45* rake angle and 5* clearance angle was used. In this the ultrasonic vibration cutting improves the tool wear and surface finish. In experiment it was found that vibration diamond cutting helps in the potential for producing high quality optical shape on glass than conventional cutting [12].

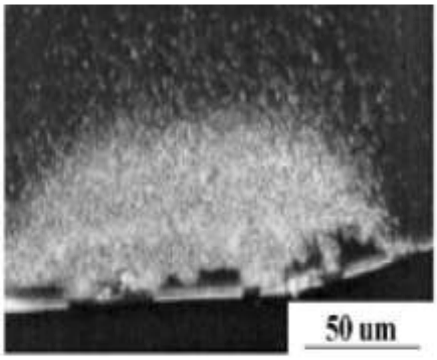


Fig.5 Tool wears in Conventional Cutting

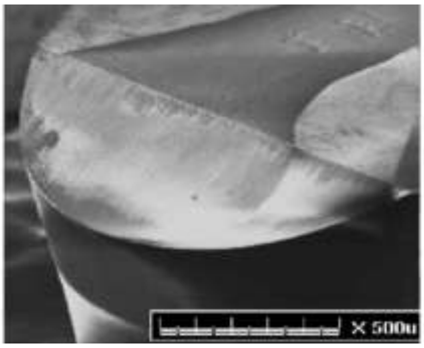


Fig.6 Tool wear in Ultrasonic Vibration Cutting

The investigation is made which shows that machining parameter such as type and concentration of abrasive particles feed rate and grit size is more effective while the finishing of glass-ceramics work surface. High of abrasive concentration wood normally result in poor surface finish created. Hence, experimental analysis gives the

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best result the abrasive concentration 5% for 60 microns SiC, 20% for 2 microns SiC, 10% for 5 microns and 33% for 3 microns having grit size of aluminium oxide (FAN Wei-Haw)

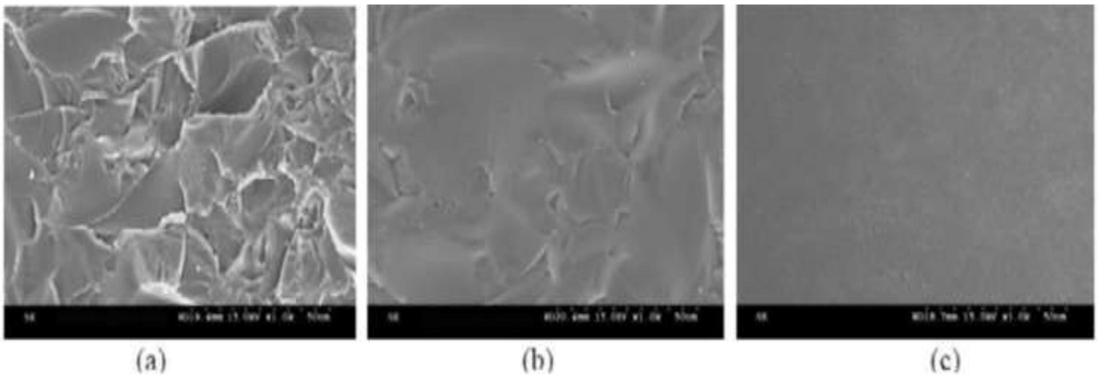
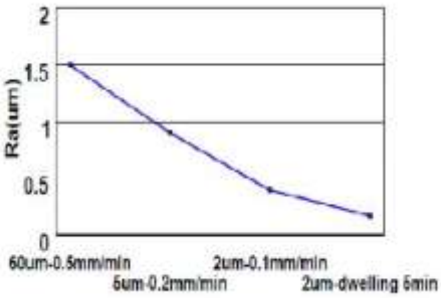


Fig.7 SEM Micrograph of surface using micro USM using

(a)60 micronsSiC,abrasive,5% concentration and federate of .5mm/min,(b)2 microns SiC abrasive 20% concentration and feed rate of .1mm/min.(c)2 microns SiC abrasive 20% concentration and dwelling(zero feed. rate) for five minute



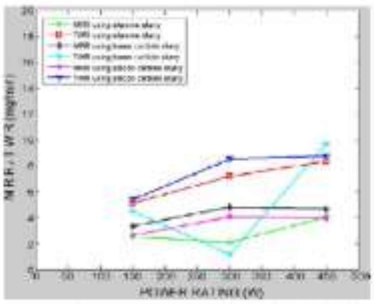


Fig.8 Surface finish (Ra) of the machined surface at different stage Fig.9 MRR and TWR vs. Power Rating using (W/P Titan 31 & tool stainless steel) [14

The experiment was conducted for the drilling holes on three advanced structure ceramics, silicon carbide, zirconia and alumina. In experiment the results got is that the two ceramics good for material removal mechanical for integrity of wall in USM process. The roughness of the wall can only be minimized not fully eliminated. The minimization of this can be done by reducing the grit size of the particles because the crack length is depends on the grit size [13].

It works on titanium and its alloy with three different slurries namely silicon carbide, boron carbide and alumina and works on ultrasonic drilling. Diameter of 5mm is used for hole in pure (titanium) or titanium alloy (31) on USM. The use of 20 KHz piezoelectric transducer with the three solid tools of stainless steel tool which gives the best removal rate and hardness for titanium 31 material [14]. In this for hard and brittle material especially for SiC diamond abrasive particle is used and after investigating this is concluded that first 6 drilling hole times cutting force is maximum. But after some time it force started to decrease. The reason behind this is dulling of diamond grain or weakness of abrasive grain [15].

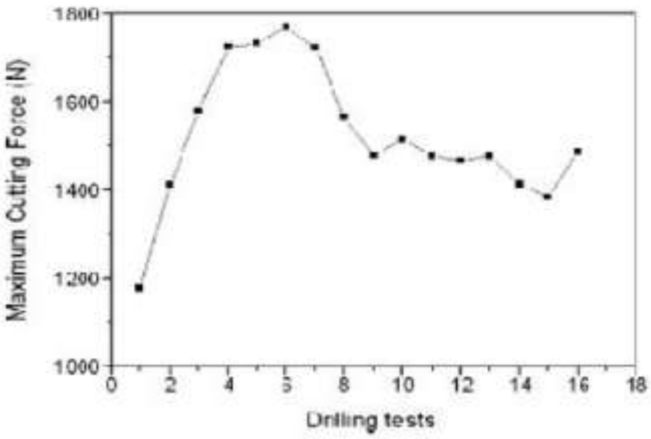


Fig.10 Max. Cutting vs. no. of drilling test [15]

It is investigated that with addition of ceramic composite the hardness of ceramic composites is varied and also by adding the lanthanum phosphate or alumina. In this the alumina used is 70% and 30% of lanthanum phosphate for the best result regarding hardness. By non-linear absorbers the vibration of tool can be controlled. Multi-tool is used for saving time and to improve the efficiency [16]. The spindle speed play an important role on cutting force and surface roughness but it is not important for MRR [17]. The vibration of Ultrasonic is assisted EDM (electric discharge machining) with the help of USM having a D.C. power supply, whose positive and negative poles are connected to the work piece and tool electrode. The experimental analysis shows that the MRR can be little more by combination of EDM and USM but there is no change in roughness [18]. In this the investigation is made on the drilling of zirconia ceramics and it was found that MRR increases with the amplitude in a manner of power law. A larger specific load can be beneficial for a finger surface but to avoid rough surface mid-range amplitude should adopted so larger amplitude results in larger tool wear [19].

IV EFFECT OF PROCEE PARAMETER ON MRR AND SURFACE ROUGHNESS

The MRR and surface roughness is affected by the machining parameter [20]. There are five parameter which play an important role to affect MRR i.e. Mean diameter of abrasive grain, frequency of vibration, amplitude of vibration, Volumetric concentration of abrasive particles in slurry and the static feed force as shown in fig.11 [21].It was observed that the edge chipping, commonly observed in RUM of ceramic material, not only posses accurate geometry but also cause an increase in machining cost. The effect of three parameter mainly support length, cutting depth, pretightening load on the max is done by Finite Element Analysis (FEA).von misses stress theory and normal stress theory where the chipping part of ceramics initiates. This shows that if the cutting depth increases the max. Value of the von misses and normal stress increase and the effect of pretightening load are not significant but when the support length increase then both the stress theory starts to decrease [8].

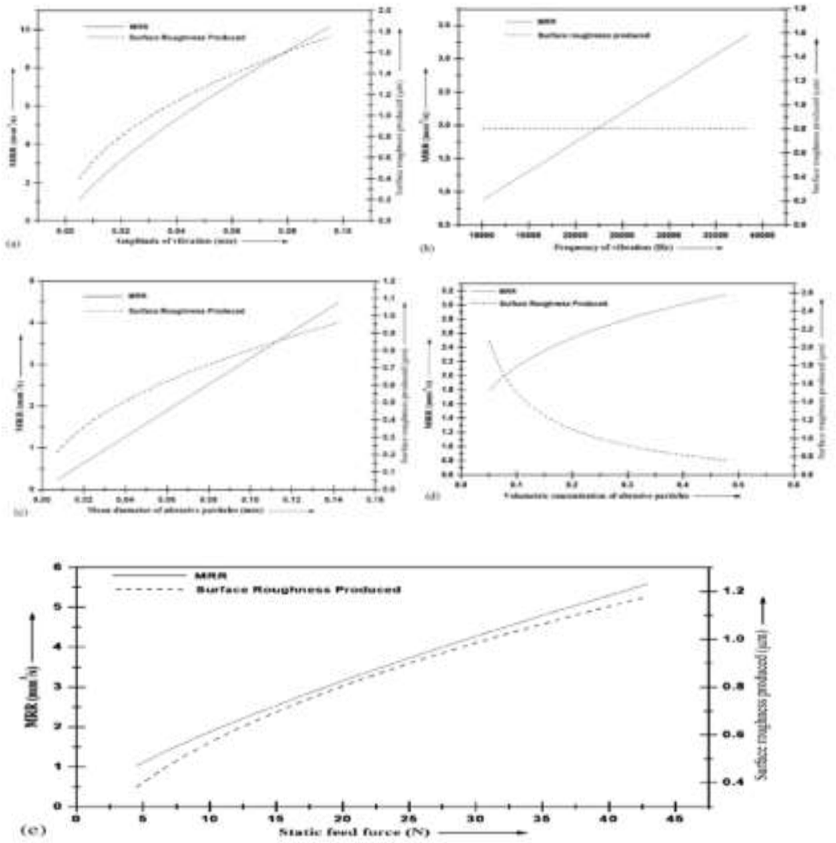


Fig.11 Variation of MRR and Surface roughness constraints with (a) amplitude of vibration (b) frequency of vibration(c) mean dia. Of abrasive particles (d) volumetric concentration of abrasive particles (e) static feed force [21].

It investigates importance of debris on surface roughness and MRR. It also investigated that the abrasive particle is also important factor which influence the surface roughness. It shows that the other machining parameter have no effect on surface roughness. The speed of machining decrease with an increase in the static load beyond a certain level in Fig 12.

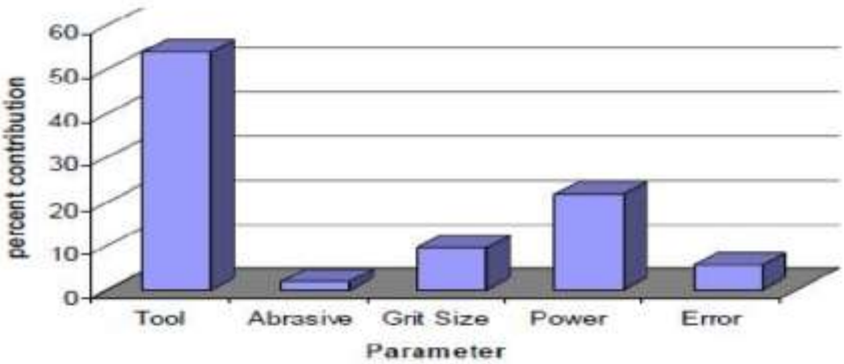


Fig.12 Percent contribution of various factors [17].

It investigate that the rake or clearance angle through the cycle of elliptical vibration cutting for ultrasonic machining is proposed and finally it show that by ultrasonic elliptical vibration cutting the machining accuracy can be improved[22].

V. CONCLUSION

USM is applicable for hard and brittle material above 40 HRC mainly glass, ceramics. The widest use of this material is in aircraft industry, die casting. For maximising the MRR the design of tool and it material play an important role in USM. Rotational ultrasonic machining is the best method for advanced ceramics and the increase in MRR and Machining speed is achieved by the vibration of the tool. The transport medium for the abrasive should shows low viscosity with a high thermal conductivity and sufficient heat for effective cooling.
Water should be the best option to transport media for slurry and hardness of slurry material more than the work piece. Damper or non-linear absorber is used to control the over vibration of ultrasonic tool holder. To increase the MRR for glass material a hydrofluoric acid solution is added in the abrasive particles. Ti alloy shows the lowest tool wear rate as compared to high speed steel, high carbon steel or titanium. If it is used with boron carbide slurry and stainless steel tool it provides better removal rate.

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