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Surface Hardness Study in Hybrid Spark Assisted Abrasive Flow Machining Process

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Abstract : In recent times due to industrial revolution, products with better life cycle and performance are highly demanded. Abrasive Flow Machining is a finishing technique used for the polishing of the complex surface. Although this process provides better surface integrity but even though there is a scope of achieving better surface finish by increasing the material removal. This paper discuss about a newly developed hybrid technique that uses spark energy for melting the workpiece surface and corresponded easy removal of material from the surface. The effect of various parameters (i.e pressure, duty cycle and current intensity) on the micro hardness was also studied.

Keywords: Hybrid Machining, EDM, Abrasive Flow Machining, Microhardness,.

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1. INTRODUCTION

Abrasive Flow Machining (AFM) is a non-traditional nano finishing technique which is used for finishing of complex profiles. This level of finishing cannot be achieved by the conventional techniques because AFM process uses a non conductive viscous media for material removal [1]. This media is a combination of polymer, gel and abrasive particles. AFM process removes the material by abrasion mechanism in which sharp cutting edges of abrasive particles abrades the finishing surface and improves the surface integrity. It provides finishing in the range of 0.05 µm [2]. The leading edge of this process over conventional process is its less time consumption for better surface integrity [3]. This process provides good surface finish but it has a constraint of low material removal. This makes important for the researchers to hybridize this process with other non conventional techniques to take advantage of those techniques in finishing process.

Various types of hybridization is done in the AFM process such as Centrifugal assisted AFM, Rotational AFM, Ultrasonic assisted AFM, Helical AFM, Electrochemical assisted AFM, Magnetic AFM etc. Ravi et. al [4] performed finishing using Electrochemical assisted AFM and observed that voltages was contributing 45.35% towards the material removal. Tzeng et. al [5] finished micro - channel generated by Wire EDM process using self modulating abrasive media and concluded that micro-channel had a recast layer with blow holes which affected its surface quality. Tzeng et. al [6] finished stainless steel (SUS 304) having micro slits and found optimum parameter at 150 µm size of abrasive particle, 50% concentration, 6.7 MPa media extrusion pressure and 30 minutes finishing time.

Wan et. al [7] observed slip line velocity and wall shear stress variation against different pressure and concluded that zero order methodology can be used for less variation in cross-section. Jain and Jain [8] determined active number of abrasive particles involved in the cutting process and found experimentally that active abrasive grain density increases with abrasive mesh size. Gorona et. al [9] proposed a model for the calculation of stress generated on single abrasive grain while removing the material from the surface.

Kenda et. al [10] studied the effect of parameters on the surface roughness and residual stress of the finishing surface for AISI D2 material and observed improvement in surface integrity after finishing by AFM process. Jain et. al [11] concluded that larger media extrusion pressure reduces the surface roughness. Rhoades et. al [12] observed negligible effect of media flow rate on the material removal of the workpiece. AFM process cannot be used for larger surface irregularities because it removes the material in form of micro chips uniformly from the surface [13]. The experimental result showed that while developing the centrifugal force in the media flow path required reduced amount of cycles for removing the same material in case of conventional AFM [14]. Using the centrifugal force in the media flow path increases the dynamic abrasive particles [15]. CFAAFM process gives better surface finish after few numbers of cycles compared to the conventional AFM process [15].

Sushil et. al [16] finished Al/SiC MMCs using AFM process and found extrusion pressure and workpiece material as the most significant parameter. Mali et. al [17] found the abrasive particle mesh size as the significant parameter during the finishing of Al/15 wt.% SiC-MMC.

Marzban et. al [18] developed Abrasive Flow Rotary machining and concluded that applying spin motion along with the workpiece rotation gave better material removal rate. Mohammadian et. al [19] finished SLM- built IN 625 components using Chemical Abrasive Flow Machining and stated that this process can reduce the surface roughness up to 45%. Venkatesh et. al [20] finished bevel gear using Ultrasonic assisted AFM and found that abrasive particles in UAAFM can easily remove the surface material compared to the conventional AFM process. Uhlmann et. al [21] proposed a model and found that media flow velocity and shear rate increases the cutting but this decreased the abrasive holding capacity in the media. Abrasive Flow Machining provides nano level finishing but it has a constraint of low material removal. So many researchers hybridized this process with other process to increase the material removal. This paper discusses about a new hybrid AFM technique which increases the material removal and provides good level of surface integrity.

2. EXPERIMENTAL SET UP

The developed Hybrid AFM technique uses the spark energy for melting the finishing surface material which made the material soft and abrasive particle easily took away the soften material and increased the material removal. The experimental set up includes the pulsed dc power supply for producing the spark, gears, 3-phase induction motor for electrode rotation, fixture for holding the workpiece and guiding the media from one media cylinder to the other.
The figure of developed experimental set up is as shown in figure 1.

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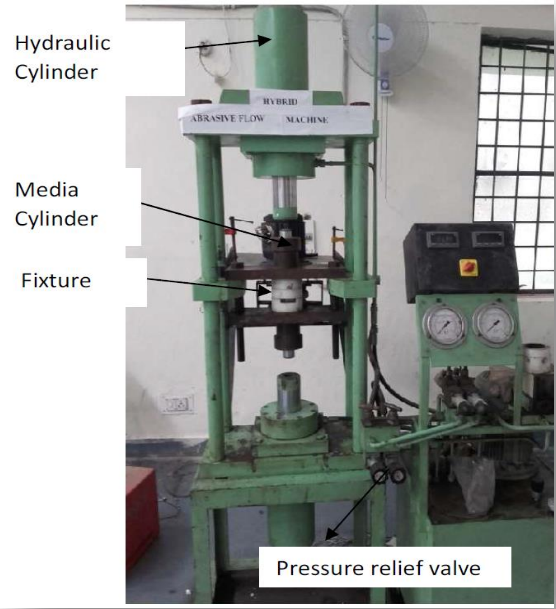

Fig 1 (a) Experimental set up of developed Hybrid AFM process

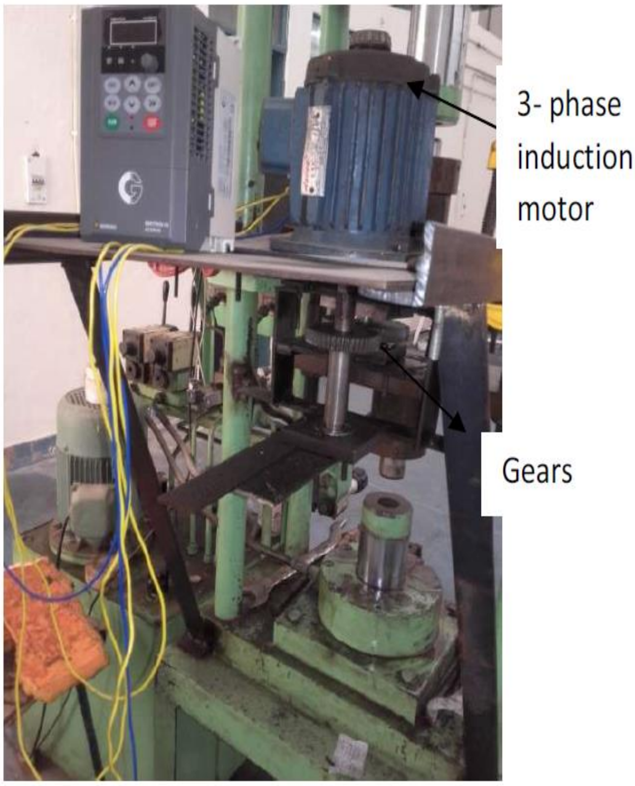

Figure 1 (b) Arrangement of gears and 3- phase induction motor

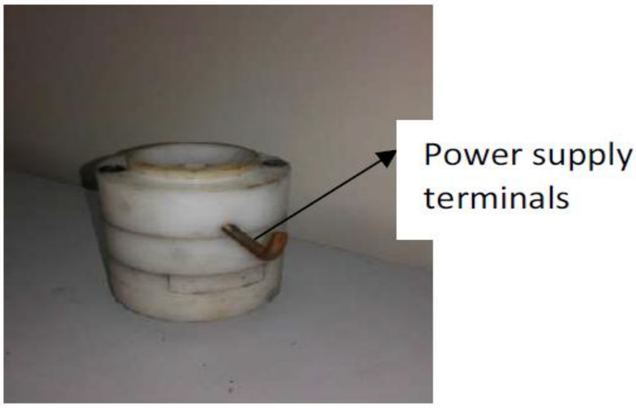

Figure 1(c) Fixture

Fixture includes terminals for the pulsed power supply. It's one pole is connected to the positive supply and other is connected to the negative supply. There should be some disturbance between both the poles with a non conductive environment between them. This non conductive environment is maintained by the media. Electrode should be very near to the workpiece surface for the spark generation. Whenever the electrical supply is given to both the poles electrons will start emitting from the electrode and it ionizes the media molecules. Due to collision more number of ions is being generated and can be seen as a spark. The electrode is rotated for the uniformity of surface through gear arrangement.

2.1 Workpiece

The workpiece material was taken as brass as shown in Figure 2. The geometry of the hollow workpiece is shown in Figure 3.

Fig 2. Brass work pieces

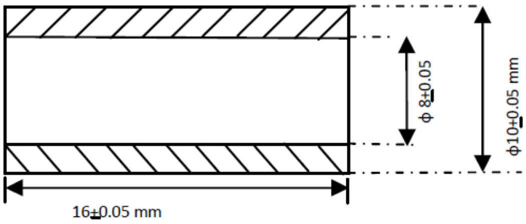

Fig 3. Geometry of the workpiece

2.2 Micro-hardness

Micro hardness testing was performed to determine the resistance of the material against plastic deformation by the penetration of another harder material. Micro hardness tester (FISCHERSCOPE HM2000 S) as shown in fig 4, was used for the measurement of micro- hardness of the surface. This paper discusses the effect of variable parameters such as current , Duty cycle, extrusion pressure on the micro hardness of the work piece.

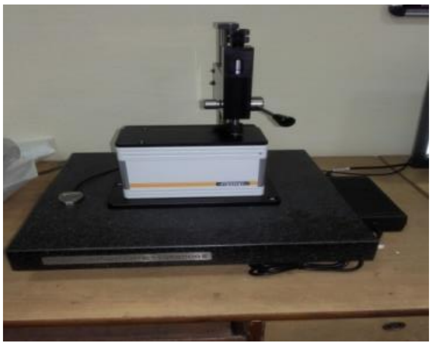

Fig. 4 Micro hardness Tester

3. RESULTS AND DISCUSSION

Effect of extrusion pressure on the micro hardness of the workpiece

The experiments were performed at different values of extrusion pressure i.e 10 MPa, 15 MPa, 20MPa & 25 MPa. The experimental results showed that as the pressure increased micro hardness also increased. On increasing the pressure abrasive particles impact the surface with a larger force and removed more material from the surface which improved the surface quality. These causes increase in the micro hardness of the surface. Graph also shows that after a particular value of extrusion pressure micro hardness decreases. The reason for this may be that on further increasing the pressure, degrades the surface quality which reduces the micro-hardness of the surface.

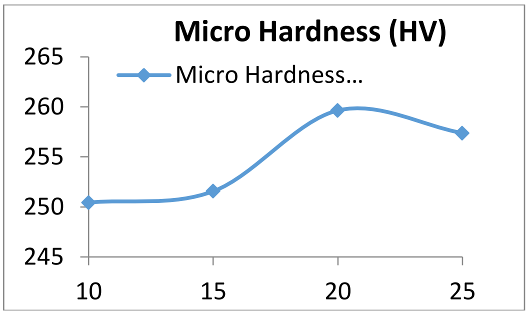

Fig. 5 Graph of Pressure Vs Micro hardness

		HM	EIT/ (1-vs^2)	HV
Mean value	x. :	1744.88 N/mm²	109.10 GPa	207.13
Confid.interval	q :	------ N/mm²	------ GPa	------
Standard. Dev.	s :	------ N/mm²	------ GPa	------
No of Readings	n :	1	1	1
Min. Reading	:	1744.9 N/mm²	109.1 GPa	207.1
Max. Reading	:	1744.9 N/mm²	109.1 GPa	207.1
Range	R :	------ N/mm²	------ GPa	------
Range/%	R/%:	0.00	0.00	0.00

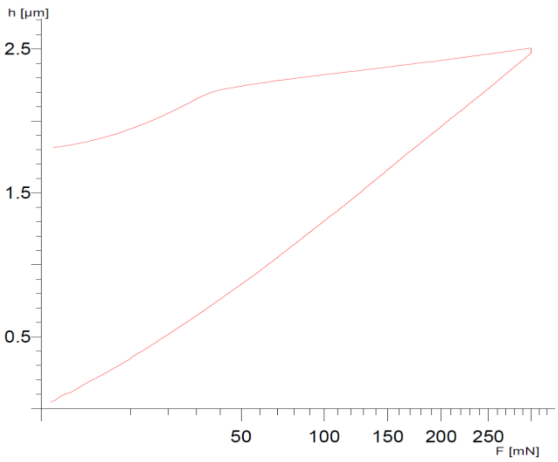

Fig. 6 Micro hardness at duty cycle of 0.63

		HM	EIT/ (1-vs^2)	HV
Mean value	x. :	1942.87 N/mm²	97.30 GPa	238.94
Confid.interval	q :	------ N/mm²	------ GPa	------
Standard. Dev.	s :	------ N/mm²	------ GPa	------
No of Readings	n :	1	1	1
Min. Reading	:	1942.9 N/mm²	97.3 GPa	238.9
Max. Reading	:	1942.9 N/mm²	97.3 GPa	238.9
Range	R :	------ N/mm²	------ GPa	------
Range/%	R/%:	0.00	0.00	0.00

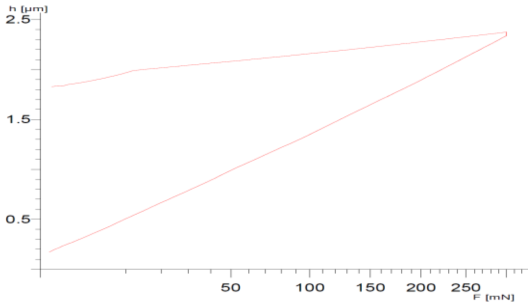

Fig. 7 Micro hardness at duty cycle of 0.68

		HM	EIT/ (1-vs^2)	HV
Mean value	x. :	1974.27 N/mm²	102.25 GPa	239.40
Confid.interval	q :	------ N/mm²	------ GPa	------
Standard. Dev.	s :	------ N/mm²	------ GPa	------
No of Readings	n :	1	1	1
Min. Reading	:	1974.3 N/mm²	102.3 GPa	239.4
Max. Reading	:	1974.3 N/mm²	102.3 GPa	239.4
Range	R :	------ N/mm²	------ GPa	------
Range/%	R/%:	0.00	0.00	0.00

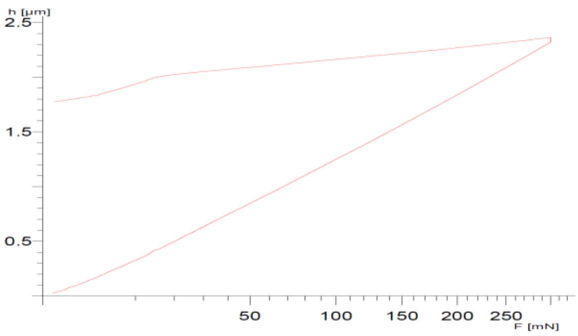

Fig. 8 Micro hardness at duty cycle of 0.73

		HM	EIT/ (1-vs^2)	HV
Mean value	x. :	2235.62 N/mm²	91.73 GPa	288.85
Confid.interval	q :	------ N/mm²	------ GPa	------
Standard. Dev.	s :	------ N/mm²	------ GPa	------
No of Readings	n :	1	1	1
Min. Reading	:	2235.6 N/mm²	91.7 GPa	288.9
Max. Reading	:	2235.6 N/mm²	91.7 GPa	288.9
Range	R :	------ N/mm²	------ GPa	------
Range/%	R/%:	0.00	0.00	0.00

Fig. 9 Micro hardness at duty cycle of 0.78

4. CONCLUSIONS

The following conclusions can be made from the experimental study:

- The developed hybrid process is capable of producing products having better micro hardness.
- With the increase of extrusion pressure micro hardness of the surface increases initially but on further increase in extrusion pressure, micro hardness decreases.
- With increase in the current and duty cycle, micro hardness value increases.

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