Experimental Work on Process Parameters of Hybrid Electric Discharge Machining

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Abstract: Electric discharge machine(EDM) is used for manufacturing purpose. It is used to cut the hard materials in machining by the non-conventional process, to remove the material from work piece by the fusion, ablation and evaporation which caused by the heat energy developed through electric spark when the electric energy supplied on it. It has more advantages on the machining the products such as performance and characteristics. In the present study, to improvement the performance and characteristics like Micro hardness, Material removal rate(MRR), Surface finish and Residual stresses, The Additive gaseous and powder mixed near dry EDM is used. By using this method good surface quality of product is achieved. In this study, it is found that less surface roughness(SR 1.121 μm) when helium gas is combined with graphite powder as a dielectric medium and more material removal rate(3.489mg/min) is obtained by the combining of nitrogen gas with graphite powder as a dielectric medium. And also found the minimum residual stress(RS) is229MPa and largest micro hardness(MH) is 821.32(VHN) which obtained when helium gas is combined with zinc powder as a dielectric medium.

Keywords: EDM; Dielectric powder; inert gas; Micro hardness; MRR; Residual stress.

1. Introduction

EDM(Electrical discharge machine is a non-traditional machining process to cut the material and produce Variety of shapes and sizes of product and several application. There are various other forms of EDM to enhance the machining characteristics such as higher material removal, better quality machined products etc. The Electrical Discharge machine system normally comprises of three main constituents: EDM circuit, Dielectric unit and Servo feed control as shown in Figure 1.The servo control mechanism manages the tool feed. For spark initiation at the gap of machining between the tool electrodes and conductive work piece, the current is generated in pulses by the DC pulse[1]. For the maintenance of the circulation of the dielectric oil, the provided pump is responsible while the pressure gauge maintains the pressure of the dielectric medium.

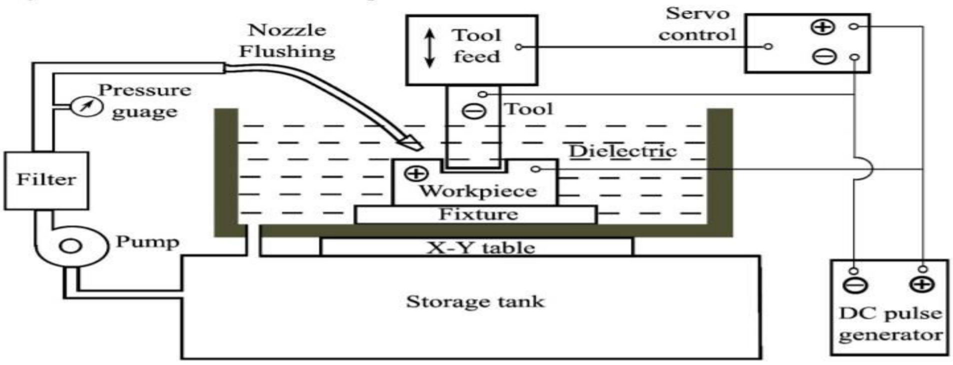


Figure 1. Electric Discharge Machine (Tallaet al. 2017)[3].

Earlier studies reported the effects on performance and characteristics such as MRR, Surface finish, Micro hardness, Tool wear rate, Residual stress etc.
It was stated that although the requirement of toxic fumes bulk quantity of oil are abolished by the dry EDM but debris deposition becomes a major concern which consequently leads to reduction of Material removal rate and also worsensthe machined surfaces accuracy. After performing Electrical discharge machine in gas, it was observed that the tool wear rate (TWR) was negligible by this machining method [9].However it was also noted that very fine glossy surfaces are created by the distribution of spark at the discharge gap when some powders, such as graphite and silicon when mixed with dielectric in EDM. The proper addition of metallic powders to the dielectric fluid leads to the increment in MRR and reduction in Tool wear rate (TWR)[2]. In EDM process Sic and Al powder in dielectric oil are utilized. It was noted that the working gap increases between workpiece and tool when there is an addition of metallic powder. Discrete sparks are generated due to enlarged gap and easily removes the material from the workpiece and therefore leads to large finishing surface[13].Similarly, it wasstudied about the metallic powder in Electrical discharge machine. It was notedthat due to decreasing in strength of insulating then the metallic powder disperse in dielectric medium Electrical discharge machining process oil and lead to the generates of more amount energies andstability in plasma channel which cause higher MRR and spark gap between workpiece which developed a very fine finish surface[12]. Moreover,also studied about the simulated residual stress and experimental value of stress which are obtained by the atomic force microscopy and techniques of Nano-indentation which responsible to find the stress value at the eroded surface which is 300MPa [6].While to increase the tool life of near dry machining as comparison of smaller life time dry machining or machining with dielectric in complete gaseous form. While the Near dry machine was proved good characteristics of product developed such as high quality of machined product which was quite costly produced. And remove the harmful fumes which developed at the machining time[22]. It was studied to improve the material removal rate and better surface finish by the experimentation with powder mixed near dry EDM. Research on machining efficiency of PMND-EDM was done for the different-2 material combination of tool and workpiece electrodes. It was illustrated that W18Cr4V workpiece electrode and brass tool and gain higher MRR[10]. Later it was also studied about the enhancement of the performance and characteristics of machining product such as material removal rate and surface finish by powder mixed near dry EDM is compared with the advantageous of near dry EDM. Research work was conducted on the basis of different combination of workpieceelectrodes and tool powder mixed near dry-EDM. Gas –liquid- powder mixture of three phases was used in PMND-EDM for material removal process and it was noted that MRR higher as compared to EDM different-2 methods of machining[14].
And also performed the experiments for surface finish, tool wear rate and MRR based on the comparatively study between the PMND-EDM and ND-EDM, Non- conventional electrical discharge machining.As a result of the by PMND-EDM process observed lower tool wear rate as the comparison of ND-EDM, Non -conventional electrical discharge machining [11].

The main objective of this work is to improve the characteristics and performance such as material removal rate(MRR), Surface Finish, Micro hardness and Residual stresses.In the present experimental work, to enhance the performance and characteristics of product The Additive gaseous and powder mixed near dry EDM is used. By using this method good surface quality of product is achieved. In this study, it is found that less surface roughness (SR 1.121 μm) when helium gas is combined with graphite powder as a dielectric medium and more material removal rate(3.489mg/min) is obtained by the combining of nitrogen gas with graphite powder as a dielectric medium. And also found the minimum residual stress(RS) is 229MPa and largest micro hardness (MH) is 821.32(VHN) which obtained when helium gas is combined with zinc powder as a dielectric medium.

2. Experimental Setup

The experiments were conducted as per the different-2 conditions for Gas additive powder mixed near dry (GAPMND) EDM. All experiments condition and machine parameters are illustrated in table 1 and 2.
Another setup for gaseous Additive near dry EDM was also developed in order to study the effect of gases (Helium and Nitrogen) in dielectric medium in place of compressed air as shown in Fig.2. Different metallic powders such as Copper, zinc, silicon, graphite and aluminium powder were used as additives in the dielectric medium. Overall, the setup working was similar to PMND-EDM but in this case there were gases different from compressed air.

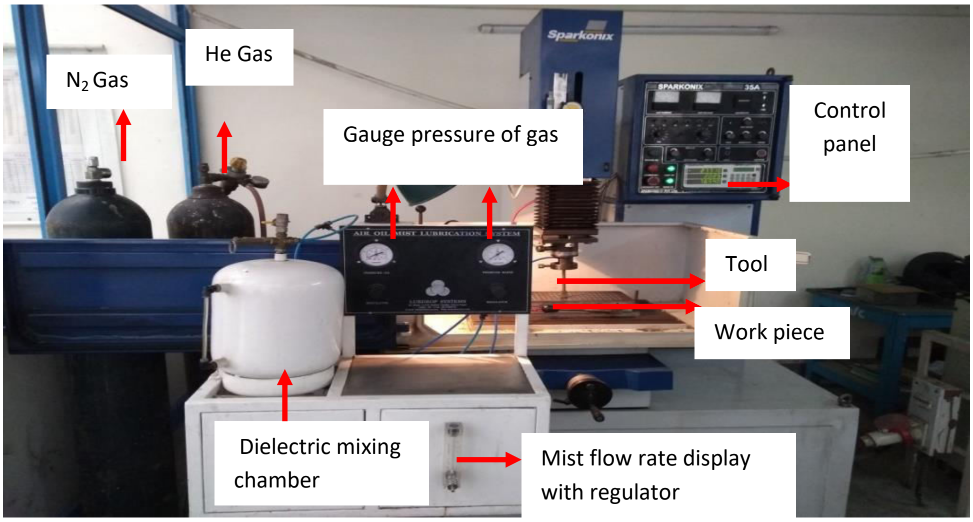


Figure 2.Setup for experimentations (GAPMND-EDM)

The different-2 experiments condition and concentration of dielectric medium issummarized in table 1. Gas additive powder mixed near dry (GPMND) EDM.

Conditions	Dielectric combination
1	Aluminium + Helium
2	Aluminium + Nitrogen
3	Zinc +Helium
4	Zinc + Nitrogen
5	Graphite + Helium
6	Graphite + Nitrogen
Dielectric oil: stabilizing agent: 4-6% glycerol, Powder concentration 8 (g/l) Flow meter of dielectric: 12 ml/min: Air and oil pressure: 0.2 - 0.6MPa, Cylindrical hollow copper rod ($ø_i$ =8mm, $ø_o$= 10mm)	

Table 1. Different-2 conditions of dielectric combination of Experimentation.

Parameters		Classification
1	Work piece	EN-31 (40 x 20 x20) (dimensions in mm)
2	Tool Electrode	Cylindrical hollow copper rod (øi 6 mm, øo8 mm)
3	Dielectric	Helium, O_2 +oil (LL-221)+metallic powder
4	Discharge Current	15A
5	Gap Voltage	30 V
6	Pulse On / Off	550 µs/35µs
7	Polarity	+ve

8	Powder concentration	8 (g/l)
9	Flow meter of dielectric	12 ml/min
10	Air and oil	0.2 – 0.6 MPa
11	pressure gauge	Accuracy: (permissible error 0.05% of span)
12	Powder material	Zinc, Aluminum, Graphite
13	Stabilizing agent	Glycerol (4-6%)

Table 2.Experimental Condition forGas additive powder mixed near dry (GAPMND) EDM

3. Formula Used

1. The results for Material removal rate are determined by the following formula:

$$\text{(Material removal rate)MRR} = (W_i - W_f) / T_m,$$

Where, W_i is the initial weight of work piece, W_f *is*the final weight of the work piece and T_m is time taken by machine to remove material from the work piece.

Weight of the specimen is evaluated by using balance of least count 0.001gram (Asia Techno weigh India).

2. The residual stress is calculated by the following formula

$$\varepsilon_{\square 1} = 1/2\,(\varepsilon_{\square} - \varepsilon_{\pi} + \square) + (\varepsilon_{-\square} - \varepsilon_{\pi-\square})$$
$$\varepsilon_{\square 2} = 1/2(\varepsilon_{\square} - \varepsilon_{\pi+\square}) - (\varepsilon_{-\square} - \varepsilon_{\pi-\square})$$

$$\text{(Residual stress)}\sigma_X = -\frac{E}{1+V} * \frac{1}{SIN2\eta} * \frac{1}{SIN2\varphi 0} * \frac{\partial \varepsilon\alpha 1}{\partial cos\alpha}$$

Where, α = Azimuth angle of debye-sherre ring.

$\varepsilon_{\pi+\square}$ = strain measured in the direction of $\pi + \square$

$\varepsilon_{\square 1}$ = strain measured in the direction of vertical

$\varepsilon_{\square 2}$ = strain measured in the direction of horizontal

σ_X = Residualstress

η = Angle between axis of debye-sherre ring and the sample x-ray detector.

4. Result and Discussions

Analysis for MRR

The experiments were conducted to improve and better the higher erosion rate. So, the helium and nitrogen combine with metallic powder (Aluminium, graphite,Zinc)as dielectric medium which operate at different-2 pressure. The main reason behind this is graphite powder has more thermal conductivity and have lowest density in comparison of Aluminium and zinc combining with gas assisted(nitrogen, helium). Due to lower density and higher conductivity of graphite which lead to constitute grain particles and disperse in dielectric medium and provide better erosion rate in machining. And it can be seen that if mist pressure of dielectric medium is increase then MRR(Material removal rate) is also increased. The gas additive powder mixed near dry Electrical discharge machined samples as shown in Fig 3. It is visualized by experiments with the combination of dielectric medium gases and powder, when graphite powder combined with nitrogen gas as dielectricmixture resulted the higher material removal rate (MRR) is obtained. The achievement of higher MRR, The main reason behind it is that, the combination of nitrogen gas and powders lead to exothermic chemical reaction and responsible for oxidation process and lowest MRR is achieved with combination of Helium gas with powder as dielectric medium [8-9].

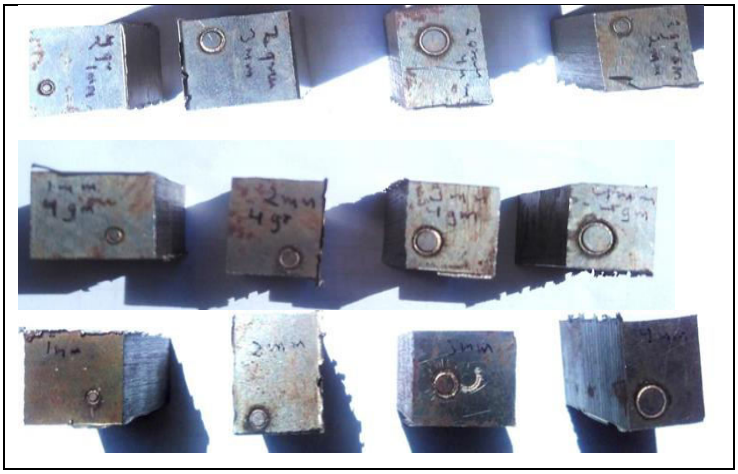


Figure 3. Machined samples(GA-PMND-EDM)

The nitrogen have lower ionization energy as compare to helium and gas has lower ionization energy tend to more ionised, resulted higher removal rate (MRR) (Li et al. 2006). While lowest ionization energy of nitrogen can't kept absolutely liable for larger material removal rate(MRR) in view of the fact that the ratio is consideration of ionization energy , if ionization energy ratio(12.57/15.75 = 0.796) i.e 0.798) was taken into consideration between nitrogen and heliumthat is 0.798. The ratio is not much large as the comparison of higher material removal rate (3.489/0.7= 4.98).

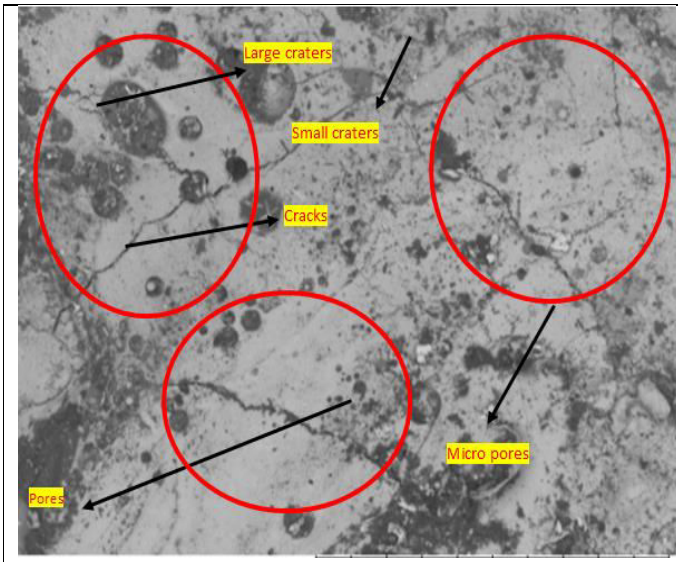


Figure 4(a) SEM image of machined sample (EN-31) by nitrogen additive with powder of graphite

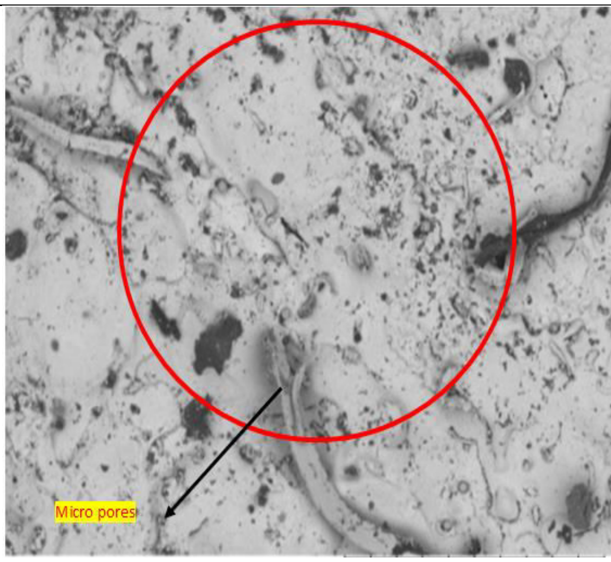


Figure 4(b) SEM image of sample(EN 31) by helium additive with powder of Aluminium

Now according to experimentation conditions 1 and 6 at 0.4 MPa, the electron affinity energy fornitrogen gas is 2.73eV as comparison of helium gas is -1.0 eV. The negative energy of helium atom means that first it has to gain some energy in order to attract the electron. Consequently, as the comparison of nitrogen gas easily ionized and make a efficiently discharge between the gap of machining and a result of higher MRR, the argon gas is not ionized properly and affect the discharge ofspark between the gap of machining [7].
From figure 4(a,c), it can be seen that the large craters, pores and cracks is formed over the machined samples when the nitrogen is additive with graphite and zinc powder and from figure 4(b, d, e), it can be seen that, pits and micro pores is visualized at the machined samples when helium gas is combined with zinc and Aluminium powder due to the lower range of MRR. From figure 4(a), visualized large craters it means the more conductivity and resulted generation of spark over the long distance between the gap of machining. The graphite powder along with nitrogen a the machined samples the largest cavity is formed due to low density and higher electrical conductivity as compared to helium gas combined with zinc and Aluminium powder.

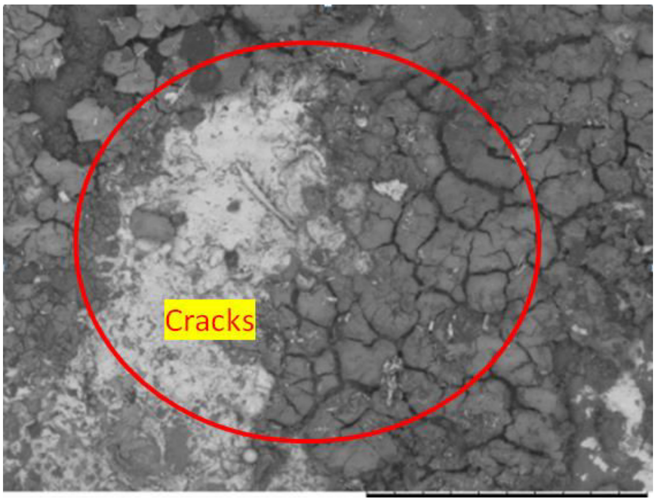


Figure4(c).SEM image of machined sample(EN-31) by nitrogen additive with powder of zinc

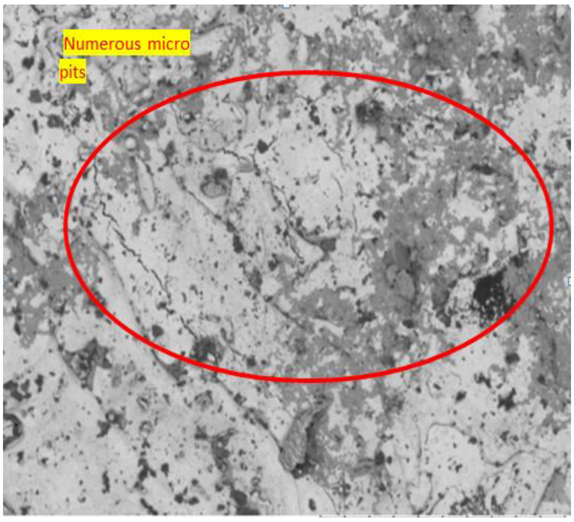


Figure 4(d) SEM image of machined (EN-31) sample by helium added with powder of Aluminium

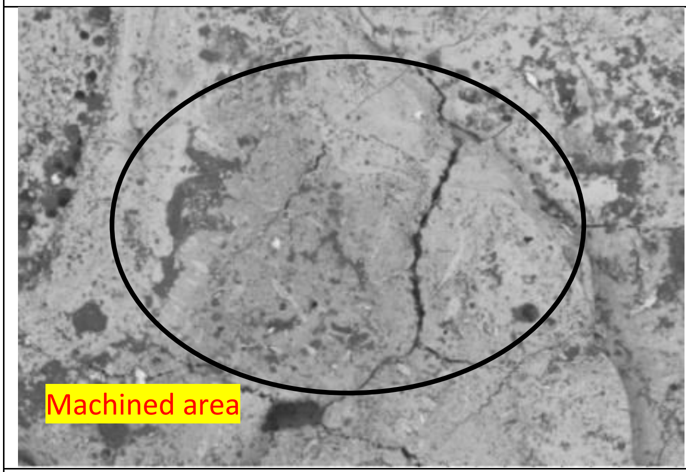


Figure 4 (e) SEM image of machined(EN-31) sample by helium added with powder of zinc

Surface finish

The experimental work and analysis is find out the surface finish by gas additive powder mixed near dry EDM for different-2 experimental conditions as shown in table 1.With the help of tomography machine the surface finish is carried out for machined sample EN-31 by an EDM with gas additive powder mixed near dry method.The surface finish is high by gas additive method as compared to non-traditional electric discharge machining. The surface finish value is (1.121 μm) when dielectric medium graphite powder is mix with the additive helium gas. The properties of graphite are liable for good finish surface. Due to good lubrication and low resistivity the characteristicof graphite as compared to Aluminium,zincdevelop a well microstructure and better effect on the particles of wetting powder by the molten surface of machine. And provide smoothly machined surface[2]as shown in fig 5(a).

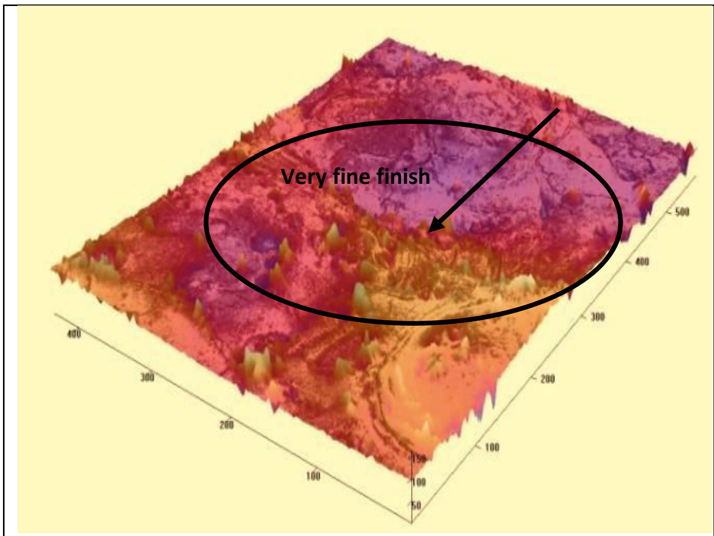


Figure 5 (a) profileof Surface with graphite powder additive helium gas

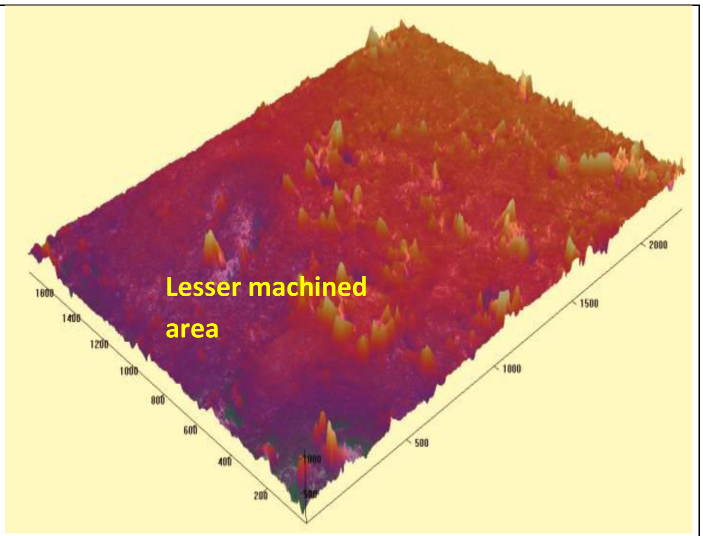


Figure 5 (b)profile of surface with Aluminium powder additive helium gas

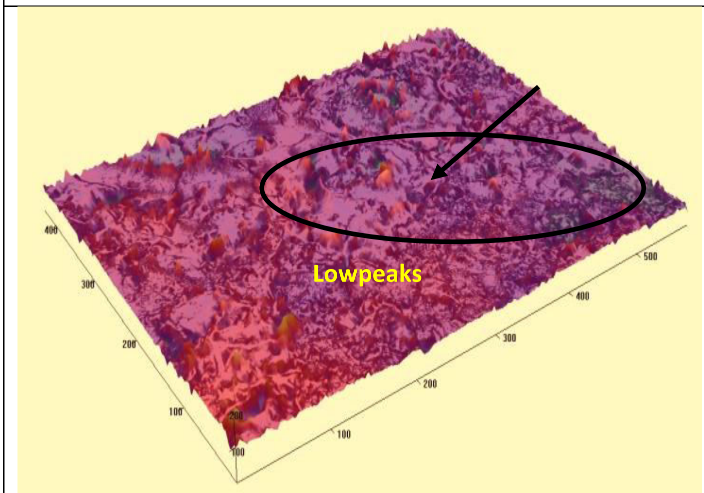


Figure 5 (c) profile of Surface with zinc powder additive helium gas

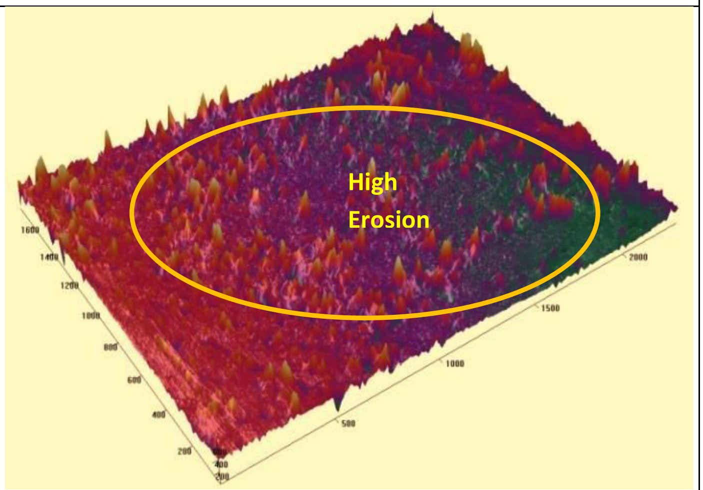


Figure 5 (d) profile of surface with Aluminium powder additive nitrogen gas

The Aluminium and zinc with gas additive give the good surface of finishing but not similar as that of graphite powder. From figure 5 (b, c),It can be seen that the machined sample surface for different-2 powder by the addition of helium gas. It is also seen that can be clearly seen from figure 5(a). Thequite smoother roughness of surfacedue to noble gases for machining. Less oxidation results in stable sparking conditions due to which the arc produced was more uniformly distributed and due to stable spark and large gap between the work piece developed a simplistic over the sample and provide the better machined finished surface.

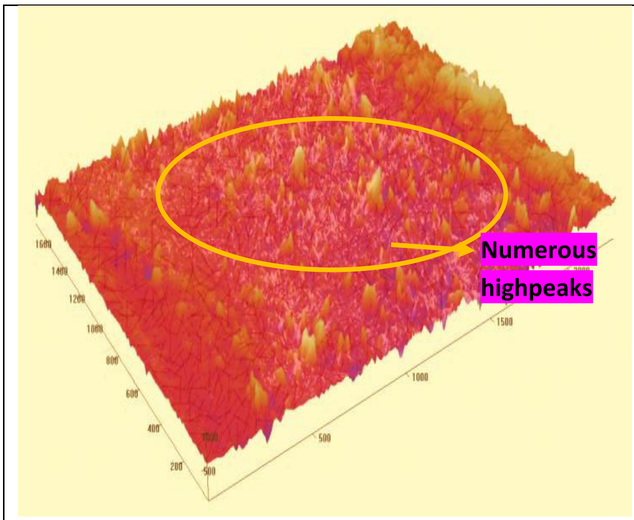


Figure 5(e) profile of surface with graphite powder additive of nitrogen

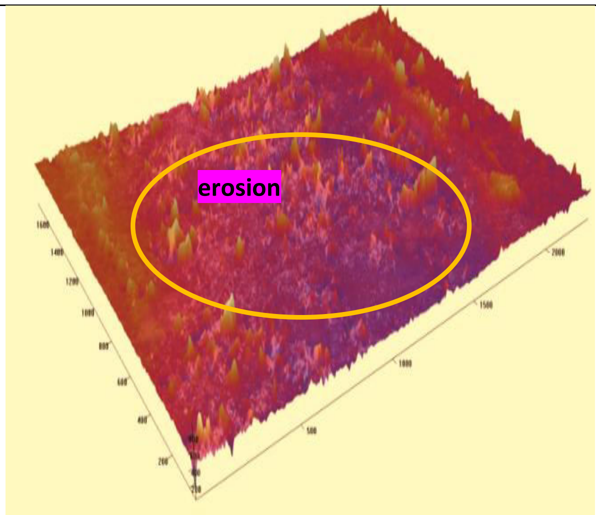


Figure 5 (f) profile of surface with zinc powder additive nitrogen gas

The radioscopy picture of sample surface for different-2 powder of metal with the additive nitrogen gas shown in fig.5 (d, e, f). It is also seen that more peaks and dis-continuity or irregularities on the machine surface of sample as the comparison of helium gas with powder mixed near dry EDM. Higher erosion due to spark over a long distance and the matter of fact was that higher oxidation rate and exothermic reaction leads to higher erosion rate and good surface finish due to higher oxidation in exothermic reaction.

Micro-Hardness

The powder of metal assisted with the dielectric (oil and kerosene) is increases the effect of ionization energy at the gap of electrode. It was found that the micro hardness is increased due to powder additive with gas.The effect of pyrolysis is observed that the carbide is formed and give hardness surfaces due to break the bonding of carbon and hydrogen[5].

In the experimental work, when the zinc powder is used then we found maximum micro hardness is821.32 (VHN) due to its larger hardness andthe aluminium powder value of micro hardness is (671.1 VHN) due to lower conductivity and Value of micro hardness of graphite is (194.13 VHN).

All of the three powders the zinc has largest micro hardness due to additive zinc powder in near dry EDM because of small spark gap.Among all the three metallic powders, zinc additive laden dielectric medium obtained highest micro-hardness because the smallest spark gap at the machining area due to its low electrical conductivity.

Residual stress

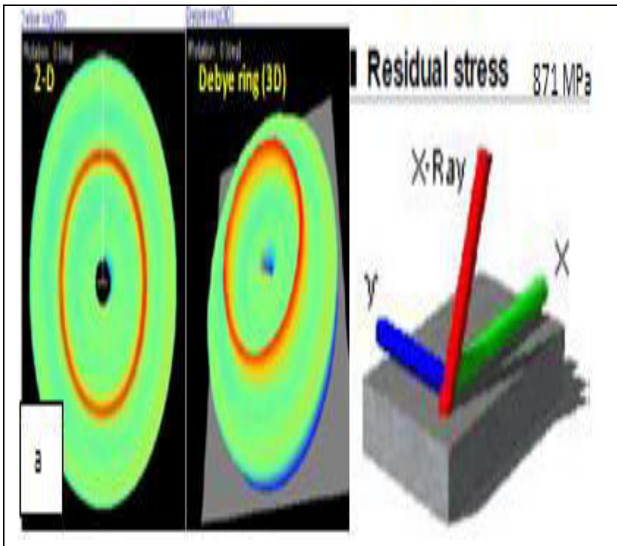


Figure 6(a) residual stress values machined sample(EN-31) samples by GAP-MND-EDM with graphite and nitrogen

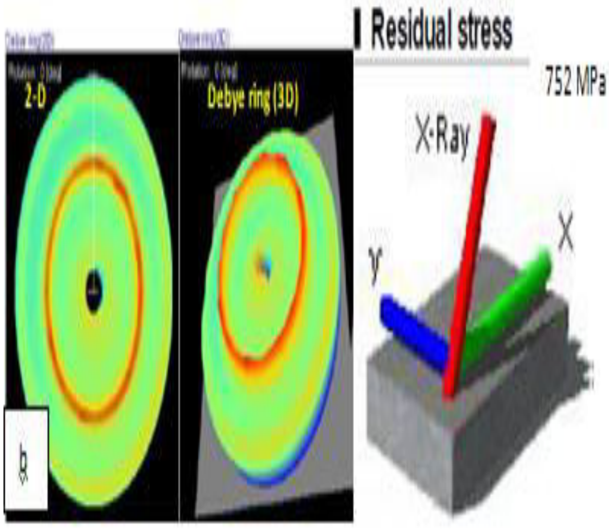


Figure 6 (b) residual stress values of machined sample (EN-31) with GAP-MND-EDM with aluminium and nitrogen

The experiments is conducted for calculate the residual stresses with gas additive powder mixed near dry EDM.The tensile stress is developed at the machined component by the quick coolingand heating. In order to minimized the residual stresses to enhance the life of product. Now, In powder mixed EDM the residual stress more developed as in the comparison of non-conventional machining process.

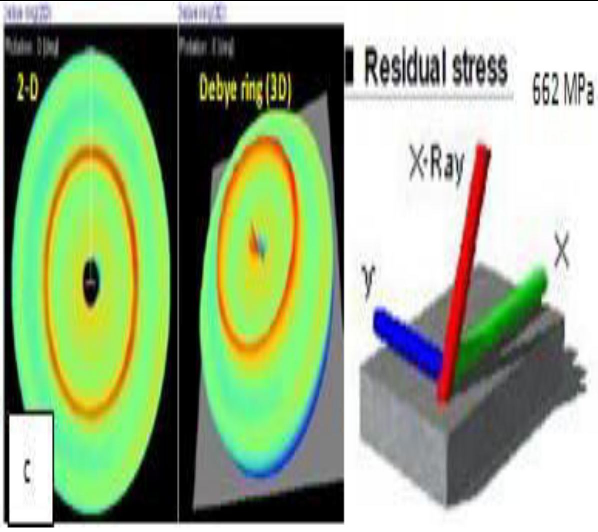


Figure 6 (c) residual stress values of machined sample(EN-31) by GAP-MND-EDM with additive zinc and nitrogen

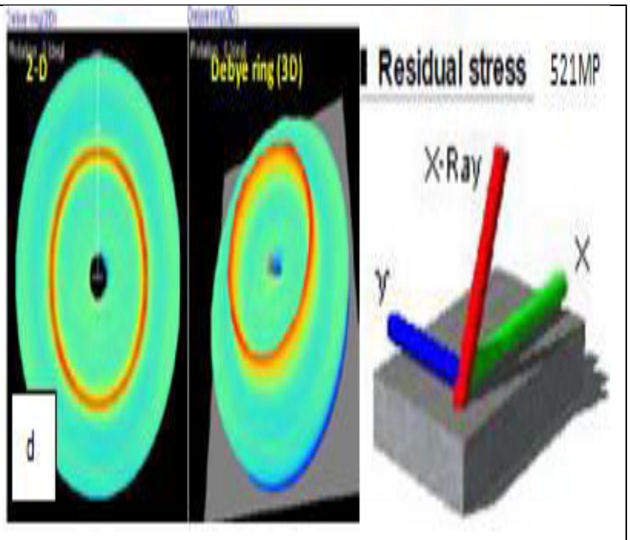


Figure 6 (d) residual stress values of machined sample (EN-31) with GAP-MND-EDM by additive helium and graphite

From fig. 6(f) It can be seen that the value of residual stress is 229MPa measured by Debye Scherer rings of machined sample EN-31 when helium gas is additive with powder mixed near dry EDM. Due to higher density in non-conventional electrical discharge machine within the powder mixed dielectric the energy of discharge reduces and less residual thermal stress is developed [3].

From Fig. 7, shows the residual stresses value with the depth of sample.From fig. 8, it can be seen that some cracks visualize of the sample of machined surface due to tensile residual stress at the same time cooling and flushing are most important factors to resist the induced stress [23]

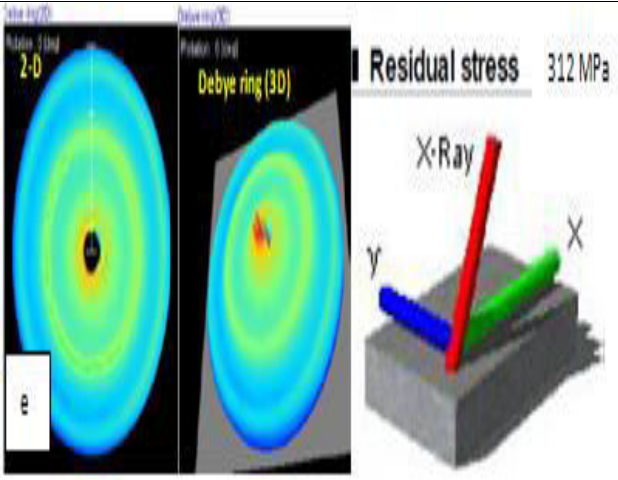


Figure 6 (e) residual stress values of machined sample(EN-31) with GAP-MND with additive helium and zinc

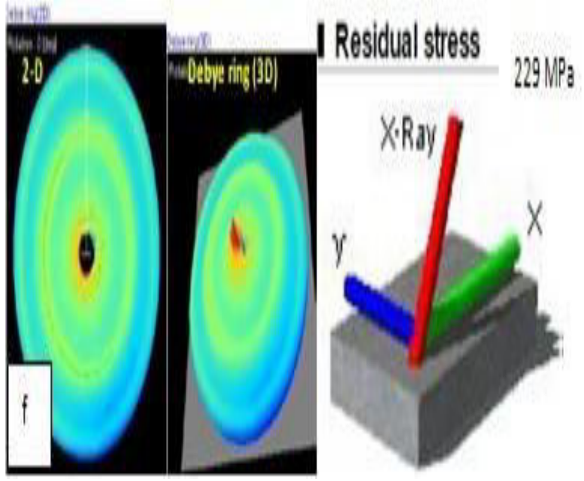


Figure 6 (f) residual stress values of machined sample(EN-31) by GAP-MND-EDM with additive helium and aluminium powder

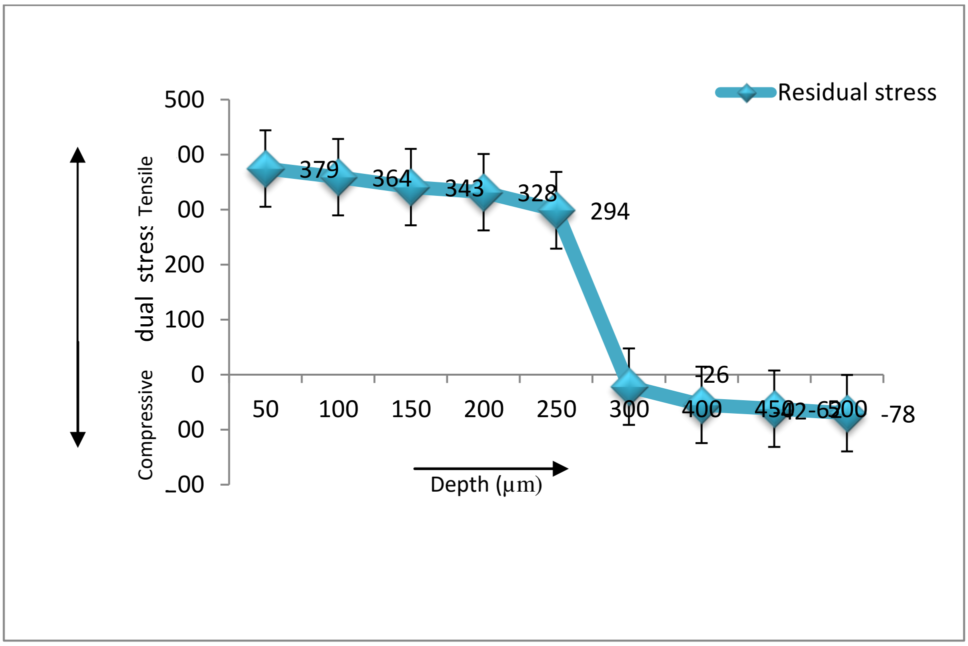
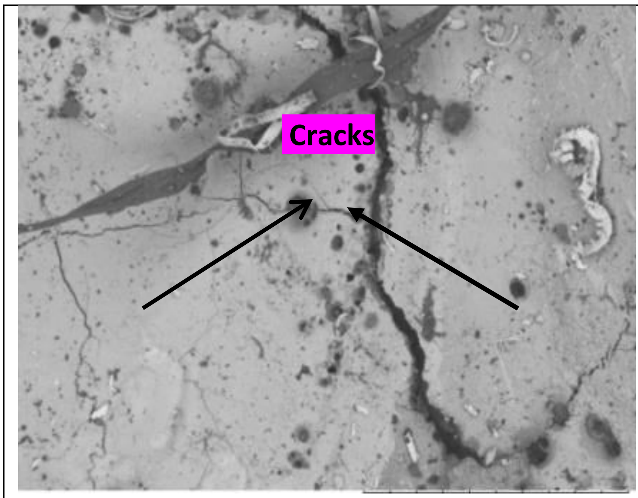


Figure 7. Residual stress variations across the depth of the machined sample



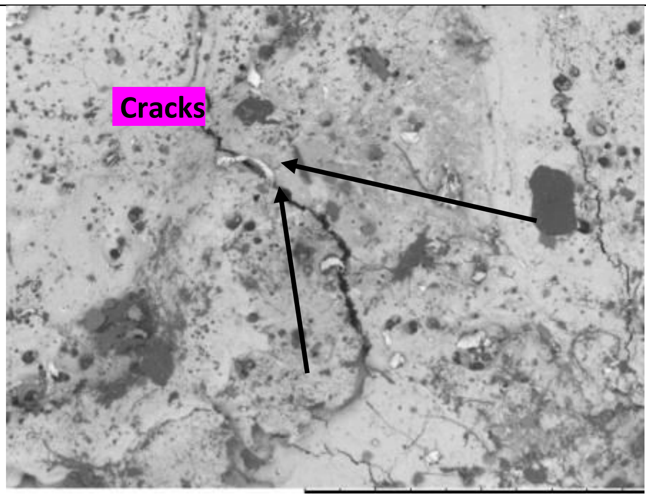


Figure 8[a] Images of some machined sample(EN-31) with micro cracks	**Figure 8**[b] Images of some machined sample(EN-31) with micro cracks

Conclusion

On the basis of results and discussion following conclusions are drawn for the Gas additive powder mixed EDM Machining.

- Gas additivepowder mixed EDM experiments was performed to optimizing and analysis for MRR, Ra, MH and RS. Graphite powder is additivewith oxygen gas as dielectric medium in terms of obtaining highest MRR (3.489 mg/min) as the comparison of another dielectric,medium combinations.

- Graphite powder with additive helium as a dielectric medium in GAPMND-EDM to be most acceptable as compared to other dielectric mediums in terms of achievement the good surface finish (Ra) of 1.121µm.
- To improve the micro hardened of machined products and tool life and other characteristics and surface modification the powder is most essential in gas additive powder mixed near dry –EDM. The maximum micro-hardness is obtained 821.32VHN by using the additive helium with zinc powder in near dry EDM process.
- The values of developed residual stress is to be decrease with additive metallic powder and was found the lowest value of tensile residual stress is 229 MPa when helium is additive with zinc powder in near dry EDM.
- The tensile stress is developed at the machined component by the quick coolingand heating.In order to minimized the residual stresses to enhance the life of product.

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