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# **Study on Surface Modification of Aluminum Alloy Electron Beam for Surgical Medical Devices**

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**Abstract.** Surgical and medical devices need excellent lightweight, surface abrasion resistance, corrosion resistance and other characteristics. In this paper, the surface modification of 6061 aluminum alloy commonly used in medicine is studied. The method of electron beam cladding 1Cr13 stainless steel powder is used to improve aluminum. The surface hardness and abrasion resistance were studied. The influence of electron beam process parameters on the cladding effect was studied. This method Provides new ideas for upgrading the industrialization of medical devices.

#### 1. Introduction

The development of medical devices began in more than 2500 BC, referring to instruments, equipment, appliances, in vitro diagnostic reagents and calibrators, and other similar or related items used directly or indirectly on the human body [1]. It is divided into three categories according to the risk level. Surgical instruments belong to the first category, which requires lightness, good flexibility and toughness, high temperature resistance, and corrosion resistance [2]. To this end, surgical medical equipment has extremely high requirements on the surface properties of the materials, and the surface modification treatment can effectively increase the surface hardness, corrosion resistance and wear resistance of the materials [3-5]. For example: nitriding, carburizing, carbonitriding, ion implantation, laser cladding, physical vapor deposition, etc. Electron beam, as the currently popular high-energy beam processing method, has been valued by researchers at home and abroad, and a lot of research has been conducted on medical 6061 aluminum alloy.

In this paper, 6061 aluminum alloy is subjected to electron beam cladding treatment to improve the comprehensive surface performance of the sample.

# 2. Experimental

#### 2.1. Test materials and sample preparation

The chemical composition of the 6061 aluminum alloy selected in this test is shown in Table 1. A 40  $mm \times 40 mm \times 30 mm$  aluminum alloy block was prepared by machining. The aluminum alloy surface was coated with 1Cr13 stainless steel by mechanical pressing.

Mechanical pressing method: First, a pressing mold is made. The upper mold is # 45 steel after quenching and tempering, the size is 40 mm $\times$ 30 mm $\times$ 50 mm, the width of the boss is 9mm, the height is 1.8mm, and the lower mold is an aluminum alloy sample. The size is 40 mm $\times$ 40 mm $\times$  30 mm, the groove width is 10mm, and the depth is 2mm. The difference between the height of the upper die boss and the depth of the lower die groove is exactly 0.2mm, as shown in Figure 1. After the upper and

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lower molds are made, the lower mold, especially the groove, is cleaned with acetone. Mix 200 mesh 1Cr13 stainless steel powder with anhydrous alcohol, put the mixed powder into the groove of the lower mold, align the lower mold with the upper mold, and finally compact it with a hydraulic press [6]. After repeating it twice, the lower mold was placed in a heating furnace and kept at 80°C for 120 minutes.



(a) Punch (b) Die Figure 1. Schematic diagram of mechanical pressing method.

# 2.2. Electron beam treatment

The electron beam machine uses a homemade electron beam welding machine. The main parameters of the equipment are: acceleration voltage 0-60kV, electron beam current 0-120mA, scanning frequency 0-3000Hz, focus current 0-1000mA. Adopting the centralized down beam scanning method, the electron beam process parameters are as follows:

	Table 1. Electron beam process parameters					
	Acceleration voltage(Kv)	Current beam (mA)	Beam diameter (D/mm)	Moving speed (V/mm/s)	Scanning frequency (Hz)	
1#	60	20	240	7	200	
2#	60	25	240	7	200	
3#	60	30	240	7	200	
4#	60	35	480	7	200	

# 3. Results and discussion

3.1. Microstructure analysis of specimen cross section

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Figure 2. Sample 2 Microstructure analysis of specimen. (a) Overall organization chart,(b) Collective organization, (c) Strengthened area organization, (d) Transition area organization, (e) Enhanced area XRD pattern.

Select sample # 2 for tissue morphology analysis, as shown in Figure 2. Its overall organization can be divided into three parts: strengthening zone, transition zone and matrix. The structure of the matrix area is mainly composed of  $\alpha$  -Al and Mg<sub>2</sub>Si, and a small amount of Al<sub>2</sub>Cu (as shown in Figure 2 (b)). As shown in Figure 2 (e), the structure is mainly composed of ferrite, acicular martensite, and Fe-Al compounds (Figure 2 (c)). After the addition of 1Cr13 stainless steel, the surface of the sample is rapidly heated and melted and solidified after the electron beam treatment. This process is similar to quenching, so a martensitic structure is formed on the surface. The metal element on the surface is mixed with the matrix element under the driving force, thereby forming an Fe-Al compound. The structure of the transition zone is mainly composed of  $\alpha$ -Al, martensite, and Fe-Al compounds (Figure 2 (d)). As a whole, the tissue particles in the matrix area are larger, the tissue particles in the strengthening area are obviously refined, and the tissue particles in the transition area are smaller than the matrix. The fineness of the tissue particles is due to the rapid heating and melting of the surface material after high energy electron beam treatment, and the formation of a large temperature gradient with the help of the cold state of the matrix. The molten material is under a great degree of subcooling Cool and solidify. Due to the short action time of the electron beam and the fast solidification speed, the grains of the tissue have solidified before they grow up, resulting in fine grains.

### 3.2. Microhardness

The cross-section hardness of the specimen decreases non-linearly with increasing distance from the surface. After the electron beam treatment, the hardness of the reinforced area of the 3 # sample is the highest, reaching 190HV, which is about three times that of the matrix. The hardness of the reinforced area of the 4 # sample is the second, which is 182HV. Compared with other samples, the hardness of the strengthened area of sample 1 is the lowest, about 160HV, but it is 2.5 times higher than the hardness of the matrix. The depth and width of the modified layer are the largest for the 4 # sample, which are about 5.5mm and 6mm, respectively, and the smallest for the 1 # sample, which are about 3.5mm, 3mm, and the 3 # sample are the next, respectively. 5mm, 5mm.

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#### 4. Summary and Prospect

After the mechanical pressing of the sample by electron beam surface alloying treatment, the structure of the surface strengthening zone is mainly composed of ferrite, martensite, and Fe-Al intermetallic compounds, and the grains are fine.

The surface properties have also been improved. The maximum surface hardness of the sample is 183 HV, and the average hardness of the reinforced layer is at least 2.5 times higher than that of the matrix.

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