EXPERIMENTAL INVESTIGATION ON DEVELOPED ONE-WAY ABRASIVE FLOW FINISHING MACHINE WITH PNEUMATIC SYSTEM

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Abstract: *Abrasive Flow Finishing is one of the important non-convectional finishing process which is used to polish, deburr and finish internal surfaces. In this process, burrs or cutting marks are removed by allowing semi-solid, abrasive dispersed putty, with pressure into the workpiece material. In the present work, a prototype of Abrasive Flow Finishing Machine (AFFM) with pneumatic system is developed and used to finish the internal surfaces of the drilled hole on AISI 304 SS material. In this there are two operations are carried out, i.e. drilling and finishing operations by Abrasive Flow Finishing (AFF). First the hole is drilled with 10 mm size on the workpiece by varying speed and feed as input parameters followed by AFF operation with a pressure of 5 bar by using silicon carbide as abrasive with an abrasive mesh size (80 & 220) and number of cycles (5 & 10) considered as input parameters. The output responses for drilling and AFF operations are considered as initial surface roughness and final surface roughness. From the experiments, it is observed that abrasive mesh size and the number of cycles are playing a significant role in the AFF operation and to improve surface finish from 30 to 40% with minimum pressure of 5 bar by using pneumatic system.*

Keywords: *Abrasive Flow Finishing, Pneumatic Circuit, Silicon Carbide Abrasive Slurry, AISI 304 SS and Surface Finish.*

1. INTRODUCTION

Smart engineering materials namely, ceramics, polymers, composites, super-alloys, etc. are developed because of the advancement of the Material Science. These materials have large uses in the modern manufacturing industries such as aircraft, automobiles, cutting tools, dies and mould manufacturing industries [6]. Machining of those materials are difficult and costly besides the good tolerances which are important in the modern era. Precision machining consists of micro or nano levels with narrow tolerances inside the holes with complex and complicated shapes and / or sizes leads to the development of new advanced non-conventional machining processes. To counter the problems such as high direct labour cost and to produce finished precision parts with specific features for finishing inaccessible areas, abrasive finishing techniques are developed. Abrasive Flow Machining (AFM) is a modern finishing operation. Abrasive flow machining is also known as extrusion honing and “no-tool” precision finishing operation. This process can be applied to an impressive range of finishing operations that provide uniform, repeatable, predictable results. In this process, the small quantities of work material are removed by flowing semi solid, abrasive disbursed putty, under pressure through or across workpiece material. The carrier media containing abrasive particles is called as “Self-Deformable stone” [7]. The basic principle of one-way abrasive flow machining as shown in Fig. 1.

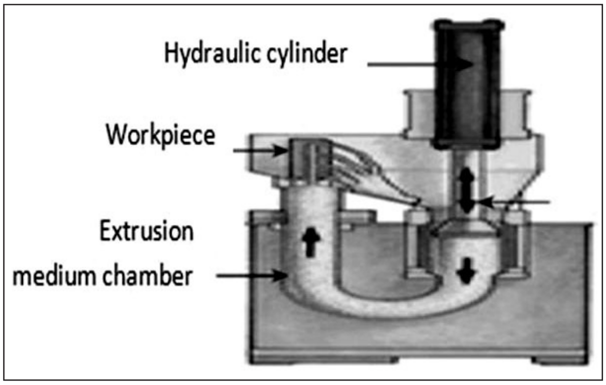

Fig 1. One-way Abrasive Flow Machining

Rhoades, [1], studied the basic principle of AFM and delineated that the depth of cut primarily depends on extrusion pressure, abrasive grain size, relative hardness and sharpness. The axial forces in AFM are highly subjected to the behavior of the AFM medium. The flow pattern of the abrasive medium depends on the characteristics of the applied medium, machining parameters, as well as the shape of the workpiece. Somashkar, et al. [3], investigated on machining of the aerospace precision component " Nitralloy Coller Sleeve" using developed Two - Way AFFM. In this paper some of the results obtained while performing the investigation on machining of intricate profiles and inaccessible areas in the workpiece finishing efficiently and effectively. A marginal improvement in the surface texture is found in the beyond 6^{th} pass. Gururaja, et al. [5], investigated on machining of Aluminum and Mild steel nozzles using developed One - Way AFFM. Aluminum and Mild steel nozzles are machined with CNC turning machine. Finishing operation is carried out with abrasive flow finishing machine. A significant surface improvement is found in the R_a after 12 AFM cycles.

In this paper, the experimental setup of Abrasive Flow Finishing Machine (AFFM) with pneumatic system is developed for finishing of drilled holes using silicon carbide abrasive slurry on AISI 304 SS material.

2. EXPERIMENTAL SETUP OF AFFM

In the present work abrasive flow finishing machine is developed with pneumatic system. Pneumatics systems are powered by compressed air and are nonhazardous to our environment and it is abundantly available in nature. Hydraulic systems are generally more difficult to operate compared to the pneumatics. Fig. 2 shows the developed prototype of Abrasive Flow Finishing Machine (AFFM) setup consisting of FRL Unit, Flow Control Valve, 5/2 Directional Control Valve, Double Acting Pneumatic and Abrasive Slurry Cylinders. The two cylinders are connected to the flexible coupling. Compressed air (6 bar) is used to drive the pneumatic cylinder. Regulate the pressure upto 5 bar in FRL unit. The pneumatic cylinder is actuated with the help of 5/2 manual directional control valve. To control the linear motion of the connecting rod, flow control valve is used. Pneumatic cylinder is actuated with 5 bar observed in the pressure gauge and located in between the pneumatic cylinder and 5/2 directional control valve. Silencers are inserted

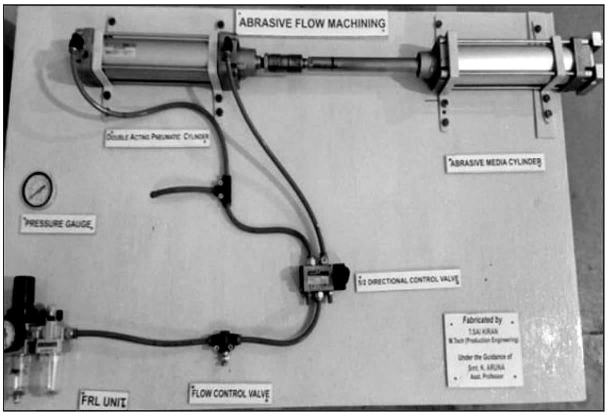

Fig 2. Abrasive Flow Finishing Machine Setup

in to the exhaust ports to avoid noise of air in the pneumatic system. The linear motion of the pneumatic cylinder of the connecting rod are given by the compressed air to push the slurry media present in the abrasive slurry cylinder through the workpiece that has to be machined.The travel of slurry from slurry cylinder to slurry tank and this action is called one cycle. Time required to completing one cycle found being 10 seconds. After finishing the workpieces with required number of cycles, they are cleaned with acetone and then measure the surface roughness in "Mitutoyo surftest 201-P series". The care should be taken to measure the surface roughness values for every 5^{th} and 10^{th} cycles.

3. EXPERIMENTATION

In the present study, there are two operations are carried out, i.e. drilling and finishing operations by Abrasive Flow Finishing (AFF). First the hole is drilled with 10 mm size on the workpiece by varying speed and feed as input parameters followed by AFF operation with a pressure of 5 bar by using silicon carbide as abrasive with an abrasive mesh size (80 & 220) and number of cycles (5 & 10) considered as input parameters. Average Roughness (R_a), Ten-point mean Roughness (R_z) and Root Mean Square Roughness (R_q) are measured. Table 1 & Table 2 shows the machining conditions and control parameters of drilling and AFFM operations and their levels.

Based on the machining conditions and control parameters of drilling and AFFM operations, the finishing operation is conducted on drilled hole of AISI 304 SS workpiece in order to improve surface finish of an internal surface of the hole. In Table 3 shows the 1^{st} row shows the surface roughness values of drilled hole at Speed-100 and Feed-0.15 and 2^{nd} & 3^{rd} rows shows the surface

Table 1: Machining Conditions and Control Parameters of Drilling Operation

Machining conditions		
Depth of cut	10 mm	
Workpiece material	AISI 304 SS	
Control parameters	**Levels**	
	1	**2**
Speed (rpm)	100	350
Feed (mm/rev)	0.15	0.2

Table 2: Machining Conditions and Control Parameters with Mesh size-80 using AFFM

Machining Conditions		
Extrusion pressure	5 bar	
Abrasive concentration	30%	
Abrasive type	Silicon carbide	
Stroke length	160 mm	
Force	981.5 N	
Workpiece material	AISI 304 SS	
Control parameters	**Levels**	
Number of cycles	5	10

Table 3: Experimental Data with Response Data for Mesh size-80 on AISI 304 SS

No. of Cycles	Avg. Roughness (R_a) in µm		10-point Mean Roughness (R_z) in µm		Root Mean Square Roughness (R_q) in µm	
After Drilling (0) cycles	1.45	1.75	13.91	10.83	3.54	2.38
	1.19		9.56		1.61	
	2.61		9.03		1.99	
After 5 cycles	1.13	1.29	9.51	7.93	2.94	1.74
	0.85		7.63		1.05	
	1.89		7.02		1.23	
After 10 cycles	0.98	1.12	7.97	6.91	2.59	1.52
	0.72		6.56		0.89	
	1.66		6.2		1.08	

roughness values of after AFF operation.

From Table 3 it is observed that the Average Roughness (R_a) decreased from 1.75 µm to 1.12 µm, 10-point mean Roughness (R_z) decreased from 10.83 µm to 6.91 µm and Root Mean Square Roughness (R_q) decreased from 2.38 µm to 1.52 µm.

Table 4. Experimental Data with Response Data for Mesh size-220 on AISI 304 SS

No. of Cycles	Avg. Roughness (R_a) in µm		10-point Mean Roughness (R_z) in µm		Root Mean Square Roughness (R_q) in µm	
After Drilling (0) cycles	2.12	1.6	12.98	10.06	3.03	2.24
	1.23		8.95		1.98	
	1.45		8.26		1.72	
After 5 cycles	1.92	1.32	10.09	8.32	2.84	1.84
	0.86		7.3		1.25	
	1.18		7.57		1.43	
After 10 cycles	1.59	0.99	8.05	6.19	2.29	1.37
	0.45		4.93		0.78	
	0.93		5.59		1.05	

The finishing operation is conducted on drilled hole in order to improve surface finish of an internal surface of the hole. In Table 4, the 1st row shows the surface roughness values of drilled hole at Speed-350 and Feed-0.2 with AISI 304 SS workpiece. The 2nd and 3rd row shows the surface roughness values of after AFF process.

From Table 4, it is observed that the Average Roughness (R_a) decreased from 1.6 µm to 0.99 µm, Ten-point mean Roughness (R_z) decreased from 10.06 µm to 6.19 µm and Root Mean Square Roughness (R_q) decreased from 2.24 µm to 1.37 µm.

4. RESULT AND DISCUSSIONS

The effects of input parameters on output responses are determined at various levels and the characteristic curves are drawn for no. of cycles Vs Surface roughness, 10-point mean roughness of different mesh sizes 80 & 220.

From Fig. 3 and 4 it is concluded that the increase in Number of cycles, Surface Roughness decreases.

From Fig. 5 and 6 it is concluded that the increase in Abrasive meshes size and Number of cycles, Surface Roughness decreases.

Surface Roughness and surface finish are opposite to each other, these are quantitative parameters.

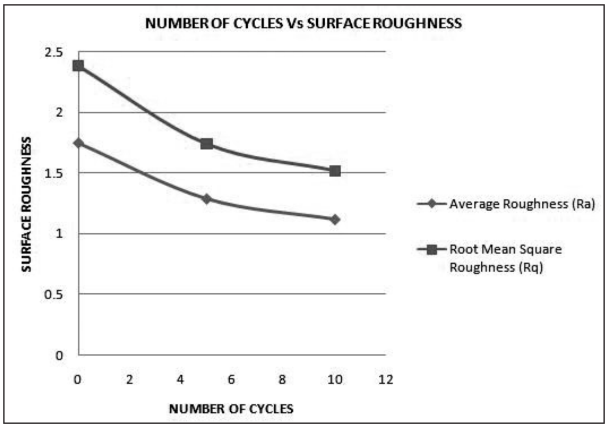

Fig 3. Number of Cycles Vs Surface Roughness using Mesh Size-80

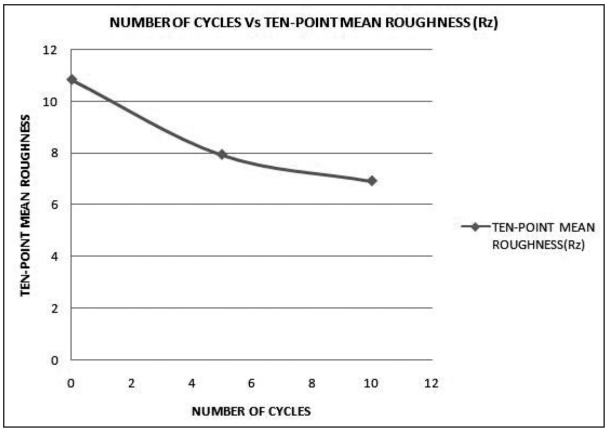

Fig 4. Number of Cycles Vs Ten-point Mean Roughness (Rz) using Mesh size-80

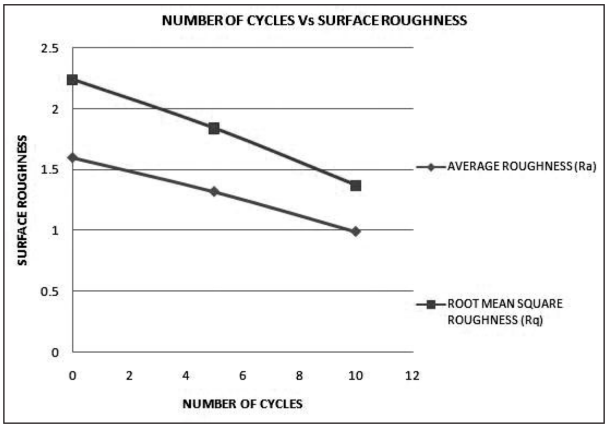

Fig 5. Number of Cycles Vs Surface Roughness using Mesh Size-220

Surface roughness is often expressed in units of length when it's measuring. A measurement of finely spaced deviations of the actual surface within units of length (µm) is the measuring of surface roughness. Lesser the value of surface roughness higher the surface finish is claimed.

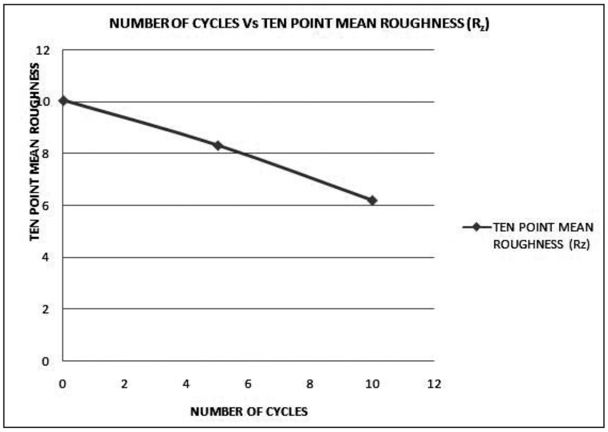

Fig 6. Number of cycles Vs Ten-point mean Roughness (Rz) using Mesh size-220

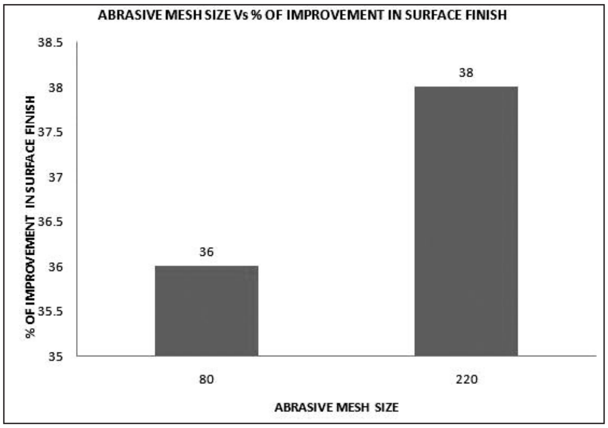

Fig 7. % of Improvement in Surface Finish

Table 5. Percentage of Improvement in Surface Finish

Abrasive Mesh size	Percentage of Improvement In Surface Finish
80	36
220	38

The percentage of improvement in surface finish is calculated below formula

% of improvement in surface finish =

$$\frac{\text{Initial } (R_a) - \text{Final } (R_a)}{\text{Initial } (R_a)} \times 100 \qquad ....(1)$$

In this present work, percentage of improvement can be measured at 10 cycles and corresponding surface finish percentages are shown in Table 5.

From Fig. 7, it is observed that increase in abrasive mesh size leads to increase in percentage of improvement in surface finish.

5. CONCLUSIONS

Based on experimentation, the following conclusions are drawn:

- An indigenous experimental setup of prototype Abrasive Flow Finishing Machine (AFFM) with pneumatic system is developed which is used to perform finishing operation for the internal surfaces.
- In Drilling operation, it is observed hat speed increases, surface roughness decreases and there is no significant effect on surface roughness.
- From the experiment, it is observed that abrasive mesh size and number of cycles are playing significant role in abrasive flow finishing operation related to surface roughness and surface finish.
- The overall results are observed from the AFF process with developed AFFM setup there is a possibility for 30-40% of improvement in the surface finish with minimum pressure i.e. 5 bar by using pneumatic system.

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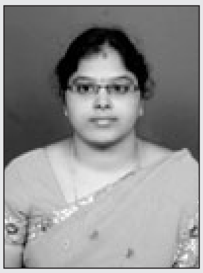

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