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Research Paper

STUDY OF ULTRASONIC MACHINING WITH WORKPIECE ROTATION OF BOROSILICATE GLASS

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Ultrasonic machining with workpiece rotation is an alternative to further increase the area of application of non-traditional manufacturing. This is a process variant of ultrasonic machining (USM) process. This is a very useful process where machining of hard and brittle material becomes very difficult or in some cases it is impossible to machine these materials by conventional methods. Selection of parameters has been done for achieving the better results (Metal Removal Rate (MRR), Surface Roughness (SR)). Therefore considering all the economic and precision factors, maximization of MRR, minimization of SR criteria's were followed. In this study experiments have been conducted on solid cylindrical Borosilicate glass rod by one-factor-at-a-time approach and output characteristics have been measured and studied.

Keywords: Ultrasonic machining, Borosilicate glass, MRR, SR

INTRODUCTION

A non-traditional machining technique ultrasonic technology (Weller and Haavisto, 1984) has been introduced to enable easier machining of otherwise hard to machine materials, There exist various reports on ultrasonic abrasive machining and slurry drilling (Kremer, 1991). Non-conventional machining is a process where workpiece material hardness or workpiece material fragileness becomes immaterial because of no physical contact between tool and workpiece. This is the major advantage of unconventional machining over conventional machining. Ultrasonic machining (USM) is best suited process for those materials which have the hardness more than 40 HRC (Shaw, 1956) and also the workpiece material may or may not be electrically conductive or material may be fragile also. In this process there is no thermal damage to the workpiece surface during machining (Miller, 1957). Ultrasonic machining has few drawbacks without the rotation of workpiece like limitations of geometries production (grove making on cylindrical parts) and effects on outputs. So by considering these

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problems this study has been conducted. A rotary motion has been given to the workpiece. The mechanism of material removal in this process was erosion caused by abrasive particles. Mechanism of metal removal includes direct hammering of abrasive particles (Shaw, 1956) followed by free impact of free moving abrasive particles (Miller, 1957) then cavitation erosion (Ghosh and Mallik, 1996) and at last some of the materials removed by the chemical reaction between the abrasive slurry and workpiece (Rozenberg and Kazantsev, 1964).

In the present investigation solid cylindrical glass tube was taken as workpiece material and mild steel was the tool material. Tool geometry was circular cross-section. Tool was set above the workpiece at a distance approximately mm. The material was cut or removed by the impact of abrasive particles stricking on the workpiece. These abrasive particles were forced by the vibrating tool on the workpiece. The input parameters which were taken in this study were rotation speed of workpiece, abrasive concentration and power rating. After examining it was found that workpiece rotation had the effective results on glass.

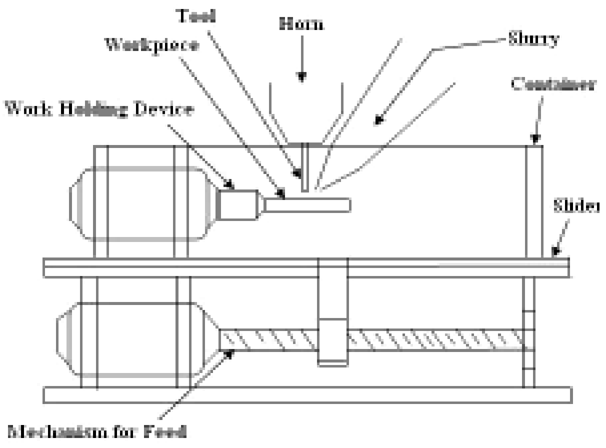
EXPERIMENTAL DETAILS

A set-up was fabricated in house and attached to the ultrasonic machine. Rotation to the workpiece was provided by a dc gear motor and another dc gear motor was to provide linear feed to the workpiece for further machining as shown in Figure 1. A nut and screw mechanism was attached to the shaft of the feeding motor. This nut and screw mechanism converts the rotary motion into linear motion in the form of feed for the upper container in which another motor was fixed. Rotary motion which is necessary for this operation was given to the workpiece by the upper motor. Tool was kept over the workpiece at a distance about. The slurry was coming in between the tool and worpiece and material was removed due to erosion caused by abrasive particles in the slurry. The feed and

Table 1: Machining Conditions for Experimentations

1.	Abrasive used	Silicon carbide (SiC)
2.	Tool material	Mild steel
3.	Frequency of vibration (kHz)	21
4.	Amplitude of vibration (μm)	10-15
5.	Tool Geometry	Circular cross-section
6.	Slurry temperature	Ambient Room Temperature
7.	Slurry Media	Water
8.	Slurry Concentration (volume %)	25, 30, 35
9.	Abrasive Size (mesh number)	220
10.	Power rating (%)	30, 40, 50
11.	Rotation Speed (rpm)	30, 60, 90

Figure 1: Schematic of Setup



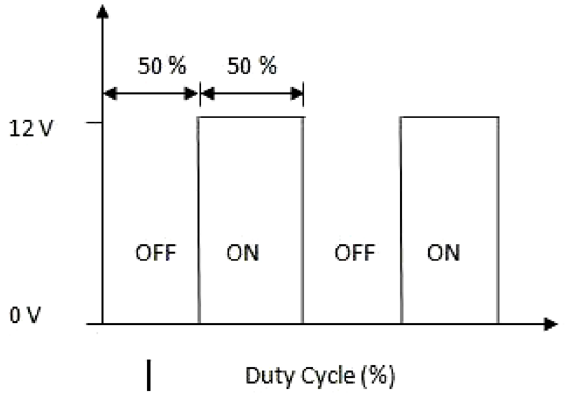
rotation speed was controlled by a circuit known as Pulse-Width Modulation (PWM) circuit. It is an ordinary used technique for controlling power to inertial electrical devices, practical sensible by modern electrical power switches. In this circuit the voltage (and current) feed to the load is controlled by turning the switch load ON and OFF at a fast pace. The longer the switch is ON as compared to the OFF period higher will be the power provided to the load. Here the term duty cycle describes the proportion of ON time to the regular interval or period of time. Occasional duty cycles correspond to low power, as a result of most of the time the power is OFF. Duty cycle is expressed in %, 100% ones it is totally ON.

The main advantage of PWM is that power loss within the switching device is extremely low. Once a switch is OFF it means there is no current, and once it is ON, there is no drop across the switch. Power loss is the product of voltage and current, is therefore in each case near to zero.

Output = (12*50)/100

= 6 Volt.

Figure 2: Duty Cycle



The workpieces were used in this study were borosilicate glass solid cylindrical rod workpieces of diameter 5 mm. Mild steel tools of circular cross-section were used, which were assembled to the threads of the horn.

Figure 3: Tool Used for Pilot Experimentation

RESULTS AND DISCUSSION

Effect of Rotation Speed on MRR

Figure 5 shows that as we increase the speed of rotation of the workpiece from 30 rpm to 60 rpm, MRR is increasing up to this value and after that from 60 rpm to 90 rpm with increase in speed of rotation MRR is decreasing. The reason behind this may be as the rotation speed increases more number of abrasive particles come into contact with the workpiece due to the centrifugal force so in that case MRR will be more but as we further increase the speed of rotation of the wokpiece abrasive particles start to slip instead of striking properly and as a result of that MRR will be less in the case.

Table 2: Parameters

Notification	Parameters		
	Rotation Speed (rpm)	Abrasive Concentration (%)	Power Rating (%)
a	30	25	30
b	60	30	40
c	90	35	50

Figure 4: Workpieces After Experiments

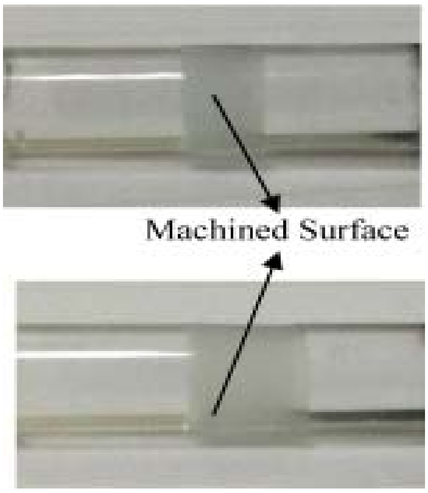
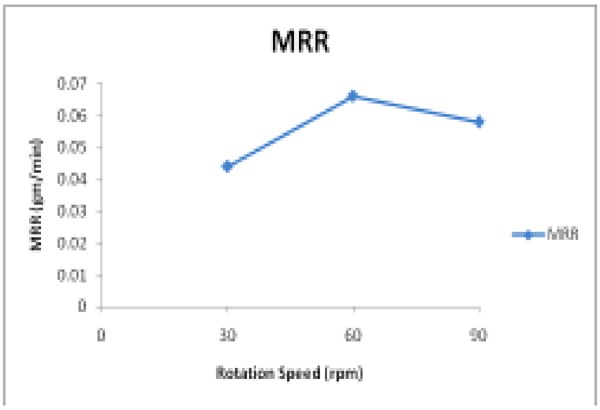


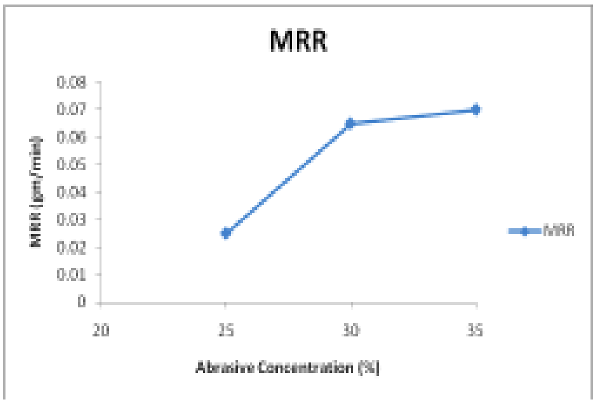
Figure 5: Variation in MRR with Rotation Speed



Effect of Abrasive Concentration on MRR

Figure 6 shows the relationship between MRR and abrasive concentration Figure 6 indicates that as the concentration increases, MRR also increases but from 30% to 35%, the increasing rate is less as compare to 25% to 30% (Ghosh and Mallik, 1996). This is because as the number of abrasive particle increases after a certain value the abrasives start to strike to each other and as a result the hammering action will be less in this case so less material removal take place is this case.

Figure 6: Variation in MRR with Abrasive Concentration (%)



Effect of Power Rating on MRR

Figure 7 shows that as we increase the power rating from 30 to 50%, MRR also increase but the rate of increment was more in the range of 40-50% as compared to 30-40%. This was because in the range of 40-50% there was a good acoustic bond between tool and horn as compared to 30-40%.

Effect of Rotation Speed on Surface Roughness

Figure 8 shows the variation in SR with rotation speed. It shows that as we increase rotation speed from 30 rpm to 90 rpm, surface roughness in decreasing almost with the same

Figure 7: Variation in MRR with Power Rating

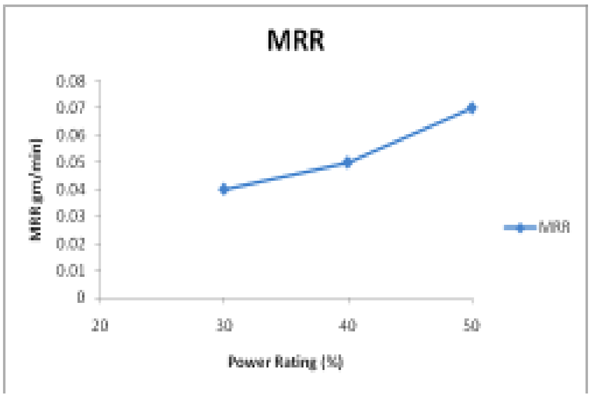
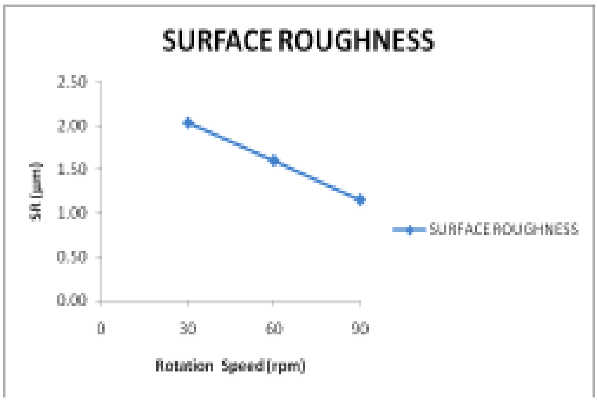


Figure 8: Variation in SR with Rotation Speed

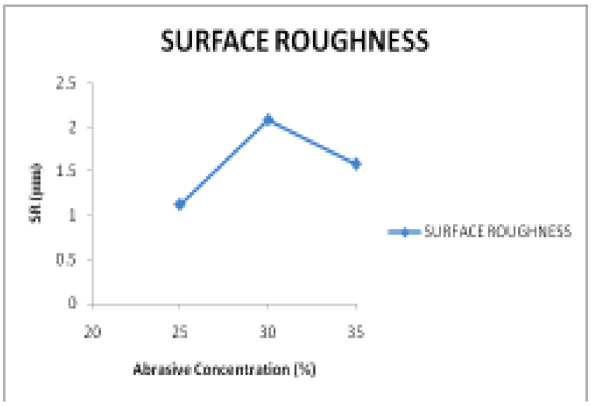


rate. In this case SR is better at 90 rpm. The reason behind this may be that at 90 rpm the less number of abrasive particles were striking on the workpiece as compared to 60 rpm and 30 rpm.

Effect of Abrasive Concentration on Surface Roughness

Figure 9 shows that more abrasive concentration causes more surface roughness. If we compare 20% to 25% concentration with level 25% to 30% then in 2nd case surface roughness is less means surface finish is better this is because as we earlier discussed after a certain value MRR will be less and also surface roughness will be less (Ghosh and Mallik, 1996).

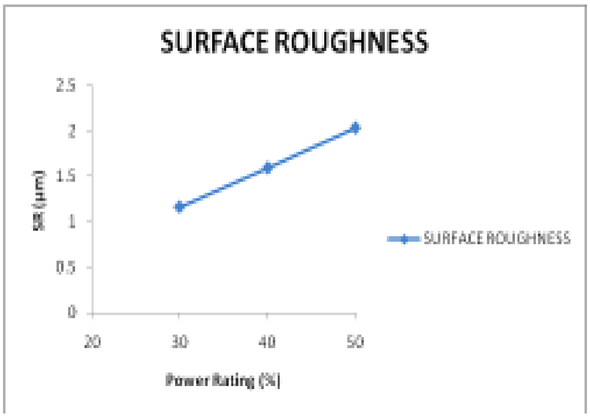
Figure 6: Variation in SR with Abrasive Concentration (%)



Effect of Power Rating on Surface Roughness

Figure 10 shows that when power rating was varied from 30% to 50%, there was an increament in surface roughness. The reason of increased surface roughness is that at high power rating there is good acoustic bonding between the horn and tool so machining is smooth and MRR is high so surface roughness was more (Ghosh and Mallik, 1996).

Figure 10: Variation in SR with Power Rating



CONCLUSION

Based on the experimental results the following can be concluded:

- Workpiece rotation can enhance the area of ultrasonic machining with more geometry formations. We can make groves on cylindrical type of workpieces.
- It can be concluded from the experimental results that increasing the value of rotation speed results increased MRR up to a certain value then it decreases. On the other hand increasing the value of rotation speed results in decreased surface roughness.

- By increasing the value of abrasive concentration MRR first increases and then decreases, surface roughness also increases initially and then decreases.
- It can be concluded that by increasing the value of power rating MRR and surface roughness also increases.

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