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Mechanical Characteristics of Pumimpeller Blades Surface Produced by Electro-Spark Deposition

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Surface strengthening technology is an important mean to improve the surface or fatigue performance of material. The metallographic structure and microstructure of the coating were analyzed by electrospark deposition test, the hardness, microstructure and abrasion resistance of the pump blade were tested by selecting and controlling the process parameters. The experimental results manifest that EDM can significantly improve the hardness, wear resistance and corrosion resistance of the blade surface, and reduce the consumption of the underwater environment. In addition, in the case of the same electrical parameters, the thickness of the strengthened layer in the argon atmosphere is slightly lower than that in the air, and strengthened surface roughness is significantly reduced. Hence, the reason may be two aspects, one is due to the protection of argon atmosphere, eliminating the impact of oxidation, the droplet easier to spread in the substrate surface, the other hand is similar to the principle of welding. Consequently, the electrode material in the form of a transition to the workpiece in the form of transition to the surface. Due to the small droplets, it can get a relatively low enhanced surface roughness, which is to improve the reliability and extend the life of the pump is of great significance.

1. Introduction

Cavitation is a kind of liquid kinetics phenomenon to capture characters' attention, and maybe produce a lot of tiny bubbles because of low pressure. It forms the repeated load of high frequency and high pressure on the surface of the contact surface, which causes the wall of the blade to bear fatigue and destroy (Barash and Kahlon, 1964, and, Kruth et al., 1995, and, Kunieda and Yoshida, 1997). An advocated it for the first time, scholars in Japan have first demonstrated the feasibility of air-borne spark discharge (Parkansky et al., 1993, and, Giulio et al., 2016). Subsequently, if not most researchers have studied the discharge of an electric spark in the air. In recent years, domestic scholars have done a lot of investigation on gas micro-EDM (Electrical Discharge Machining) deposition (Zhang et al., 2012). Afterwards, the usual liquid containing gas (such as oxygen, etc.) or solid cavitation nuclei, by means of bubble condensation heat release on the metal leaf from the chemical corrosion, resulting in the surface of the pockmarks to cause pitting holes (Zhang et al., 2016, and Janmanee and Muttamara, 2012, and, Agarwal and Dahotre, 1998; Xi, 2016; Edgar and Edgar, 2016). In particular, thickness of the pump blade is the balance in terms of thinner the better, in improving the efficiency of the pump at the same time, but also for the long-term cavitation damage brought about by hidden dangers (Zhang et al., 2016, and, Lee et al., 1988). Actually, it is serious when metal grains loose and flake showing a honeycomb-like or even the wall erosion, leading to pump impeller life is much shorter, lower operating efficiency, and accompanied by vibration and noise and other defects. Pulsed electrode deposition alloying technology is developed on the basis of the traditional process of metal deposition on the surface of the new process (Estévez et al., 2009, and, Lin et al., 2013, and, Bailey, 1992, and, Azhari et al., 2012). The weld layer and the matrix can form a metallurgical combination of high bonding strength, and it also forms the deposition layer on the metal surface through the appropriate electrode material. Additionally, its mechanical properties and chemical properties are superior to the original metal surface, which can extend the service life of metal products. In this regard, the technique has the advantages of low investment, sample preparation process and

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flexible use, and does not make the workpiece annealed or deformed under the condition of heat transfer. It can be applied to the surface of the part and can be deposited on the plane or surface of the general geometrical shape (Xu et al., 2015, and, Alexander and Orhan, 2003). Moreover, the coating prepared on the metal surface of the blade can remarkably improve the hardness, wear resistance and corrosion resistance of the metal, and it has great application prospect in metal repair.

However, the ionized YG8 electrode material can be transferred to the surface of the blade by high-speed transfer under the electric field. Without destroying the circumference datum of the cavitation defect, the roots of the leaves and the outer edge of the deposition of the formation of dense wear-resistant corrosion-resistant metallurgical-type solid binding layer (Gärtner et al., 2006, and, Carlos et al., 2015, and, Wick et al., 2000, and, Heitman, 2004). Accordingly, the nanostructured coating was formed on the surface of the blade by controlling the deposition rate and adjusting the output power. Needless to say the white layer, the transition layer and the heat-affected zone were formed in the cavitation damage area of the blade, and the grain structure should be small. Furthermore, containing nanocrystalline grains, to improve the performance of the deposited layer (Li et al., 2013, and, Monteleone and Giaconia, 2013, and, Picas et al., 2009, and, Irissou et al., 2008, and, Xie and Wang, 2009, and, Kornienko et al., 2011). The surface of the pump blade surface treatment to enhance the surface, so that the ultimate access to small surface microstructure, thereby greatly improving the pump blade wear resistance and corrosion resistance. The results show that the high performance of thin shell hardened layer introduced by strong spark discharge is an important factor to improve the life of pump blade.

2. Experiment and Technology

First, with a fine sandpaper polish the surface of the substrate to remove the rust of the blade surface, dirt and other impurities, the damaged leaves and the outer edge of the concentration of 99.5% acetone solution washed and dried for about 10min. Next, the ground clip of the EDM device is clamped on the edge of the blade and the YG8 cemented carbide electrode with a diameter of 5mm is clamped on the tip of the gun. The chuck is adjusted so that the electrode is located at the center as far as possible (Tkachenko et al., 2013). The output frequency is 300-1400Hz, and deposition power is 1-5min/cm^2. Finally, open the argon gas atmosphere to protect a good flow of 10L/min, and press the hand-held motor switch and switch self-locking button, real-time adjustment of the gun axis and the blade surface normal angle. So that the electrode and the blade surface was 30°-50° in a certain direction of movement, around the circuitous swing amplitude of 15mm-30mm, after deposition of a layer, the specimen rotated 90° to continue deposition, making the sedimentary layer has a bright metallic color. The microcells in contact with the blade surface instantaneously flow through the high density current of 105-106 A/cm^2. The elongated length of the electrode is 2-8mm, other deposition Process Parameters such as Table 1.

Table 1: Deposition process parameters

Sediments	Current (A)	Time (Min)	Shielding gas
Substratum	2	15	Ar
Surface layer	3-5	30	Ar

Owing to the new type DZS1400 type sparking equipment, YG8 (mainly composed of WC and Co) as the consumable electrode of the anode is fixed in the deposition gun at the blade surface high speed rotation, protected by the argon atmosphere atmosphere of the welding material. A high density current (105-106A/cm^2) is instantaneously flowed to the microcells in contact with each other on the electrode rod and the blade surface under the condition of high-temperature (5000□-10000□), which is caused by the air ionization between the YG8 and the stainless steel blades, which makes the short-circuit between the high-speed rotating welding consumables and the water pump blades. The high temperature generated in the tiny region of the discharge makes the local material of the region ionized.

3. Results and Discussion

3.1 Hardness testing

In strict accordance with the following table processes specification deposition layer, thickness of about 30-50um. 20H steel surface by EDM after tungsten carbide deposition in the steel surface of the formation of three different with the matrix metallographic structure. From the surface and the inside, the most surface layer of the white layer, followed by the transition layer, the third layer is the heat-affected zone and then goes inside the original matrix of steel in Figure 1.

As can be seen from Figure 1 the bright white layer exposed surface, good corrosion resistance, this layer of the organizational structure and composition depends on the electrode and the metal material (Teplenko et al., 2002, and, Zamulaeva et al., 2008). Close to the white layer is the transition layer, which is formed by infiltration and diffusion of some of the constituent elements of the electrode material into the matrix metal material and then quenched rapidly. From the metallographic photographs of the transition layer black, mainly due to high temperature cooling, the precipitation of small carbides attached to the fine martensite above, after corrosion black. The heat affected zone is mainly due to the high temperature discharge of the role of this layer of steel to the original organization of the steel by different effects, and the color of the corrosion after the transition from shallow to shallow, indicating that the heating temperature is not the same, Its main organization is tempered martensite. Hardness test carried sample indentation in Figure 2, 20H steel through the same material deposition, hardness than cast iron deposition effect, but the composition is stable, metallographic display, the organizational structure of small uniform.

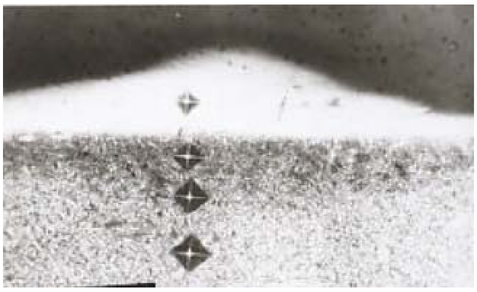

Figure 1: Sedimentary facies

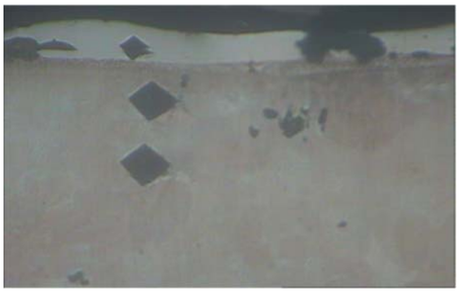

Figure 2: Sample indentation figure

This test used the HSV1000 microhardness tester to measure the hardness of the EDM layer. The composition of the EDM layer is related to the material of the electrode and the substrate, and the distribution of the composition is also related to the deposition process specification. The YG8 cemented carbide was used as the electrode, and the deposited layer of the stainless steel was analyzed as the result of the distribution of the elements in the sedimentary layer in Figure 3. Although the spark deposition process time is extremely short, but the composition of the electrode and the workpiece are the proliferation of various elements (Wang et al., 2014). Wherein elements such as Fe, Cr, Mn, and Ti in the matrix material diffuse to the surface layer, and the elements in the electrode material and the base material have penetrated each other. The results are shown in Figure 4. The results show that the hardness of the deposited layer is higher than that of the substrate, and the hardness of the deposited layer is higher than that of the substrate from the sedimentary layer to the substrate of the transition layer. The hardness of the deposited layer is up to 1400 HV and the average hardness is 1331HV. The hardness of the deposited layer is higher than that of the substrate, and the microhardness of the substrate from the deposited layer to the transition layer gradually decreases. We have to enhance the surface layer distance of less than 20um called the deposition layer, 20um-30um called the transition layer, greater than 30um for the matrix. It is known from the above that the structure of the deposited layer contains complex carbides of high hardness and the like, and these carbides having a fine granular high hardness are dispersed in a dispersed form, and since the heating and cooling of the spark deposition is instantaneously performed. Since EDM heating and cooling are instantaneous, there is a high density of dislocations and a high residual stress, which lead to a higher microhardness of the deposited layer.

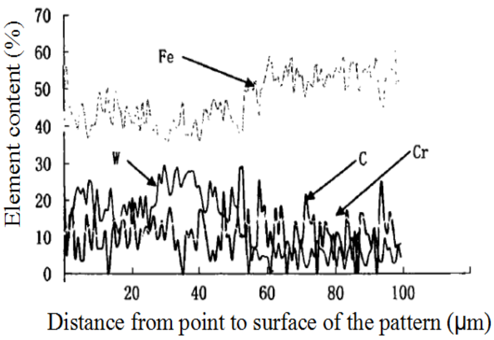

Figure 3: Elements distributing in deposited coating

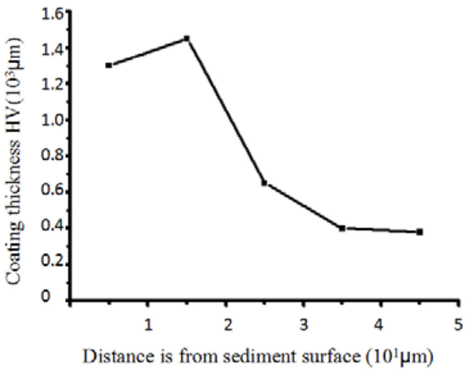

Figure 4: Hardness curve along with distance change

3.2 Wear mechanism of reinforced

The surface-strengthened and non-sparked surface-hardened specimens were subjected to a wear test, and the results are shown in Figure 5. The comparison of absolute wear shows that the wear resistance of the strengthened specimen is better than that of the unenhanced specimen, which shows that the hardened layer has a good wear resistance. Therefore comparison of Wear Resistance between EDM and unreinforced Surface Layer, the abrasion marks in the strengthening layer are mainly peeling off from the formation of carbides, and the furrows on the base metal are deeper, and the hard carbides removed from the metal surface play the role of abrasive grains. The main wear mechanism is abrasive wear. Although the hardened layer has high hardness and good wear resistance, the brittleness is large. Under the normal stress, the brittle phase develops microcracks and expands, which eventually leads to the crushing and falling off of the hard phase particles and the formation of peeling pits. As the time expands, the area of the carbide exfoliation increased and deepened. Therefore, the peeling of the carbides exerts a controlling effect on the wear of the reinforcing layer.

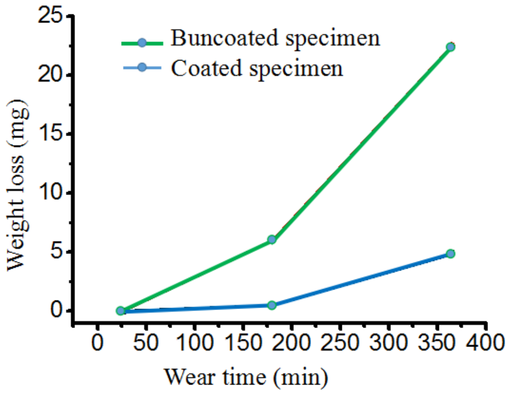

Figure 5: Comparison of wear resistance

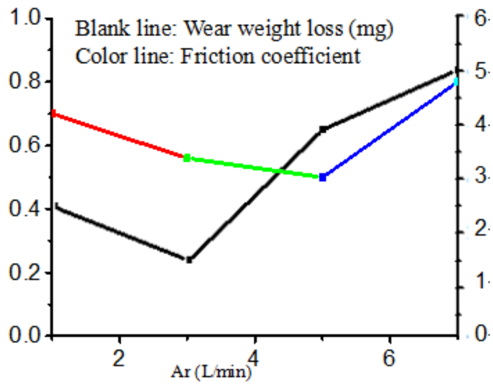

Figure 6: Friction coefficient and wear weight loss

Here, we choose argon flow as a variable for comparison and study. The influence of argon flow rate on the friction and wear properties of the tungsten carbide spark-enhanced layer is shown in Figure5. With the increase of the flow rate of argon gas, the friction coefficient and weight loss of the Ni-based hardening layer decrease. When the argon flow rate is 5L/min, the friction coefficient and weight loss of the strengthening layer are the minimum. However, if the flow rate of argon gas continues to increase (7L/rain), the friction coefficient and wear amount of the strengthened layer increases, so the argon gas flow rate of 5L/min. Tungsten carbide strengthening layer has the lowest friction coefficient and the best wear resistance, and the structure and the wear morphology of the tungsten carbide strengthened layer prepared under different argon flow is shown in Figure 6. It can be seen that argon flow is too small (1L/rain), not enough to form a good protection, EDM in the tungsten carbide deposition is easy to oxidize, affecting the quality of the strengthening layer, the wear surface of the strengthening layer serious rugged phenomenon with large pieces of peeling marks, which indicates that the oxidation layer due to deterioration caused by wear and tear increased weight loss, the wear mechanism is mainly micro-brittle fracture wear.

Argon gas flow rate is appropriate (5L/min), argon played a good protective effect. On the one hand can effectively avoid the oxidation of the strengthening layer. On the other hand, by blowing an argon gas stream having a cooling effect on the reinforcing point, the surface hardening region is hardened by the micro-hardening effect, so that the structure of the reinforcing layer is uniform and compact, the porosity is small, and the bonding strength is high, and the abrasion resistance is enhanced. When the argon gas flow rate increased to 7L/min, the wear surface of the strengthening layer appeared a lot of peeling, fracture and other phenomena, the main wear mechanism of micro-fracture wear. Because the argon gas flow is too large, although the oxidation of the material to avoid the phenomenon, but the deposition process will produce a rebound in the substrate surface after the formation of turbulence. And the inclusion of air into the protection one will cause micro cracks and holes in the strengthening layer. This will reduce the compactness of the microstructure and strengthen the wear.

4. Conclusions

In summary, this work discussed surface strengthening technology, the hardness of the hardened layer is improved, which is mainly due to the high hardness carbide structure. The surface properties of the strengthening layer does not depend largely on the electrode material used, but rather different electrode materials can be used to achieve different properties as required. Additionally, the abrasion resistance of the specimens treated by the surface strengthening treatment is significantly higher than that of the untreated samples, and the main wear mechanism is abrasive wear. Furthermore, protective gas argon flow should be controlled about 5L/min, strengthen the organization of uniform density, porosity, showing overwhelmingly wear resistance. In addition, argon gas flow rate is too small or too large, will cause oxidation of the strengthening layer or to strengthen the layer to produce defects such as pores or micro-cracks, thereby reducing the wear resistance of the reinforcement layer.

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