*International Journal of Engineering & Technology*, 7 (4) (2018) 4455-4461

**International Journal of Engineering & Technology**

*Website: www.sciencepubco.com/index.php/IJET*
*doi: 18087*
***Research paper***



# The effect of different dielectrics on material removal rate, surface roughness and white layer thickness in EDM process

**Shukry H. Aghdeab [1] *, Haneen L. Aldulaimy [1]**

[1] *Production Engineering and Metallurgy Department, University of Technology, Baghdad*
**Corresponding author E-mail:*

**Abstract**

The electrical discharge machining (EDM) is a highly non-traditional manufacture method in which material exclusion happens because of repeated electrical discharges at small periods in the presence of a dielectric medium. It is adopted in numerous processes involving the industry of dies and molds, surface alloying, surface texturing of steel rolls, manufacture of aero engine parts and manufacture of the metallic prosthesis. In EDM, the key output factors are the material removal rate (MRR), the surface roughness (SR) and white layer thickness (WLT). The operational fluid has an imperative function in machining and effecting the MRR, SR, WLT and the properties of the machined surface. This study aims to investigate the influence of using different dielectric such as vegetable oil, transformer oil and gas oil to obtain the maximum MRR with lower surface roughness and minimum whit layer thickness in EDM for stainless steel 316L specimens with a copper electrode. The result shows that the vegetable oil can be used as a dielectric in EDM, it gives extreme MRR while the relative SR is lower and higher WLT when compared to transformer oil and gas oil. Analysis of variance results indicated that the current and pulse-on-time are the most important factors that effect on MRR, SR and WLT. The MRR in vegetable oil and transformer oil produced 66% and 61% higher MRR, respectively, than gas oil. Additionally, vegetable oil and transformer oil resulted in 38% and 13% lower SR than gas oil, while vegetable oil and transformer oil resulted 28% and 14% higher in WLT than gas oil.

***Keywords***: *Electrical Discharge Machining; Material Removal Rate; Surface Roughness; White Layer Thickness; Pulse-On-Time.*

## 1. Introduction

Electrical discharge machining (EDM) is a thermo-electric method based on removing material from a workpiece by a sequence of repeated electrical sparks amid electrode and workpiece, electrode immersed in or flushed by the dielectric fluid. EDM can be employed in manufacturing for high-precision machining of entire categories of conductive materials as in graphite, metallic alloys and even several ceramic materials [1-3]. It is also used in machining possibility for fabricating geometrically complicated parts that are very problematic to the machine by traditional machining method [4-5].

Various investigations were shown on use of dielectric to enhance the features of materials. Yonghong et al. [6] investigated the processing features of the EDM operation by dissimilar dielectrics such as oxygen, air, kerosene, water-in-oil and deionized water. Signifying that the MRR in the liquid dielectric is higher than that of gaseous dielectrics. Wang et al. [7] studied the effect of dielectric features, specifically, electrical conductivity and titanium alloy viscosity in the compound dielectric, kerosene and distilled water, signifying that the compound dielectric resolves the complications of small MRR in kerosene and reduced surface quality in distilled water. Sadagapan and mauliprasanth [8] study the influence of different dielectrics such as transformer oil, biodiesel and kerosene on the MRR, EWR and SR in EDM. They found that the biodiesel dielectric gives high MRR, less EWR and better SR than that kerosene and transformer oil. Pandey et al. [9] made a comparative investigation of HSS machining using dielectric materials of compressed air and water. They found that MRR had 62% greater as compared with conformist EDM. Misbah et al. [10] investigated the effects of parameters on MRR, EWR, and microstructure were evaluated and comparison were made for the accomplishment of dielectrics involving kerosene and distilled water.

This study examines the influence of different dielectric on the processing machining features as an attempt for machining stainless steel 316L using vegetable oil, transformer oil and gas oil as dielectric for the first time and the consequences have been deliberated.

## 2. Experimentation

### 2.1. Materials and electrodes

The machine used in this experiment is called CHMER of the model (CM 323C). Mechanical features and chemical composition of the workpiece material (stainless steel 316L) employed for this investigation is presented in Tables 1 and 2. Entirely samples have created of the identical size of (40×30×2) mm. Copper was employed as an electrode material, the mechanical features and chemical composition of copper used in this work are displayed in Tables 3 and 4.

**Table 1:** Chemical Composition of Copper Electrode

| Metals | Zn% | Pb% | Sn% | P% | Mn% | Fe% | Ni% | Si% | Cr% |
|---|---|---|---|---|---|---|---|---|---|
| Results | 0.0001 | 0.0005 | 0.0005 | 0.0001 | 0.0002 | 0.0091 | 0.0004 | 0.0373 | 0.0008 |
| Metals | Al% | S% | As% | Ag% | Co% | Bi% | Cd% | Sb% | Cu% |
| Result | 0.0024 | 0.0001 | 0.0001 | 0.0024 | 0.0004 | 0.0001 | 0.0001 | 0.0017 | Residual |

**Copyright © 2018 Shukry H. Aghdeab, Haneen L. Aldulaimy. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.**

**Table 2:** Mechanical Properties of the Copper Electrode

| Mechanical Properties | Description |
|---|---|
| Tensile Strength (MPa) | 620 |
| Elongation (%) | 7 |
| Yield strength (MPa) | 579 |
| Hardness Brinell | 80 |

**Table 3:** The Chemical Structure of the Workpiece Material (AISI 316L)

| Metals | C% | Cr% | Cu% | Mn% | Mo% |
|---|---|---|---|---|---|
| Results | 0.0137 | 16.5675 | 0.3935 | 1.2375 | 2.1170 |
| Metals | N% | Ni% | P% | S% | Si% |
| Result | 0.0494 | 10.0450 | 0.0290 | 0.0010 | 0.2400 |

**Table 4:** Mechanical Features of 316L Stainless Steel 316L

| Mechanical Properties | Values |
|---|---|
| Tensile Strength (MPa) | 485 |
| Elongation (%) | 49 |
| Yield strength (MPa) | 519 |
| Hardness (RB) | 84 |

### 2.2. Experimental design

An experimental investigation was conducted to discover the weight of diverse processing of variables input parameters for the dielectrics selected for the experimentation with designated levels as given in Table 5. Nine investigational processes have achieved independently for vegetable oil, transformer oil and gas oil.

**Table 5:** The Parameter with the Selected Level

| No. | Parameter | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|
| 1 | Current (A) | 10 | 24 | 50 |
| 2 | Pulse-on-time (µs) | 50 | 100 | 200 |

## 3. Investigational process

Founded on the range magnitudes that are employed for experimentation, factorial-based designs of experimentations have accomplished using simulator with an L9 Orthogonal Array (OA) for two factors and three levels. All samples were machined of equivalent size of (39×30×2) mm for the different dielectrics of vegetable oil, transformer oil and gas oil through the experimentation. The MRR was found by measuring the weight balance earlier and next to performing every experiment. MRR was calculated using equation 1 [11].

$$\text{MRR}=\frac{\text{weight of material removed from workpiece}}{\text{density}\times\text{machining time}}=\frac{\text{Wb}-\text{Wa}}{\rho\times\text{Tm}} \quad (1)$$

Where
MRR= Material removal rate (mm3/min)
Wb= Workpiece before machining weight (g)
Wa= Workpiece after machining weight (g)
ρ= Density of workpiece (g/mm3)
Tm= Machining time (minutes)
After EDM machining, the surface roughness (SR) measurement have taken at three changed regions on the machined surface, and the average of these three measurements was taken as the concluding value for the surface roughness measurements were performed by using type Pocket surface roughness device, the probe scans the surface, compare between peaks and valise to indicate the SR.
The samples were cut by EDM, they must be mounted by a mixture of self-curing dental base acrylic resin as a powder with special liquid then mixing them very fast and pouring them on the sample. The mixture is left on the sample for several minutes until it becomes hard and dry. Then, it grinded continuously with silicon carbide papers of grit sizes 120, 320, 500, 1000, and 1200 and the third step is polishing with a slurry of alumina (Al2O3) until they become like a mirror. They have subsequently imprinted with oxalic acid, picral and distilled water for one min. For investigates the white layer thickness, the optical microscope has been used.

## 4. Experimental outcomes and discussion

The investigational outcomes for MRR, SR and WLT are shown in Table 6, 7 and 8. Influence of parameters (current and pulse-on-time) on MRR, SR and WLT has evaluated for vegetable oil, transformer oil and gas oil, separately.

**Table 6:** Tentative Consequences for MRR, SR and WLT with Vegetable Oil Dielectric

| Expt. No. | MRR (mm3/min) | SR (µm) | WLT(µm) |
|---|---|---|---|
| 1 | 12.0067 | 3.2 | 6.6 |
| 2 | 15.8798 | 3.7 | 7.1 |
| 3 | 19.5581 | 4.2 | 8.2 |
| 4 | 21.0426 | 5.3 | 11.9 |
| 5 | 32.9239 | 5.5 | 13.2 |
| 6 | 41.2251 | 5.6 | 13.6 |
| 7 | 47.9760 | 6.9 | 14.2 |
| 8 | 67.1293 | 7.2 | 15.5 |
| 9 | 81.0872 | 7.5 | 17.5 |

**Table 7:** Tentative Consequences for MRR, SR and WLT with Transformer Oil Dielectric

| Expt. No. | MRR (mm3/min) | SR (µm) | WLT (µm) |
|---|---|---|---|
| 1 | 11.500 | 4.5 | 5.3 |
| 2 | 14.987 | 5.0 | 6.3 |
| 3 | 15.551 | 5.2 | 9.6 |
| 4 | 24.211 | 5.9 | 12.2 |
| 5 | 28.663 | 6.0 | 13.0 |
| 6 | 29.099 | 6.3 | 13.6 |
| 7 | 33.337 | 7.0 | 13.8 |
| 8 | 40.000 | 8.2 | 14.0 |
| 9 | 46.873 | 10.4 | 15.1 |

**Table 8:** Tentative Consequences for MRR, SR and WLT with Gas Oil Dielectric

| Expt. No. | MRR (mm3/min) | SR (µm) | WLT (µm) |
|---|---|---|---|
| 1 | 4.496 | 5.2 | 4.1 |
| 2 | 4.883 | 5.4 | 4.8 |
| 3 | 8.817 | 5.5 | 5.0 |
| 4 | 12.333 | 7.7 | 7.2 |
| 5 | 14.632 | 7.9 | 8.1 |
| 6 | 14.927 | 8.5 | 8.9 |
| 7 | 22.917 | 9.2 | 11.0 |
| 8 | 24.884 | 10.2 | 12.2 |
| 9 | 32.355 | 13.0 | 12.5 |

### 4.1. Vegetable oil dielectric

Fig. 1a and Fig. 1b represents the plots of material removal rate rises with the increased current (10 to 50) A for the reason that additional energy density comes to be a ready at upper magnitudes of current due to melting and eliminates more materials and augments pulse-on-time from (50 to 200) µs [12-13]. Besides, it is detected that the surface roughness (SR) augments with increased current. Furthermore, increased pulse-on-time (Pon) raises SR in the three levels as shown in Fig. 2a and Fig. 2b. This is because additional discharge energy comes to be existing at advanced current levels and pulse-on-time, caused the creation of crater and large cracks.

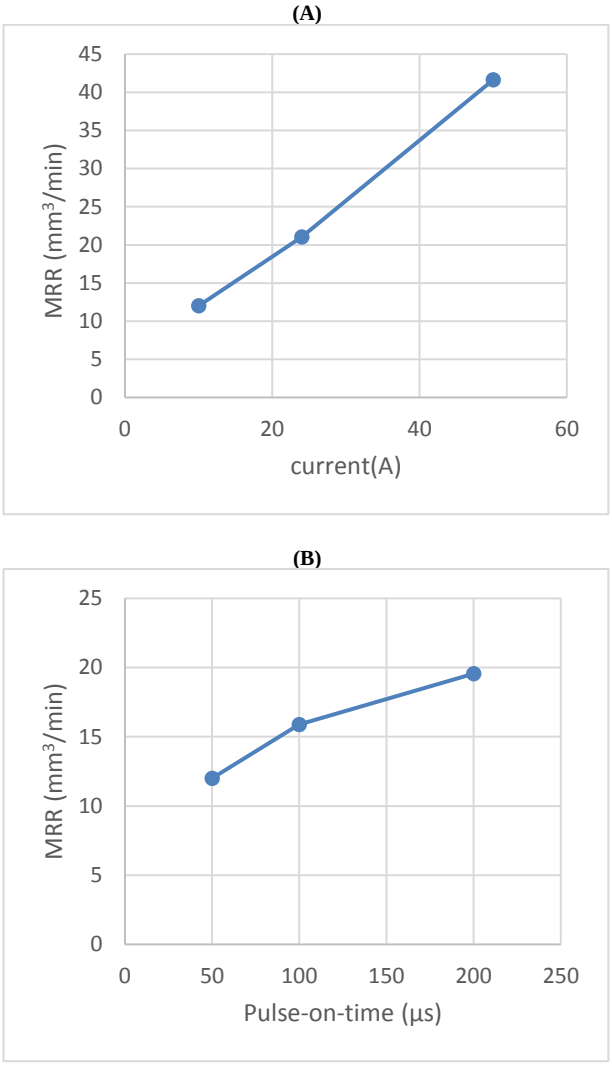
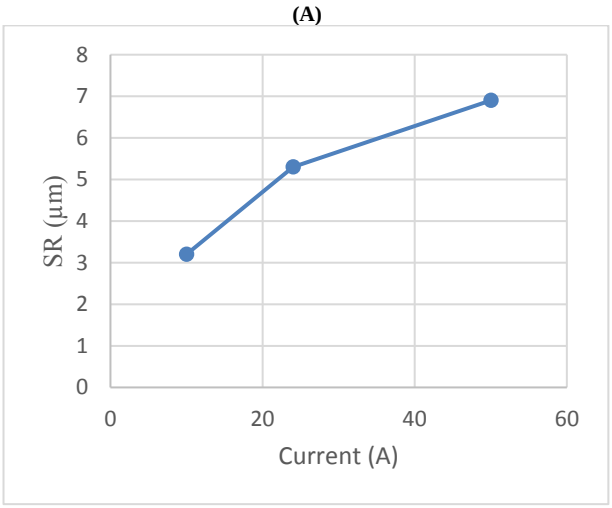



**Fig. 1:** Effect of Parameters on MRR for Vegetable Oil: (A) Current; (B) Pulse-On-Time.



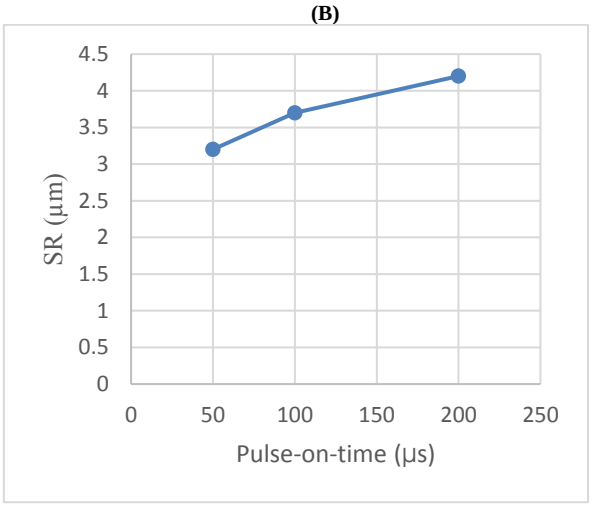




**Fig. 2:** Effect of Parameters on SR for Vegetable Oil: (A) Current; (B) Pulse-On-Time.

White layer thickness (WLT) has a significant part in the porosity development. A thicker white layer can reduce the solidification speed of the molten material and pay a regular contribution to the creation of bag pores [14-15]. Analysis of white layer thickness was implemented for diverse current levels whereas preserving Pon value at 50µs for vegetable oil comparison of WLT at 10A and 50A current for vegetable oil, as illustrated in Fig. 3a and Fig. 3b, correspondingly. Showed that at higher current, the white layer is thicker. Likewise, Pon showed the same effect and WLT is augmented with increased Pon from (50 to 200) µs.

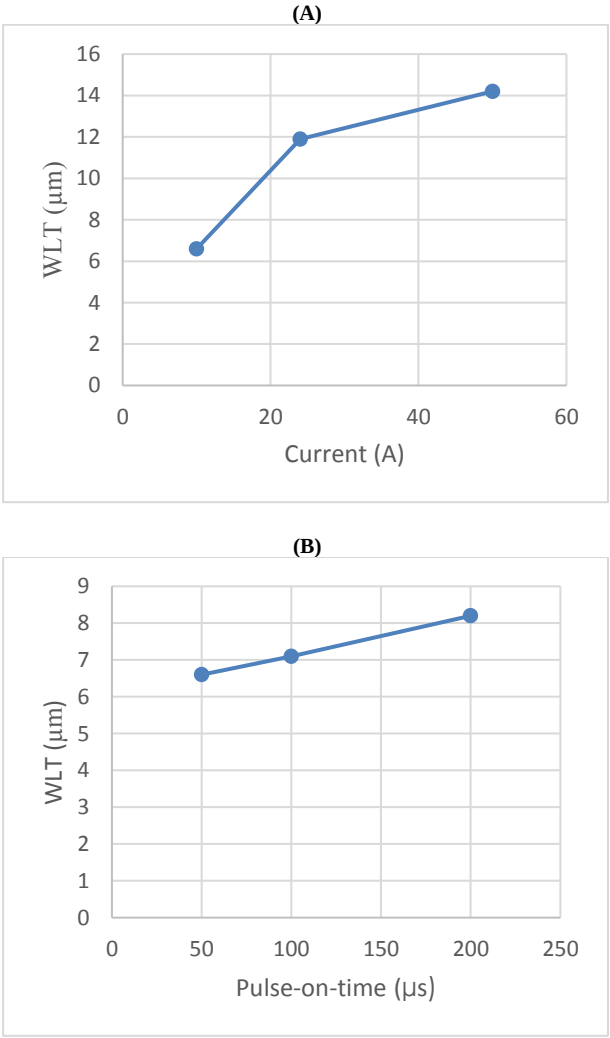



**Fig. 3:** Effect of Parameters on WLT for Vegetable Oil: (A) Current; (B) Pulse-On-Time

### 4.2 Transformer oil dielectric

From Figs. 4, 5 and 6, it is detected that the material removal rate, surface roughness and white layer thickness rises with increased current and pulse-on-time.

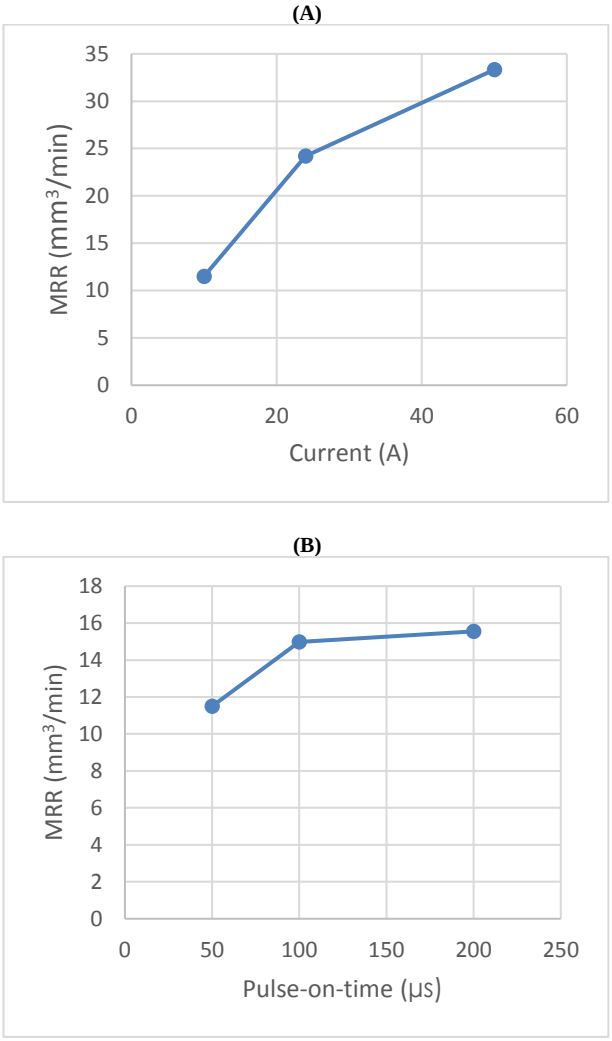
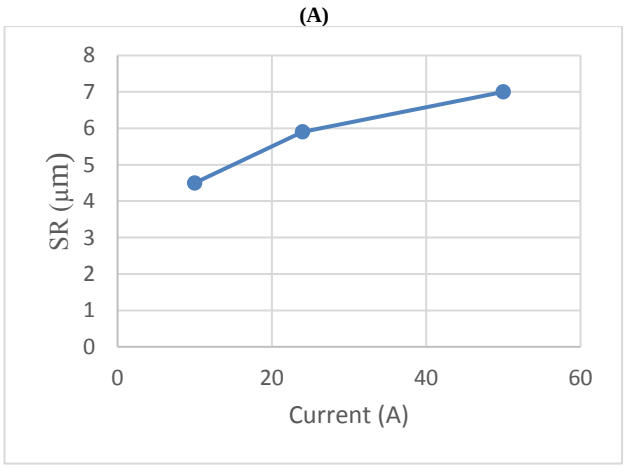



**Fig. 4:** Consequence of Parameters on MRR for Transformer Oil: (A) Current; (B) Pulse-On-Time.



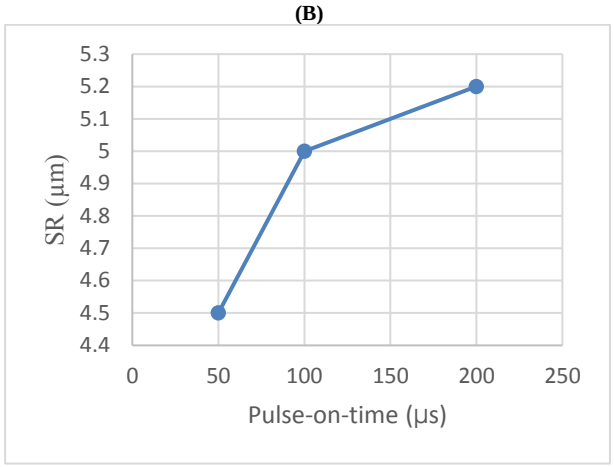




**Fig. 5:** Consequence of Parameters on SR for Transformer Oil: (A) Current; (B) Pulse-On-Time.

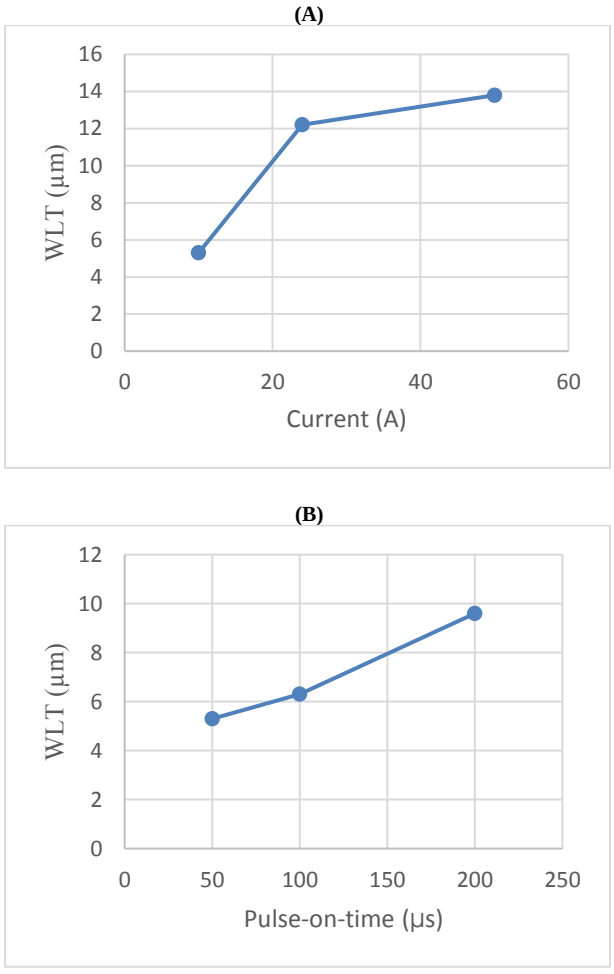



**Fig. 6:** Consequence of Parameters on WLT for Transformer Oil: (A) Current; (B) Pulse-On-Time.

### 4.3. Gas oil dielectric

The main output parameters are the material removing rate, surface roughness and white layer thickness. Figs. 7, 8 and 9. Show the effect of current and Pon on MRR, SR, WLT on the gas dielectric. It is perceived that the current has the first level that signifies for the extreme effect on MRR, SR and WLT, while Pon has the least influential effect on outputs. Outputs raise with the increased current and the intensification in Pon raises MRR, SR, WLT in three levels.

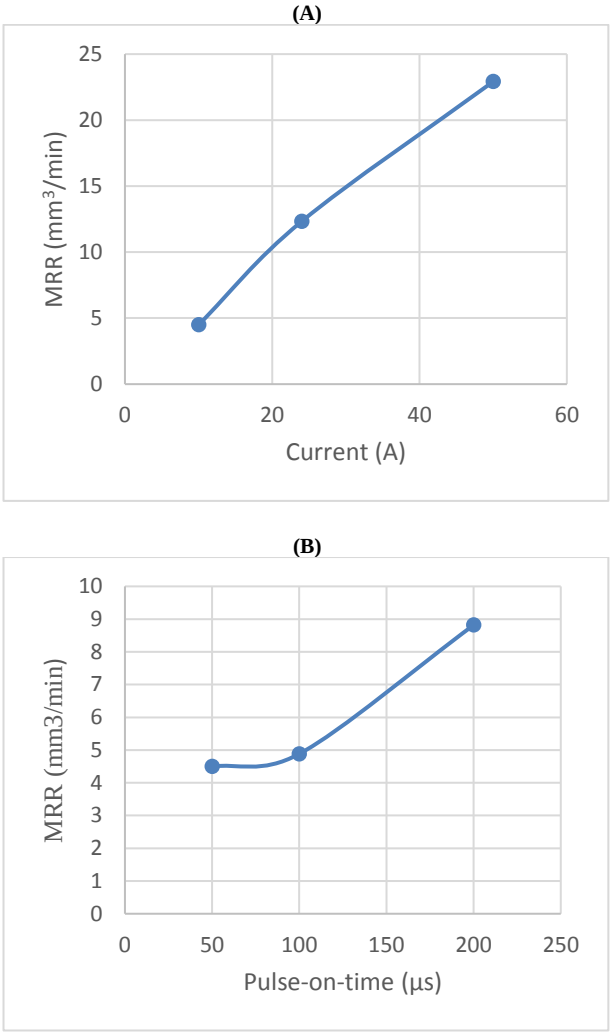
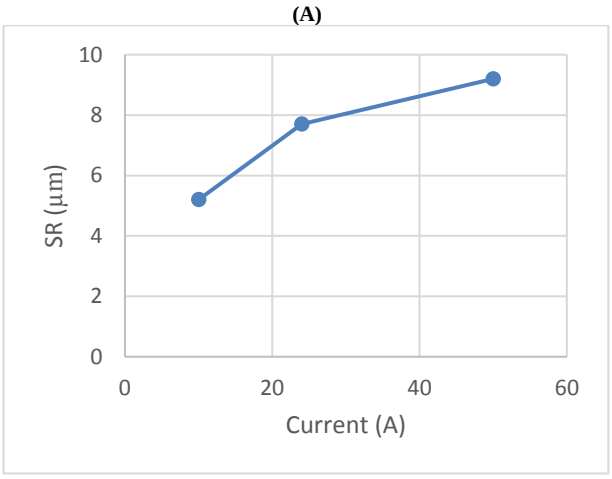



**Fig. 7:** Effect of Parameters on MRR for Gas Oil: (A) Current; (B) Pulse-On-Time.



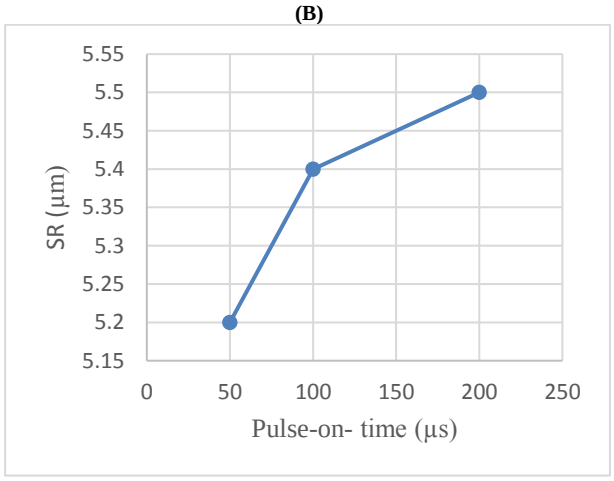




**Fig. 8:** Effect of Parameters on SR for Gas Oil :(A) Current; (B) Pulse-On-Time.

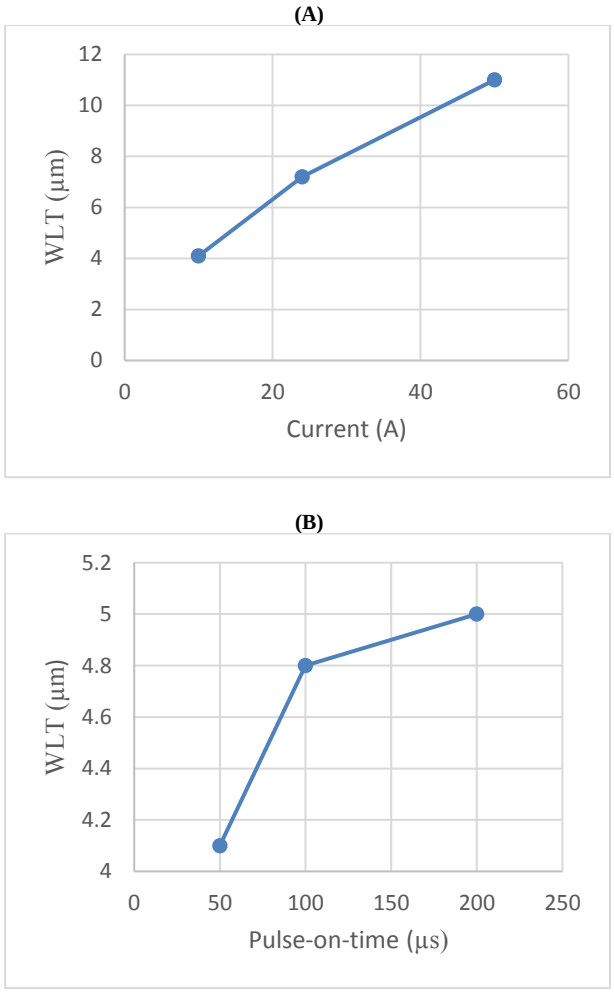



**Fig. 9:** Effect of Parameters on WLT for Gas Oil: (A) Current; (B) Pulse-On-Time.

The material removal rate assessment for vegetable oil, transformer oil and gas oil is shown in Fig. 10. It is perceived that in the situation of vegetable oil, the material removal rate is very greater than transformer oil and gas oil. Nevertheless, it is evident that the MRR in transformer oil is marginally better than that of gas oil. This is because the viscosity of vegetable oil is much larger than that of transformer oil and gas oil, the craters obtained in vegetable oil should be bigger and deeper than those obtained in gas oil. In addition, vegetable oil has a higher dielectric strength that contributes for higher discharge energy density due to higher breakdown voltage, which leads to higher molten volume of workpiece.

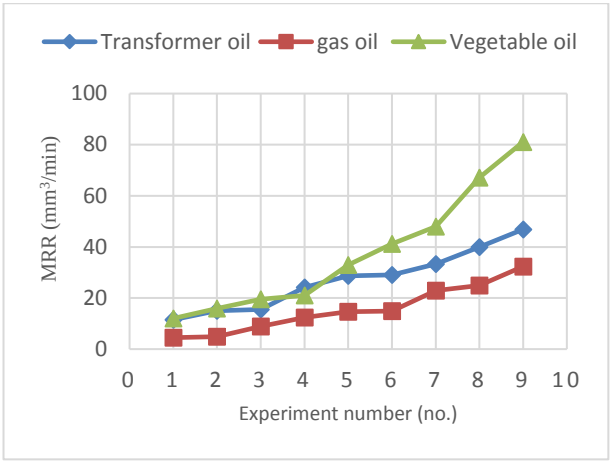



**Fig. 10:** Comparisons of MRR for Vegetable Oil, Transformer Oil and Gas Oil.

Comparison of SR for all dielectrics has been presented in Fig. 11. It is seen that the surface roughness is a smaller amount of vegetable oil than transformer oil and gas oil as a dielectric. The surface roughness with vegetable oil as a dielectric is somewhat less than transformer oil dielectric. . This is because the vegetable oil had lower heat conductivity than transformer oil and gas oil. Moreover, the vegetable oil would decompose to produce additional oxygen and showed minimal heat conductivity. This characteristic weakened the capacity of the vegetable oil for heat transmission and caused the minimal temperature difference in the workpiece. As a result, the influence of the thermal cycling stress on the workpiece was relatively small, and the micro-cracks produced on the surface were few and fine.

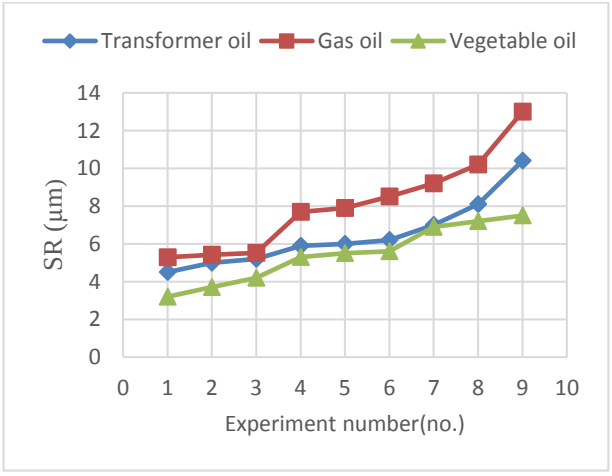



**Fig. 11:** Comparisons of SR for Vegetable Oil, Transformer Oil and Gas Oil.

Fig. 12 shows a comparison of WLT for all dielectric, it is observed from the graph that WLT is higher in vegetable oil as compared to transformer oil and gas oil with the same machining parameters. This is because vegetable oil has a much higher viscosity gas oil, it cannot clear away the molten material, and so it builds up on the surface of the sample. During subsequent cooling, this molten material resolidifies to form the white layer, the depth of which depends on the volume of molten material that was left on the sample surface during machining. Standard deviations for measured white layer thicknesses indicate that increasing the discharge energy increases the white layer thickness deviation considerably.

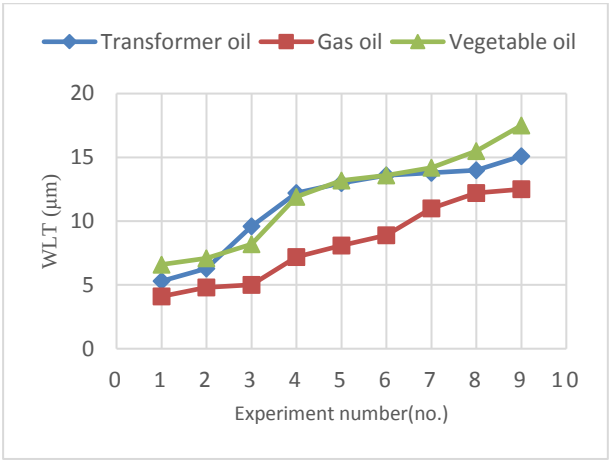



**Fig. 12:** Comparisons of WLT for Vegetable Oil, Transformer Oil and Gas Oil.

## 5. Conclusion

As compared with the related reported studies in the literature [6 – 10], [16], and [17], it is found that there are no studies reported on EDM using vegetable oil as a dielectric for machining stainless steel 316L In this paper, an attempt is made to machine stainless steel 316L with high hardness using vegetable oil, transformer oil and gas oil as dielectric and compare between them. The effect of the different dielectric on the WLT was studied, in addition to the MRR and SR. The surface roughness, material removal rate and white layer thickness is mainly affected by current followed by pulse-on-time.

Greater current and pulse-on-time values cause maximum MRR and higher surface roughness as well as when the white layer thickness is thicker. In this study, it is noted that vegetable oil is feasibly employed as a dielectric in EDM. It gives high MRR while the relative SR is lower and higher WLT when compared to transformer oil and gas oil. It is found that vegetable oil can be used as the best dielectric in EDM. It gives high MRR, less SR than transformer oil and gas oil. It is characteristic of vegetable oil emit fewer odor and lesser smoke, while dielectrics used in other reported researches emit toxic gases that are hazardous to the health of the working staff.

The viscosity of dielectric is the important characteristic that affects WLT. Lower white layer thickness possible at lower viscosity.

## 6. Recommendations for future work

1) Using others materials containing high carbon to study the effect of different dielectric on heat effect zone.
2) Study the improvement of electric discharge machining (EDM) performance with addition of graphite powder to dielectric.
3) Study the effect of other parameters on EDM process such as (voltage, workpiece thickness, polarity, etc.) on machining responses.
4) Researching on influence of dielectric characteristics such as (oxidability, electrical conductivity, viscosity, etc.) on the EDM of any alloy.
5) The influence of dielectric type on porosity formation on electrical discharge machined surface must be investigated.

## References

[1] Kunieda M, Lauwers B, Rajurkar KP, Schumacher BM (2005)Advancing EDM through fundamental insight into the process.CIRP Annals-Manufacturing Technology 54(2):64–87. https://doi.org/10.1016/S0007-8506(07)60020-1.

[2] K.H Ho and S.T. Newman, "State of the art electrical discharge machining (EDM)," Int. J. Machine Tools Manufac., vol. 43, pp. 1287-1300, 2003. https://doi.org/10.1016/S0890-6955(03)00162-7.

[3] Mahdavinejad, R.A., Mahdavinejad, A., 2005. ED Machining of WC-Co. Journal of Materials Processing Technology 162-163, pp.637-643. https://doi.org/10.1016/j.jmatprotec.2005.02.211.

[4] Krar SF, Check AF (1997) Electrical discharge machining, Technology of Machine Tools. Glencoe/McGraw-Hill, New York.

[5] Soo Hiong Lee, Xianoping Li. 2003. Study of the surface integrity of the machined workpiece in the EDM of Tungsten Carbide" Journal of Materials processing Technology 139, pp. 315-321 https://doi.org/10.1016/S0924-0136(03)00547-8.

[6] Yonghong Liu, et al. "Investigation on the influence of the dielectrics on the material removal characteristics of EDM." *Journal of Materials Processing Technology* 214.5 (2014): 1052-1061. https://doi.org/10.1016/j.jmatprotec.2013.12.012.

[7] Wang, Xiangzhi, et al. "Research on the influence of dielectric characteristics on the EDM of titanium alloy." *The International Journal of Advanced Manufacturing Technology* 72.5-8 (2014): 979-987.

[8] Sadagopan, P., and B. Mouliprasanth. "Investigation on the influence of different types of dielectrics in electrical discharge machining." *The International Journal of Advanced Manufacturing Technology* 92.1-4 (2017): 277-291.

[9] Pandey H, Dhakar K, Dvivedi A, Kumar P (2016) parametric investigation and optimization of near-dry electrical discharge machining. Journal of Scientific & Industrial Research 74:508–51.

[10] Niamat, M., Sarfraz, S., Aziz, H., Jahanzaib, M., Shehab, E., Ahmad, W., & Hussain, S. (2017). Effect of Different Dielectrics on Material Removal Rate, Electrode Wear Rate and Microstructures in EDM. *Procedia CIRP*, *60*, 2-7. https://doi.org/10.1016/j.procir.2017.02.023.

[11] Sultan T, Kumar A, Gupta RD. Material Removal Rate, Electrode Wear Rate, and Surface Roughness Evaluation in Die Sinking EDM with Hollow.

[12] Muthuramalingam T, Mohan B. Influence of discharge current pulse on machinability in EDM. Mater Manuf Process 2013; 28(4): 375-380. https://doi.org/10.1080/10426914.2012.746700.

[13] Lin YC et al. Machining characteristics and optimization of machining parameters of SKH 57 high-speed steel using electric-discharge machining based on the Taguchi method. Mater Manuf process 2006; 21(8): 922-929. https://doi.org/10.1080/03602550600728133.

[14] B. Ekmekic: Metall. Mater. Trans. B Process Metall. Mater. Process Sic., 2009, vol. 40, pp. 70-81.

[15] Zhang, Yanzhen, et al. "Influence of dielectric type on porosity formation on electrical discharge machined surfaces." *Metallurgical and Materials Transactions B* 43.4 (2012): 946-953. https://doi.org/10.1007/s11663-012-9653-3.

[16] Nguyen, Minh Dang, Mustafizur Rahman, and Yoke San Wong. "An experimental study on micro-EDM in low-resistivity deionized water using short voltage pulses." *The International Journal of Advanced Manufacturing Technology* 58.5-8 (2012): 533-544.

[17] Chakraborty, S., V.Dey, and S. K. Ghosh. "A review on the use of dielectric fluids and their effects in electrical discharge machining characteristics." *Precision Engineering* 40(2016):1-6. https://doi.org/10.1016/j.precisioneng.2014.11.003.