Parametric optimization of PTFE using Ultrasonic Machining - A review

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Abstract **- The objective Of Study to develop an 'Experimental Set-up' of the process that can be used for a better understanding of the process. The effect of 'parameters' on machining performances can be studied and determined. The effect of parameters on the process can be studied that can be useful for various analysis. The factors affecting USM performance are pressure, amplitude, and variation in thickness of PTFE sheets are found from review & the effect of same is to be experimentally investigated on Material removal rate, overcut, and Taper.**

IndexTerms **- PTFE, USM, Ultrasonic Machining, MRR, Taper, Overcut, Pressure, Amplitude, Ultrasonic Drilling**

I. INTRODUCTION

Ultrasonic machining (USM) is the removal of material by the abrading action of grit – loaded liquid slurry circulating between the work-piece & tool vibrating perpendicular to the workface at a frequency above the audible range. In USM abrasive slurry freely flows between the work-piece & vibrating tool. The tool never contacts the work-piece 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.

The working process of an ultrasonic machine is performed when its tool interacts with the Work-piece 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.

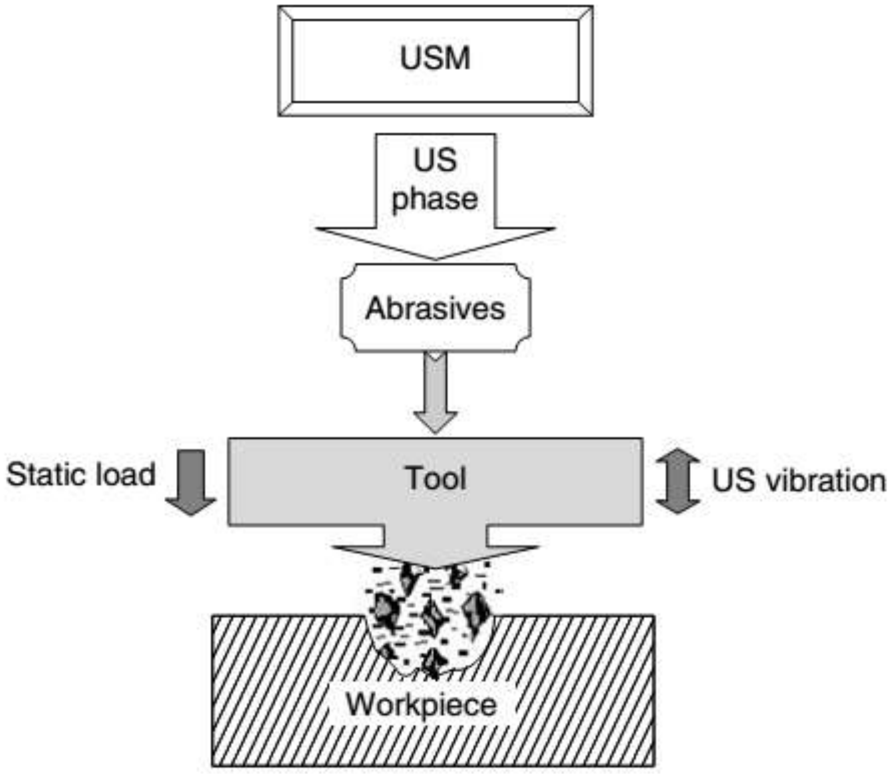

Fig. 1.1 Mechanism of material removal of USM [22]

II. MECHANISM OF MATERIAL REMOVAL FOR USM:

As the tool vibrates abrasive particle indents the work material. During indentation, due to hertzian contact stresses cracks would develop just below the contact site and as the indentation goes on, cracks would propagate due to increase in hertzian stresses thus leading to brittle fracture of work material under each interaction between abrasive grit and work piece.

In ultrasonic machining, tool of desired shape vibrates at ultrasonic frequency (19-25 kHz) with amplitude of 15-50 Microns over work-piece. In Ultrasonic machining material removal is due to crack initiation, propagation and brittle fracture of material. USM is used for machining hard and brittle materials, which are poor conductors of electricity and thus cannot be processed by (ECM) or (EDM).

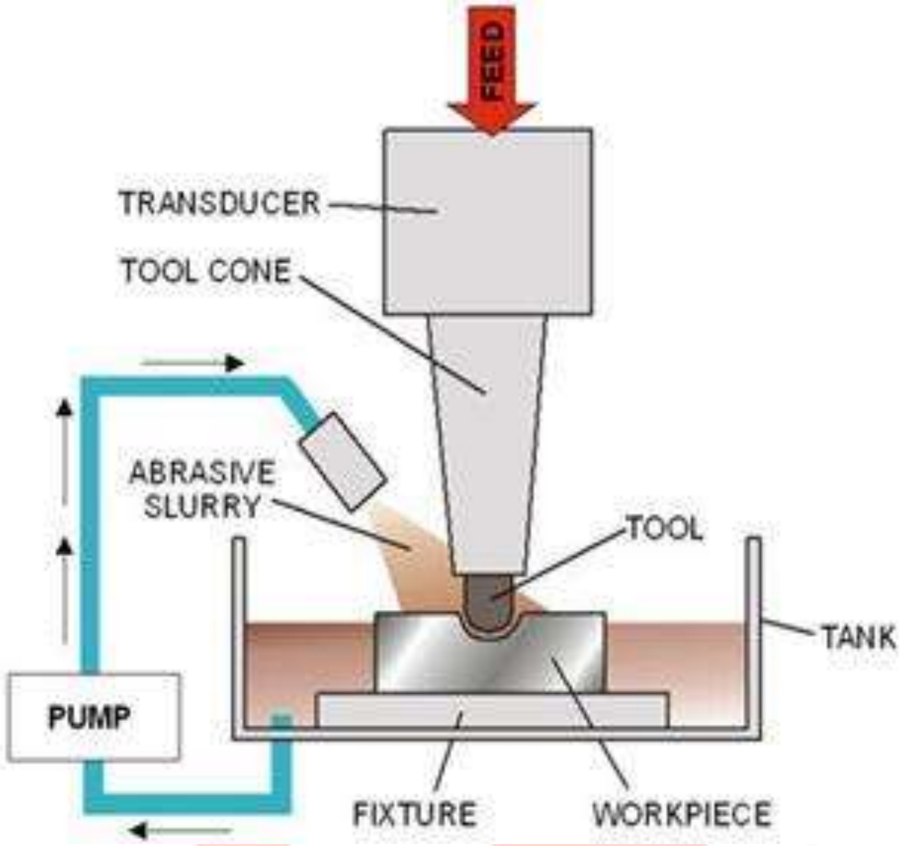

Fig. 1.2 Principle of USM [21]

III. LITERATURE REVIEW

Various researchers are working on laser cutting process to cut various materials. They are working on various parameters.

T.B.Thoe et. al. [1] highlighted that the Ultrasonic machining is of particular interest for the cutting of non-conductive, brittle work piece materials such as ceramics. Unlike other non-traditional process such as laser beam and electrical discharge machining, etc., ultrasonic machining does not thermally damage the work piece or appear to introduce significant levels of residual stress, which is important for the survival of brittle materials service. The fundamental principles of ultrasonic machining, the material removal mechanisms involved and the effect of operating parameters on material removal rate, tool wear rate and work piece accuracy were reviewed, with particular emphasis on the machining of engineering ceramics. The problems of producing complex 3-D shapes in ceramics were outlined.

Wang et al. [2] discussed fundamental principles of ultrasonic machining, the material removal mechanism and important factors are calculated. They concluded that the average cutting forces in ultrasonic vibration cutting are smaller than those in conventional cutting. They also concluded that Decrease in the cutting speed of the work piece and/or increase in the vibration frequency will result in better surface quality.

Zarepour and Yeo [3] developed a model to predict material removal modes in ductile and brittle material when the brittle material is impacted by single sharp abrasive particle in micro ultrasonic machining process. They predicted the material removal modes for silicon <100> and fused quartz. They studied morphology of the crater formed and observed three modes of material removal namely pure ductile, partially ductile (transition mode) and pure brittle.

Basem M. A. Abdo et. al. [4] investigated that difficult-to-machine materials such as Ti-6Al-4V are very hard, tough, and possessed high impact resistance, their machinability is low and sometimes impossible with traditional machining processes. The results of this work identify that the cutting forces increase significantly with increase in coolant pressure, vibration amplitude, depth of cut and feed rate while decrease with increase in spindle speed.

M. Wiercigroch et al. [5] conducted an experiment and showed that an introduction of high-frequency axial vibration significantly enhances drilling rates compared to the traditional rotary type method. It has been found out that the material removal rate (MRR) as a function of static load has at least one maximum. It is postulated that the main mechanism of the MRR enhancement is associated with high amplitudes of forces generated by impacts. Novel procedures for calculating MRR are proposed, explaining an experimentally observed fall of MRR at higher static loads.

Kang et al. [6] investigated the material removal rate and surface quality of the alumina (Al2O3) which was ultrasonically machined using SiC abrasive under various machining conditions. They investigated that material removal rate increases as the static pressure and slurry concentration increases. They concluded higher material removal rate in case of rectangular sectional profile of the tool as compared to square sectional profile of the tool when tool of same cross-section area are used. They resulted an improved surface roughness of about 0.76 µm when machining was done by using abrasive of mesh number 600.

Chandra Nath and M. Rahman et al. [7] studied the effect of three important parameters: tool vibration frequency, tool vibration amplitude and work-piece cutting speed on ultrasonic vibration cutting (UVC). They concluded UVC method as a suitable technique to achieve high-quality finish surfaces for Inconel 718. They concluded that a minimum Ra value of 0.6 mm and 2.4 mm was achieved with the UVC method CT method respectively. They also concluded that value of TWCR should be kept as low as possible that is by increasing both the tool vibration frequency and amplitude, as well as by decreasing the work-piece cutting speed.

Shrikrushna B. Bhosale et al. [8] reported through experimental investigation and analysis of material removal rate, tool wear rate, and surface roughness in ultrasonic machining of alumina-zirconia ceramic composite (Al2O3 + ZrO2). The experiments were conducted using full factorial DOE method with an orthogonal array. Analysis of results indicates that the amplitude has significant effect on the MRR and surface roughness. An increase in amplitude causes higher MRR and surface roughness. Pure SiC abrasives gave better surface finish, whereas the mixed abrasives produced higher tool wear and MRR.

Muhammad et al. [9] investigated the effect of vibration on cutting forces and temperature levels in a cutting region for various cutting conditions. They concluded that the cutting force increases with the increase in depth of cut. They also concluded an increase of Temperature in the cutting region increases due to increase in the depth of cut and cutting speed, both in CT and UAT.

Tamilselvan, Raguraj [10] presented Optimization of Process Parameters of Drilling in Ti-Tib Composites using Taguchi Technique. Results showed that The Taguchi’s experimental design and Analysis of Variance (ANOVA) techniques have been implemented to understand the effects, contribution, significance and optimal machine settings of process parameters, namely, spindle speed, feed rate, process, and drilling material. Conclusions were made -Thrust force decreased with the increase in spindle speed, increase in spindle speed plays a predominate role in the drastic reduction of overcut.

Jatinder Kumar et. al. [11] conducted experiments to assess the effect of three factors tool material, grit size of the abrasive slurry and power rating of ultrasonic machine on machining characteristics of titanium using full factorial approach for design and analysis of experiments. It has been concluded that titanium is fairly machinable with USM process. Moreover, the surface finish obtained is better than many of the other non-traditional processes. Surface roughness of the machined surface has been found to depend on grit size of the slurry used. Tool material and power rating have negligible effect on surface roughness. Optimum values for surface roughness were obtained with grit size 500 for alumina.

Yasuhiro Kakinuma et al. [12] investigated Ultrafast Feed Drilling of Carbon Fiber-Reinforced Thermoplastics. Demand for through-hole drilling of CFRTPs is increasing. In this study, the machinability in drilling of CFRTPs under various conditions was experimentally analyzed in terms of the material properties, and a feasibility study of ultrafast feed drilling was conducted. The results showed that delamination at the outlet surface can be significantly suppressed during high rotational drilling when the feed rate is set to more than 3000 mm/min. By providing appropriate drilling conditions to prevent polymers in CFRTPs from softening, ultra-fast drilling of CFRTPs was successfully achieved under dry conditions.

V. Baghlani et al. [13] investigated Ultrasonic assisted deep drilling of Inconel 738LC super alloy. Super alloys have a poor machinability and are often drilled using (EDM) methods. However EDM is a time-consuming process and has low surface integrity. Ultrasonic Assisted Drilling (UAD) technology is a modern method of drilling such materials. The effect of ultrasonic vibration amplitude, spindle speed and number of steps to drill each hole on machining force and surface roughness were investigated. The results show that increasing material removal rate makes drilling more difficult and increases forces and surface roughness. An average thrust force of 417N and surface roughness of 1.610µm was obtained.

Komaraiah and Reddy [14] investigated the influence of work material properties such as fracture toughness and hardness on material removal rate in ultrasonic machining of hard and brittle materials. The work-piece materials machined in this investigation were glass, ferrite, porcelain, alumina and tungsten carbide. MRR was reported to decrease with an increase in work material hardness and fracture toughness in almost linear fashion under controlled experimental conditions.

H. Dam et.al. [15] presented that a general survey of the processes that govern the ultrasonic machining of ceramics. The results were based on the drilling of holes in seven different ceramics and the aspects considered were production rate, tool wear, precision and surface quality. For tough materials, a low production rate, a high tool wear, and a low surface roughness were observed. For brittle materials the relationships are reversed; high production rate, low tool wear and high surface roughness. However, it was found also that there were important qualitative differences in the machined surfaces. Tough materials generally give material removal based on plasticity, and there seems to be a greater tendency for dense and non-porous materials to produce surfaces with texture.

Guzzo et al. [16] presented the ultrasonic abrasion of different hard and brittle materials using stationary USM. Results show that machining rate decreased with increase in hardness of the work material. For partially stabilized zirconia, an increase in the fracture toughness was reported because of the martensitic transformations induced by the mechanical stresses acting on the work surface due to repeated impacts of grains.

H. Hocheng et al. [17] carried out experiments on Zirconia ceramic for finding metal removal rate, hole clearance, surface roughness, tool wear rate of the work piece. The result found that the MRR increases with the increase of amplitude of the ultrasonic machine. At constant amplitude, the clearance decreases with applied load. Better surface roughness can be obtained by the 50% range of amplitude. An increase in applied load leads to decrease in hole clearance. And the larger the static load is favorable for a finer surface.

CONCLUSION

From the literature survey, it was found that no one has made attempt Ultrasonic Machining for PTFE (fluoropolymer) which has wide range of application in various industries now a day and also have a bright future as a “Bio-material”. It was also found that Pressure, amplitude & thickness ratio have influences on MRR. Also it was found that ultrasonic machining does not thermally damage the work piece. Study for finding the feasibility of PTFE for ultrasonic machining after developing the Fixture unit & Horn to perform operation.

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