

Research Article

Experimental Analysis of Hydrodynamic Polishing Process

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Abstract

Hydrodynamic polishing (HDP) process is a new method for polishing of the hard materials. In HDP, shear stress is used uniquely for removing material. The material removal takes place with hydrodynamic phenomenon and shear stress. The process has proved itself for any hard material and importantly without abrasive action. Lot of researchers has shown ability of the process. In this paper experimental work is presented. Experiments were conducted steel plates with rubber as tool material and alumina as abrasive. Time of polishing and spindle speed is measured and optimum time of polishing and spindle speed is decided. In this paper different parameters and their effect in HDP is also analyzed.

Keywords: Hydrodynamic Polishing Process, Surface Roughness, Aluminum oxide, abrasive slurry

1. Introduction

In hydrodynamic polishing process a constant load is applied on the rubber tool and it is rotated by spindle. This rubber tool is submerged in the pool of abrasive slurry. The tool is placed generally at 90° to the work surface. As the tool rotates at high speed it creates hydrodynamic phenomenon between rubber tool, and workpiece and the abrasive slurry flows through the gap created between rubber tool and workpiece. Due to the pressure difference at entry and exit of slurry at tool-workpiece surface, shear stress field is created (Yaw-Terng su *et al*, 2001).

The efficiency of HDP is measured in reduction of work's surface. In this process material is removed at minute level. Atomic removal is considered in HDP. This process is deterministic and surface irregularities are reduced. With this process, we can get surface finish upto 0.2 nm (Yaw-Treng Su *et al*, 2000).

Generally all polishing process involves use of abrasives including chemical-mechanical polishing (CMP). In polishing by abrasives, the surface irregularities are removed irrespective peak or valley (Tu-Chieh Hung *et al*, 2011).

Generally four parameters determine the HDP process capability. The four parameters are spindle speed, Tool hardness, abrasive particle size and load applied. As the material removal process in HDP is depend upon the shear stress of slurry flow and its distribution. Shear stress and its distribution depend upon the contact area, contact pressure and contact velocity which in turn depends upon the load, spindle

speed, abrasive size and tool hardness (Mrinal Joshi *et al*, 2012)

3. Principle of Operation

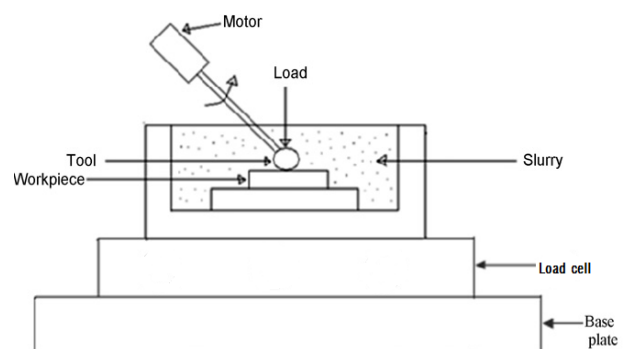


Fig. 1 HDP Mechanism (Hung Tu-Chieh *et al*, 2011)

The conceptual diagram of HDP is shown in figure 1. Slurry of abrasive particles and liquid solvent is prepared and slurry tank is filled completely. The slurry can be used for specific period of time and after some time the abrasive may get settled at the bottom. It is better to circulate the slurry. The workpiece is submerged in the slurry. The tool is placed at 45° to workpiece and it is rotated at a higher speed. The load cell is placed below the workpiece and little load is applied on tool. As the tool rotates slurry starts flowing in between workpiece and tool. The film is established on the tool. The machining rate is depends upon the film thickness and abrasive size (Hung Tu-Chieh *et al*, 2011).

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4. Experimental set up

A DC motor of 12 volt and 3 kg torque is selected and this can give maximum speed of 4500 rpm. The slurry is prepared by using Al_2O_3 and distilled water. Workpiece material used is hardened steel. The hardening is done by quenching process and has hardness upto 60 HRC. A fixture is prepared for holding the workpiece. A rubber tool is used for applying load. Workpiece is placed on a cross slide which can move in X and Y direction both. Tool is directly attached to the motor. Motor is placed on z stages which have z direction movement. Actual set up is shown in figure 2.

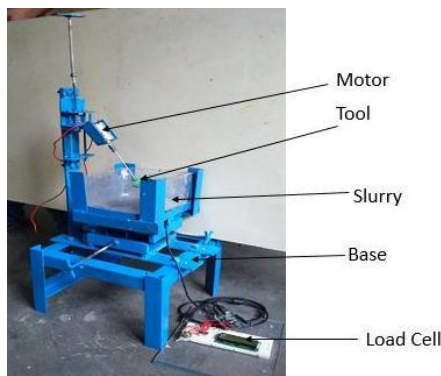


Fig. 2 Experimental set up

In this paper 4 spindle speeds are selected as 1000, 2000, 3000 and 4000 rpm. The tool hardness is kept constant. The abrasive size is also kept constant for the experimentation. Time of polishing is also an important factor in HDP. Time of polishing decides the changeover time from non-abrasive action to abrasive action. Response is measured by surface roughness meter and average surface roughness (Ra) is measured.

5. Result analysis

Three sets of experiments were conducted. First set is conducted to understand the behavior of the process. From the first set it is understood that spindle speed must be higher for good polishing and hence in next sets higher spindle speeds are used.

5.1 Three minutes of polishing

For understanding the process and workability of the same preliminary experiments were conducted. As this are preliminary experiments lower spindle speeds (1000-4000) and lower polishing time (3 min.) is selected. The observations are shown in table 1.

Table 1 surface roughness for 3 min. of polishing

Time (min)	Speed (rpm)	Ra (μm)
3	1000	1.211
	2000	1.006
	3000	0.835
	4000	0.602

The polishing is conducted for 3 minutes only and it is observed that good surface is obtained with it. Polishing is done at a point only. There was no tool movement when machining is in process.

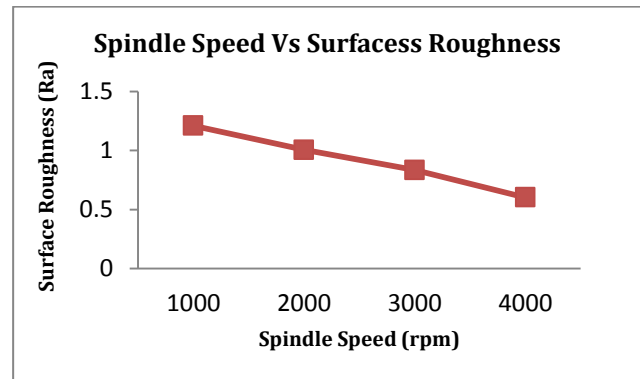


Fig. 3 Graph between Spindle speed and Ra for 3 min. polishing

From the above graph, it is concluded that as we increase the spindle speed, surface roughness value decreases that means polishing would be better. So for the next experiments spindle speed is increased from 1000 to 2000 rpm. In next two sets of polishing are conducted one for 5 minutes and another for 10 minutes.

5.2 Five and ten minutes of polishing

In this experiments the polishing were conducted for 5 minutes. The minimum spindle speed is selected as 2000 rpm. It is found that from preliminary experiments that above spindle speed of 4000 rpm the machine structure starts vibrating and process is difficult to control, so maximum spindle speed is chosen as 4000 rpm.

Table 2 five minutes of polishing

Time (min)	Speed (rpm)	Ra (μm)
5	2000	0.9018
	2500	0.8102
	3000	0.7830
	4000	0.5766

From the above table it is cleared that surface finish is improved from 3 minutes of polishing. Improvement in surface finish may happen due to enough time have been given to the abrasive particles to interact and shear stress generated would be better. So to capture this phenomenon in next set of experiment time of polishing has been increased to 10 minutes.

Table 3 Ten minutes of polishing

Time (min)	Speed (rpm)	Ra (μm)
10	2000	0.8431
	2500	0.7992
	3000	0.7147
	4000	0.5043

From this table, it is clear that for same spindle speed as time is increased from 5 minutes to 10 minutes surface finish is increased.

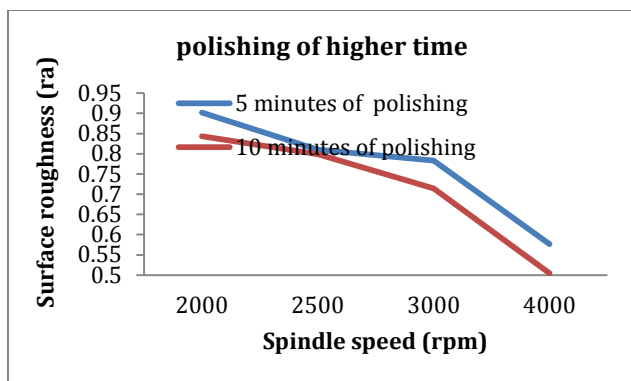


Fig. 4 Polishing of Higher time

Conclusions

From the experimental results, it is concluded that

- 1) Hydrodynamic polishing is a promising method for polishing of hard materials.
- 2) As polishing time increases the surface finish is also increases.
- 3) With increasing Polishing time, surface finish is also increases.
- 4) Best surface finish obtained in this paper is 0.5043 μm with 4000 rpm and 10 minutes of polishing.
- 5) For this machining, precise control is required as little vibration itself causes problems.

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