Recent Advancements in USMMachining-A Review Paper

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Abstract- The selection of various optimum process parameters is quite crucial for advanced machining processes, as these machining processes have very high initial investment, tooling cost, operating and maintenance costs. In this paper, a review of various process parameters for the machining of different kinds of materials in USM is presented.Ultrasonic machining is an economical and efficient method for the machining of glass or ceramic materials but some materials like super alloys still needsa research because of their numerous applications in various modern industries. Number of machining parameters like Static loading, types of abrasive, slurry concentration, power rate, grit sizeand tool geometry are studied by researchers. It has been found from the research works that the output parameters such as MRR, TWR, micro hardness and Surface finish in ultrasonic machining are highly influenced by the above machining process parameters. So, the objective of this study is to find the optimum value of various machining parameters liketypes of abrasive, slurry concentration, power rate, grit size during machining.

Keywords— Ultrasonic machining, TWR, MRR, Grit size, Abrasives.

I. INTRODUCTION

Ultrasonic machining is mechanical energy base non-traditional manufacturing process. In this process material is generally removed by erosion action when the grid loaded slurry circulates between workpiece and tool. The tool of desired shape vibrates perpendicular to work piece. The frequency of vibration is about 20 kHz with an amplitude of around 15 – 50 µm. In this machining process abrasive slurry freely flows between the workpiece and tool. It is different from other machining process because the amount of heat produced during this process is very less and it does not have any kind of thermally damage to the workpiece. The tool never contacts the workpiece that is why this process is used for machining hard and brittle materials.In ultrasonic, the frequencies of vibrations are greater than about 20 kilohertz which are greater than the audible range for humans. The ultrasonic vibrations lie beyond the 1500 hertz. The term sonic is used ultra sound waves which are of very high amplitude. There are mostly two types of waves, mainly longitudinal waves and shear waves. Longitudinal waves are mostly used because these waves can easily generate. These waves can travel in solids, liquids and gases and can travel at a high velocity so that their wavelength is short in most media.

II. RECENT ADVANCEMENTS IN USM

Soundararajan et al. [1] investigated the basic mechanism involved in the ultrasonic process. The study showed that the material removal for non-porous material is done by direct hammering of abrasives with the vibrating tool and by high velocity impact of free moving abrasives on the workpiece. In case of hard and brittle materials like glass, it has high material removal rate and surface finish.Lee et al. [2] studied the mechanism of ultrasonic machining of ceramics composites. The study concluded that increase in grit size of abrasive particles, amplitude of tool vibration, static load increases the material removal rate and enhances the surface roughness. Thoe et al. [3] reviewed the whole ultrasonic machining process and found that there is no thermal damage to the work piece and the process is stress and damage free. The tool material used in USM process should have good elastic as well as fatigue strength along with high wear resistance. The slurry should have low viscosity, good wetting properties and high specific heat for efficient cooling. The abrasive particles should be harder than the workpiece. The large size of the abrasive particles and high slurry concentration have high material removal rate. Further study showed that horn and tool design play an important role in material removal rate in USM process.Pei et al. [4] presented model of material removal in rotary ultrasonic machining for ductile materials. The model predicted that increase in tool rotation speed or decrease in number of abrasive particles or decrease in diameter of abrasive particles increases the material removal rate in case of magnesia stabilized zirconium.

Thoe et al. [5] studied combined ultrasonic and electric discharge machining for ceramic coated nickel base alloys and found that by combining ultrasonic process during electric discharge machining process, there is significantly increase in material removal rate and mild steel tool play a significant role during the combined ultrasonic and electric discharge machining process.Geo et al. [6] investigated the influence the cutting conditions of surface microstructure on ultra-thin wall parts during ultrasonic vibration cutting. Following conclusions were drawn from this research (a) in ultrasonic cutting of aluminum alloys with polycrystalline diamond (PCD) tool perform better than cemented carbide tool.(b) use of kerosene oil during ultrasonic machining improve surface roughness.(c) ultrasonic cutting gives better surface finish than any other cutting.(d) vibration ripples on machined surface can reduced by setting the tool tip higher than rotating center of the work piece by the three times of amplitude of ultrasonic vibration.

Jianxin et al. [7] explored surface intensity while cutting of ceramic composites material using different material removal processes such as electro-discharge machining, ultrasonic machining and diamond saw turning. Ultrasonic and diamond saw turning gives better surface quality than electro-discharge machining process.Hu et al. [8] studied the material removal process in rotary ultrasonic machining process (RUSM).The main parameters which affect the material removal rate are static force ,vibrational amplitude, rotating speed, grid size and grid number. Lee et al. [9] studied the micro grooving on glass by using ultrasonic machining with polycrystalline diamond tool and it has been found that better grooved shapes can be machined by using USM process along with formation of small chips during this process.Yan et al. [10] developed a process by combining micro EDM with micro ultrasonic machining for micro drilling of borosilicate glass. The experimental results showed that the diameter variation at the entrance and exit is mainly affected by the vibrational amplitude, slurry concentration and rotational speed of micro tool. For better roundness of micro holes rotational speed is important parameter whereas surface roughness is mainly affected by the size of the abrasive particles.Ichida et al. [11] studied the material removal mechanism in non-contact ultrasonic abrasive machining and the experiments were performed on aluminum alloys using machining fluids mixed with Al_2O_3 in non contact ultrasonic abrasive machining. It was concluded that in non contact ultrasonic machining material was removed not only due to abrasive particles, ultrasonic energy or mechanical removal action but it is only due to chemical action between abrasive particles and the workpiece.

Zeng et al. [12] presented the experimental observation on tool wear while machining with silicon carbide (SiC) using rotary ultrasonic machining, during machining it was observed that tool wear is on the end face much more severe than on the lateral face.Zang et al. [13] used ultrasonic assisted lapping for microstructure hard and brittle materials. This technique was used to drill holes as smaller as 5μm in diameter and larger than 5μm in quartz glass and silicon. Further study showed that ultrasonic assisted lapping process has low tool wear rate, low surface, and relatively good surface finish.Singh et al. [14] investigated ultrasonic machining for tough material like titanium and its alloys. It was concluded that if the workpiece of higher hardness is to be machined it would have more material removal rate (MRR) and surface finish varies directly with size of grid of abrasive particles of alumina slurry. Further it is possible to drill holes in commercially pure titanium and titanium alloys using ultrasonic machining process without causing excessive damage or cracks.

Choi et al. [15] observed that the Chemical-assisted ultrasonic machining process results in increase in material removal rate (MRR) and there is significant improvement in surface finish. Further study concluded that basic limitation of ultrasonic machining can be improved during which by Chemical-assist ultrasonic machining during which a low concentrated hydrofluoric acid is added to alumina slurry.Curodeau et al. [16] used thermoplastic tool during USM process for micro machining. During the micro machining, two modes were observed, one of them was hammering mode for micro machining and other was non-contact mode for micro polishing. It was concluded that the thermoplastic tool can be used for micro machining and micro polishing of steel surface.Nath et al. [17] studied the effect of machining parameters on ultrasonic vibration cutting process, in which tool-work piece contact ratio played a key role during ultrasonic vibration cutting process. The increase in tool vibration amplitude or decrease in

cutting speed results in reduction in tool-work piece contact ratio, which in turns reduces the cutting force and tool wear which results in better surface finish and pro long tool life.
Chen et al. [18] used EDM technique and combine it with ultrasonic machining to study the surface modification of Al-Zn-Mg alloys. During the experimentation, to increase material removal rate, TiC particles were added into the dielectric. The combined effect improved the surface roughness and provides better machining precision and improved its tool wear resistance.Gong et al. [19] conducted experiment to study the mechanism in rotary ultrasonic machining for hard and brittle materials. The study showed that it is better to cut hard and brittle materials with bigger depth of cut and lower feed rate in rotary ultrasonic machining compared with any other cutting process.Liu et al. [20] investigated feasibility study of rotary ultrasonic elliptical machining of carbon fibers reinforced plastics. In rotary ultrasonic elliptical machining, a rotating diamond core drilled ultrasonically vibrated in elliptical pattern and the process does not required coolant. Elliptical vibrational system has been used in which elliptical transducer has been designed and built. Furthermore study concluded that in elliptical separating cutting mechanism could reduce the average cutting forces and torque significantly. Rotary ultrasonic elliptical mechanism washes away the chips and the remove excess of heat. Moreover this mechanism improves the surface finish around the whole edges.
Ding et al. [21] studied the performance of polycrystalline Al 6061 T6 using single crystalline diamond micro-tools during ultrasonic machining process. Parameters such as cutting forces, surface finish and chip formation were observed during the machining of Al 6061 T6. The constant cutting force, better surface finish and small burr size can be maintained by applying the ultrasonic vibration on the tool tip. Cracks and voids can also be reduced by applying the same vibration on the tool tip.Singh et al. [22] studied the effect of ultrasonic machining on hard or brittle materials and parameters which affect the material removal rate and surface roughness. More over study showed the water is the best medium to transport slurry and slurry material should be harder than the work piece. Further it states that Ti alloy has lowest tool wear rate than high speed steel or high carbon steel. Boron carbide slurry and stainless steel tool provide better material removal rate.Dongxi et al. [23] tried to reduce the vibrational effects of cutting forces on rotary ultrasonic machining of BK7 glass. From the experimentation it is found the superimposing the ultrasonic vibration led to incipient the cracks nucleated the abrasive loading phase and the crack propagation leads to increase the material removal rate. Moreover to reduce cutting forces and shielding effects diamond tool was used which also reduces the wear rate of tool. Furthermore nucleation of incipient cracks resulted in more dissipation of energy when the abrasive penetrate into the hard substrate of material which would lead to develop higher residual stresses and lead to increase surface finish.Beak et al. [24] performed experimentation to enhancement the surface quality of glass in ultrasonic machining by sacrificing coating. The wax coating is deposited on the glass so that cracks developed on the wax surface rather than on the glass surface. Wax coating protects the formation of large crack size on the surface of glass and out of roundness of crack can be unavoidable. Therefore wax coating method gives better surface finish for hard and brittle materials.Egashira et al. [25] conducted experiment on drilling of holes below 10 µm in diameter using ultrasonic grinding. It was designed in order to reduce cutting forces and to prevent breakage of tool. Ultrasonic grinding was employed with the work piece ultrasonically oscillated.

III. CONCLUSION

USM machining process is purely and entirely depends upon tool properties (hardness, impact strength and finish), abrasive properties (hardness, grit size, coarseness and viscosity), work material properties like hardness and fracture toughness, and process settings (power input, static load, amplitude and frequency of vibration). The success in terms of MRR and Surface roughness purely depends on the selection of machining parameters. Hence, proper and optimum selection of various process parameters plays a vital role in ensuring the product quality, reducing the machining cost, enhancing productivity. The machining of materials such as Glass, ceramics, Tungsten carbide etc. by the conventional methods is extremely tough and generally not possible. To overcome such kind of problems USM can be utilized. Some others materials like titanium, titanium alloys and other tougher and harder materials such as nickel alloys, polycrystalline diamond compact etc.can also be machined with the help of USM for their wide application in the various industries.Study also shows that Ultrasonic and diamond saw turning gives better surface quality than electro-discharge machining process while cutting of ceramic composites material.

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