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## Study on the influence of process parameters on the performance of power-mixed neary-dry EDM enhanced TC4 reinforcement layer

To cite this article: Shijie Liu *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **252** 022121

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# Study on the influence of process parameters on the performance of power-mixed neary-dry EDM enhanced TC4 reinforcement layer

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**Abstract.** The electric spark deposition method was used to strengthen TC4 alloy surface under power-mixed neary-dry EDM. Through the medium mixed with B<sub>4</sub>C power, graphite electrode as the tool electrode, the effects of peak current, pulse width and pulse clearance on the microstructure and hardness of the reinforced layer surface were studied. The results show that the enhanced layer surface can form a layer of chrysanthemum petal-like layered reinforcing tissue, and the edge of tissue is bright white. With the peak current and pulse gap increasing, the petal-like tissue gradually grows; the hardness of the strengthening layer is increased by about 2.5 times from the 392 HV before strengthening. When the peak current is 6.6~8.2 A, the pulse width is 60~100  $\mu$ s, and the pulse gap is in the range of 80~100  $\mu$ s, the morphology and hardness of the strengthened layer are relatively better.

## 1. Introduction

Titanium alloy has been used as an important material for aerospace, military industry and medical equipment due to its low density, good corrosion resistance, high temperature resistance, high specific strength and excellent biocompatibility [1]. EDM surface strengthening technology is one of the most commonly used methods, especially for the selection of power-mixed neary-dry EDM. Sohil Parsana and others [2] used the meta-heuristic search algorithm PVS to optimize the parameters of EDM for Mg-RE-Zn-Zr alloy. Guo Yongfeng and others [3] selected electrode polarity, peak current, pulse switching time and pulse breaking time to study their effects on material removal rate, backlash and surface roughness. Ramesh Raju and others [4] used Taguchi method to optimize the C276 EDM process parameters of HASTE alloy, the results show that the peak current is the most important factor affecting the material removal rate, surface roughness and cutting degree. Manish Gangil and others [5] used Vikor method to optimize machining parameters in titanium alloy EDM process, the results show that peak current is the most important factor affecting material removal rate (MRR), tool wear rate (TWR) and surface roughness (Ra), followed by duty ratio, pulse time and supply voltage. K.

In this paper, the microstructure and hardness properties of the surface strengthening layer of the strengthened titanium alloy were analyzed to find the optimal discharge parameter range, and an intuitive understanding of the electrical parameter optimization of EDM was made.

## 2. Experimental materials and methods

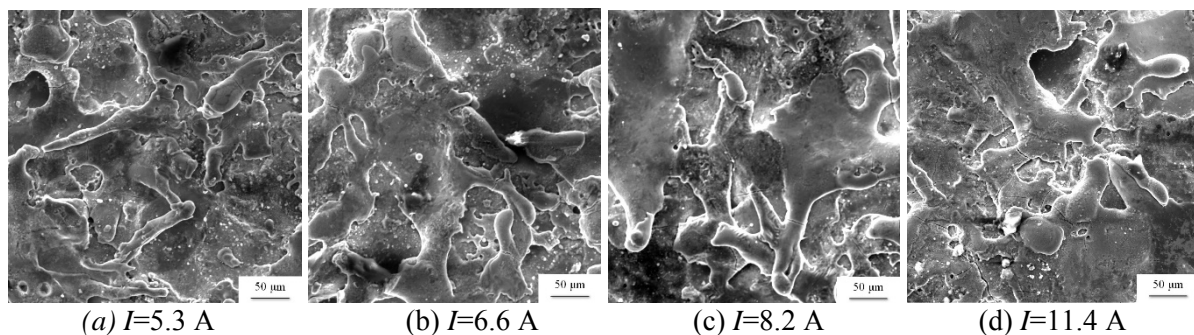
The test uses AF1000 type EDM machine tool to process TC4 alloy material by power-mixed neary-dry EDM. The strengthening medium is deionized water solution mixed with B<sub>4</sub>C powder, the concentration



is 0.3g/L, and it is sprayed in the form of mist. The process parameters used in the experiment are peak currents 5.3 A, 6.6 A, 8.2 A, and 11.4 A. The power supply discharge pulse voltage is 120 V, the pulse width is 40  $\mu$ s, 60  $\mu$ s, 80  $\mu$ s, 120  $\mu$ s, and the pulse interval is 40  $\mu$ s, 60  $\mu$ s, 80  $\mu$ s, 120  $\mu$ s. The processing depth is 0.2mm. The test material is Ti-6Al-4V titanium alloy with a size of 10 mm $\times$ 10 mm $\times$ 5 mm. The graphite electrode is used as a tool electrode. The process electrode is connected to the negative pole of the power supply, and the workpiece is connected to the positive pole of the power supply. The hardness is measured by using a micro hardness tester at five different points on the surface of the strengthening layer and numbered 1-5, and the hardness average is numbered 6.

### 3. Experimental results and discussion

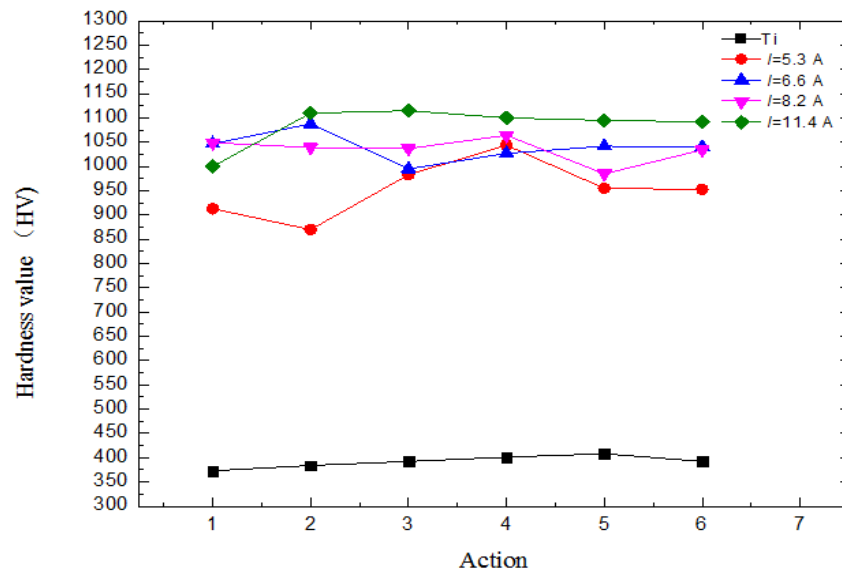
#### 3.1. Effect of peak current on the performance of reinforced layer



**Figure 1.** Microstructure morphology of TC4 titanium alloy after different peak current enhancement.

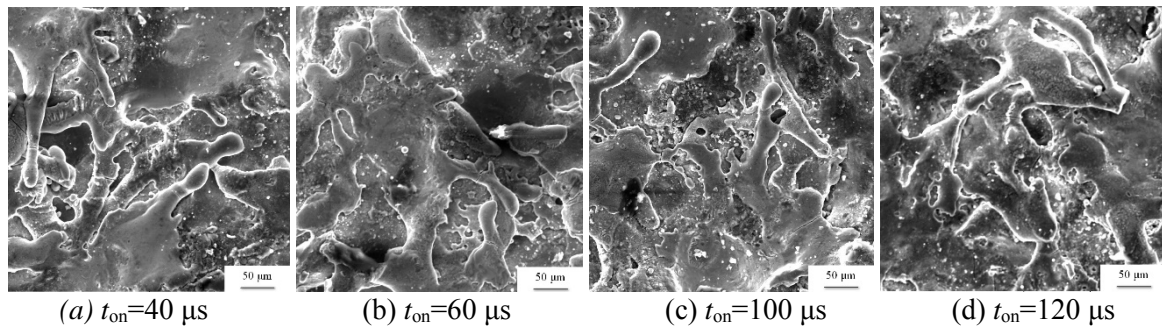
Fig. 1 shows that the surface of the strengthening layer has petal-like tissue distribution and overlaps each other, the edge position is bright white, and the micro-spherical carbides are distributed on the surface of the alloy, micro-aggregate at the edge of the flower petals. Fig. (a) Shows when the current is small, the petal-like tissue is not thick enough and is distributed in a slender branch around the discharge pit. This is mainly because the single discharge energy is lower, the discharge erosion material is less, and the molten material splashes farther, forming a fine and long tissue morphology. It can be seen from Fig. (b) (c) that the current is gradually increased to form a relatively dense and fine-grained structure with a low surface roughness. As the peak current further increases, Fig. (d) Shows the surface quality of the strengthening layer decreases, and the reinforcing layer shows obvious defects such as pores and cracks.

It can be seen from Fig. 2 that the hardness value of the strengthened layer after processing is 2.2 to 2.7 times that of the base material, which is significantly improved. Different peak current enhancement effects are different at around 150 HV, but the difference is not large. When  $I=5.3$  A, the overall hardness value is relatively low and the hardness values of different positions are different, and the curve fluctuates greatly. When  $I=11.4$  A, the average hardness value is the highest and the overall stability is the best. The main reason is that as the peak current increases, the energy of the single-pulse discharge energy increases, and the powder-enhanced medium and the matrix material participating in the reaction react sufficiently, and the formation of the strengthening phase is uniform, and the percentage is increased.



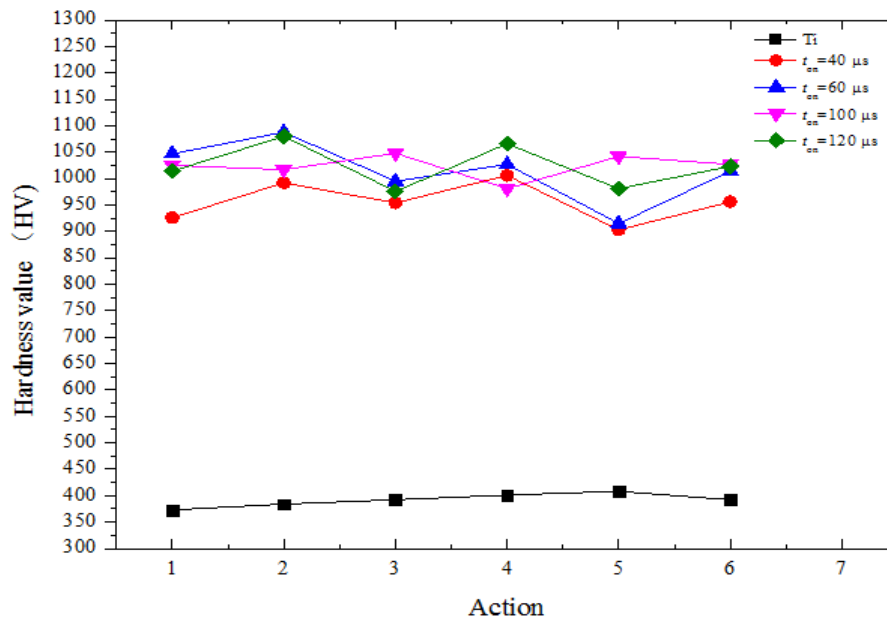
**Figure 2.** The hardness value curve of hardened layer under different peak current strengthening conditions.

### 3.2. Effect of pulse width on the performance of reinforcing layer



**Figure 3.** Microstructure morphology of TC4 titanium alloy after different pulse width enhancement.

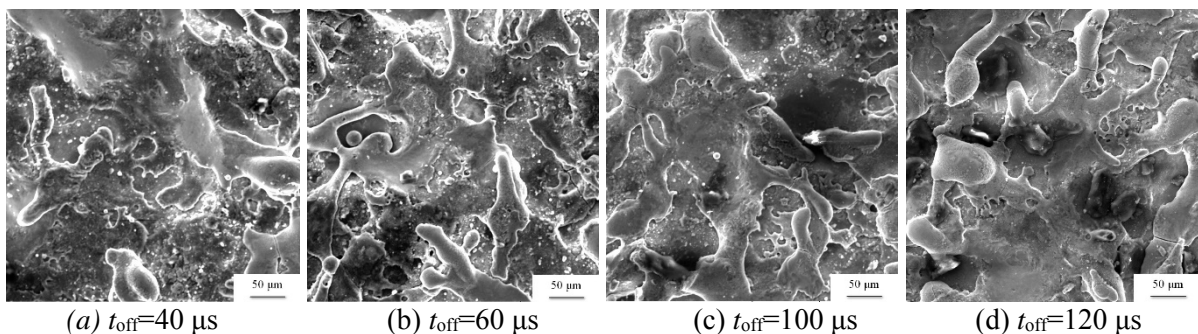
Fig. 3(a) shows when the pulse width is small, the discharge pit is relatively small and deep, the dendritic growth is short, and the surface roughness is relatively large. It can be seen from (b) (c) that the dendritic structure on the surface of the strengthening layer gradually becomes coarser and larger, the number of the discharge etch pit becomes larger and shallower, the layer is superimposed tightly, and the splash droplets attached to the surface gradually increase. As the pulse width increases, the discharge energy and the discharge channel gradually increase uniformly, resulting in a large area of uniform discharge etch pit on the surface of the workpiece, and the higher energy causes the molten material thrown by the reaction to grow vigorously, and the superposition is closer. When the pulse width is gradually increased, the strengthening layer in (d) has more molten spatter and small particles adhere, the petal-like structure has a tendency to narrow, there is a local micro-crack distribution.



**Figure 4.** Hardness value curve of hardened layer under different pulse width enhancement conditions.

It can be seen from Fig. 4 that the hardness value of the strengthening layer is about 2.5 times higher than the average hardness value of the matrix, and the difference in hardness value under different pulse width strengthening conditions is about 100 HV. When  $t_{on}=40 \mu s$ , the average hardness value of the strengthening layer is the lowest. As the pulse width increases, the hardness value increases gradually, but the increase is not large. However, under the same pulse width enhancement condition, the hardness values at different positions of the strengthening layer are different. At  $t_{on}=100 \mu s$ , the hardness value curve is the most gradual, indicating that the strengthening phase distribution in the strengthening layer is the most uniform.

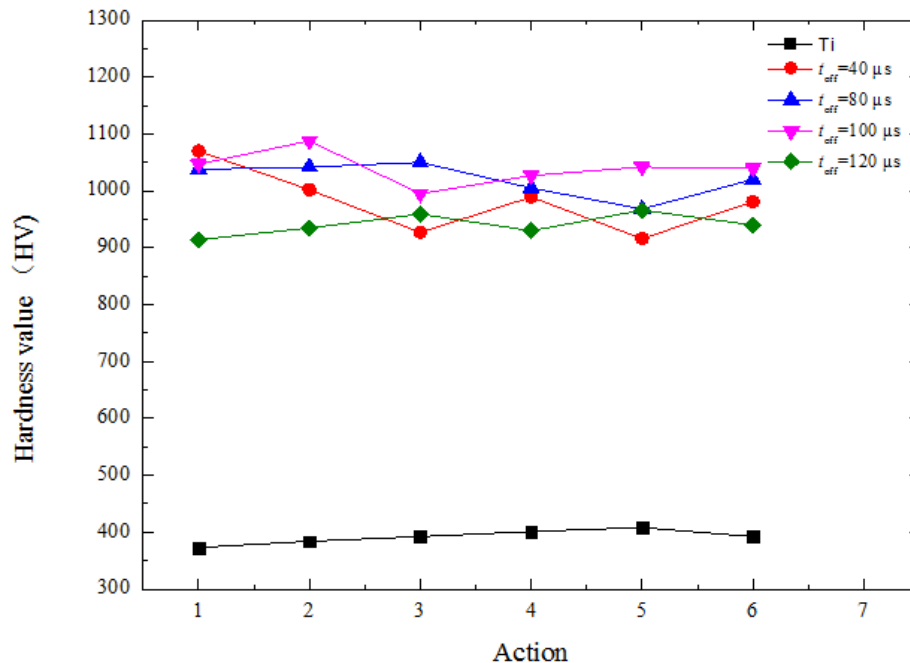
### 3.3. Effect of pulse clearance on the performance of reinforcing layer



**Figure 5.** Microstructure morphology of TC4 titanium alloy after different pulse clearance enhancement.

Fig. 5(a) shows the smaller the discharge frequency between the pulses in the same time is, the closer the position of the single-pulse discharge etch pit is, and the erosion of the etched material is more uniform after each discharge. Fig. 5 (b) (c) shows as the pulse gap is further increased, the dendritic structure of the strengthening layer gradually becomes wider and smooth, and the pulse width is  $100 \mu s$ , the surface finish is more rational. It can be seen from Fig. 5 (d) that when the pulse gap reaches the

maximum, the dendritic structure of the strengthening layer is gradually narrowed and the splash is obvious.



**Figure 6.** The hardness value curve of hardened layer under the condition of different pulse clearance enhancement.

It can be seen from Fig. 6 that the hardness value of the strengthening layer is about 2.6 times higher than the hardness value of the matrix, and the hardness difference of the strengthening layer under different pulse width strengthening conditions is about 100 HV, The average hardness value of the strengthening layer is the lowest under the pulse gap  $t_{off}=120 \mu s$ , and the highest hardness value and the curve are relatively stable when  $t_{off}=100 \mu s$ .

#### 4. conclusion

Results are summarized as follows: The microstructure of the strengthening layer obtained under different processing parameters is mostly chrysanthemum shape. When the peak current and pulse width are larger, the petal-like tissue is coarser and more uniform. The micro hardness of the surface of the strengthening layer is obviously improved compared with the TC4 titanium alloy material under different processing parameters, both of which are more than 2.5 times, When the peak current is 6.6~8.2A, the pulse width is 60~100 $\mu s$ , and the pulse gap is in the range of 80~100 $\mu s$ , the morphology and hardness of the strengthened layer are relatively good.

#### Acknowledgments

This work was financially supported by National Natural Science Foundation of China (No.51301121 and 51305301).

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