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Morphology and Microstructure of CuCrNb Alloy Prepared by Electron Beam at Different Energy Densities

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Abstract

By studying the SEBM printing process under different linear energy densities, the effects of scanning current and scanning speed on the surface morphology and microstructure of the formed specimen were determined. When the energy is too large, the surface will form bulging phenomenon, as well as violent splashing phenomenon, it is necessary to adjust the preheated process to make the powder slightly sintered, which can also prevent the occurrence of powder blowing. At the same time, the reasons for the formation of internal pores under different parameters were analyzed, when the linear energy density was small, it would lead to the existence of unmelted powder, micropores would accumulate, and when the line energy was large, the metal vapor evaporated due to excessive energy would not have time to escape and form a key hole, and the process window for printing CuCrNb alloy under ArcamA2X equipment was small, and it was necessary to continue to explore suitable process parameters to achieve a density of more than 99.9%.

Keywords

Electron Beam Printing; CuCrNb Alloy; Linear Energy; Density Surface; Topography Porosity.

1. Introduction

GRCop-84 alloy, as a new type of copper alloy, has excellent electrical and thermal conductivity properties. At the same time, fine dispersion compound Cr2Nb will be precipitated inside the printing, which makes the alloy have high strength and creep resistance at high temperature[1]. This new alloy can replace Narlay-Z copper base alloy (Cu-Ag-Cr) as a new generation of rocket engine combustion chamber lining material[2]. However, compared with the single casting molding or the traditional casting process, AM technology can effectively improve the work efficiency and reduce the cost.

Through additive manufacturing (AM) technologies such as selective laser melting (SLM) and selective electron beam melting (SEBM), direct net forming of parts can be achieved, and bottom-up two-dimensional superposition can be formed by computer aided design (CAD) model, which greatly reduces the difficulty of forming complex parts. In the SLM process of copper alloy, Cu shows high reflectance to the laser, and the laser energy can not efficiently melt Cu. Improvement of absorption rate 2.optimization of construction parameters 3.deformation of powder surface. Sebm use the electron beam as the heat source, and the alloy has high energy absorption with respect to copper. At the same time, the SEBM forming process must go through a preheating phase. It reduces residual stress and prevents component cracking. It also prevents copper from oxidizing in a vacuum environment. Guschlbauer R [3] observed that the microstructure of the sample was mainly columnar crystal with a hardness of 46.1HV under the conditions of power of 600 W and scanning speed of 1 m/s. However, under the conditions of power of 850 W and scanning speed of 1.5 m/s, isometric

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crystal appeared. The microhardness was 47.4HV. Ramirez [4] used gas atomized copper powder with a purity of 99.8% and prepared the sample with Arcam A2. A large number of precipitate dislocations were observed in the directly printed samples, which significantly increased the hardness of the samples.

The microstructure and properties of CuCrNb alloy with different composition and different process parameters are obviously different. Therefore, the microstructure and phase distribution can be changed by adjusting different process parameters. Therefore, it is necessary to systematically study the relationship between processing parameters, microstructure and mechanical properties, and develop a suitable process window to obtain printing process parameters for follow-up research.

1.1 Printing Scheme

A series of SEBM printing experiments were carried out based on the Arcam A2X system. Before printing, the electron beam was vacuumed and the light spot was concentrated on the printing platform under the action of Astigmatism coil, Focus coil and Deflection coil. The substrate is then heated and kept warm for a period of time using an electron beam before printing[5]. Sample number distribution is S1, S2, S3... Yes. The scanning strategy adopts the serpentine scanning mode, rotating 90° between each layer, and preparing the cube sample with a side length of 3cm. The preheating temperature is selected as 350 degrees Celsius. Due to the strong thermal conductivity of cu, it is difficult to maintain a high temperature [6]. The key parameters changed in this study are the beam spot current and scanning speed. The printed internal build diagram is shown in Figure 1.

2. Experiment and Characterization

2.1 Experiment

In this study, the key parameters that determine the change of line energy are the beam spot current and scanning speed, and the change of these parameters makes the line energy density.The current divided by the velocity is the linear energy density.The printed internal build diagram is shown in Figure 1.

Figure 1. Schematic diagram of Arcam A2X device

2.2 Page Numbers

The sample numbers are distributed from S1, S2, S3 to S9. The scanning strategy adopts the serpentine scanning mode, rotating 90° between each layer, and preparing the cube sample with a side length of 3cm. The preheating temperature is selected as 350 degrees Celsius. Due to the strong thermal conductivity of cu. The key parameters changed in this study are the beam spot current and scanning speed. The electron beam path is shown in Figure 2, and the random scanning strategy is adopted

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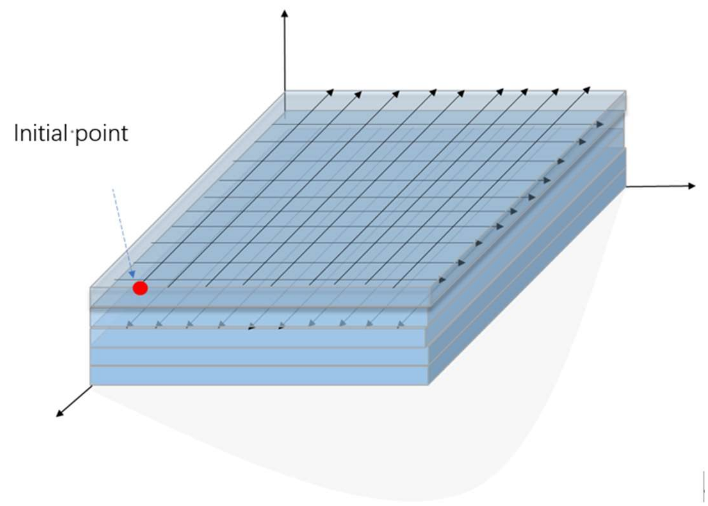

Figure 2. Print the scanning strategy diagram

The process parameters for preparing CuCrNb alloy samples by SEBM are shown in Table 1, where I is the beam current, v is the scanning speed, and d is the layer thickness. The optimal research process parameters were matched by the three-factor and four-level orthogonal method, and the development process and subsequent characterization were carried out.

Table 1. Processing parameters of CuCrNb alloy samples fabricated by SEBM. I is the beam current, v is the scanning velocity, d is the layer thickness,

Sample	I(mA)	V(mm/s)	d(μm)
S1	9	700	50
S2	9	1700	50
S3	15	700	50
S4	15	1700	50
S5	12	1200	50
S6	9	1200	50
S7	12	700	50
S8	12	1700	50
S9	15	1200	50

3. Results

3.1 Sebm process technology

The samples were constructed with different linear energy densities, and nine sets of different parameters were formed under the same preheating process by mainly controlling the beam spot current and scanning speed. Corresponding to the nine cubes, the linear energy densities ranged from 0.3 to 1.2. The plot shows the relative density change over the studied LE range. In the melting process of SEBM, the change of process parameters can directly or indirectly change the energy input, which will affect the stability of the molten pool, solidification rate and temperature gradient, and the resulting defects such as pores will significantly reduce the mechanical properties. In order to control this, the main goal is to develop a process parameter to achieve a relative density of more than 99.9%.

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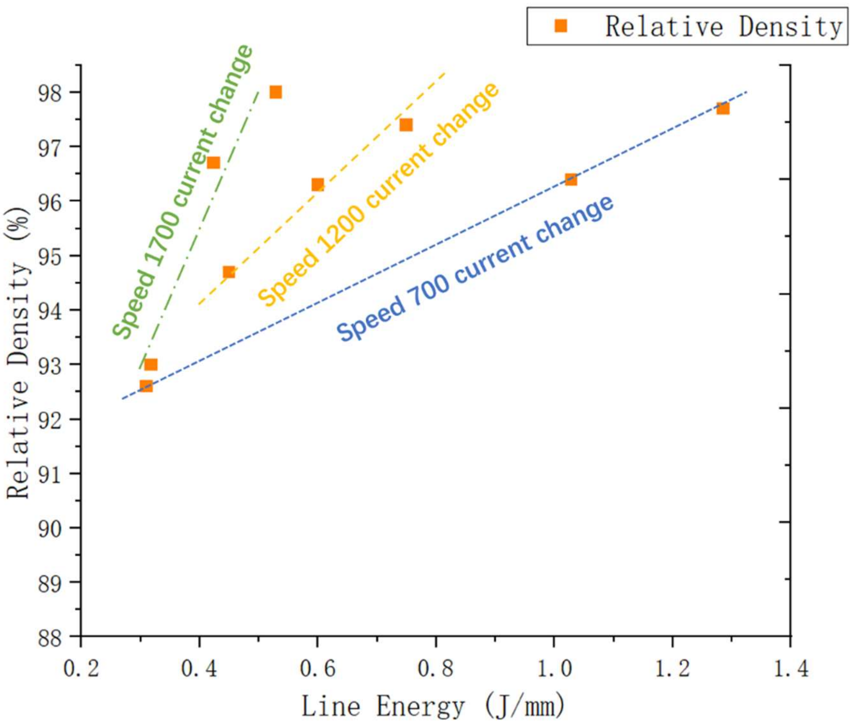

Figure 3. Relationship between EBMcucrnb sample relative density and linear energy density

Three regions with distinct characteristics can be seen from the relative density in Figure 3. Within the range of online energy density 0.3-0.45J/mm, internal pores are mainly small and micropores, distributed throughout the sample. The main reason is that insufficient energy to melt the powder leads to insufficient fusion porosity, and the pores in this region mainly exist in the form of small and micropores. The energy density of the second region is distributed in the range of 0.5-0.8J/mm, which is the region with the strongest correlation, and the highest density is achieved when the online energy density is 0.529J/mm. When the energy continues to increase beyond 1.0J/mm, pores reappear but mainly irregular polygons. Due to the excessive energy output of the electron beam, the molten pool will be unstable, and the metal vapor formed after overheating or overburning will not escape because of the solidification of the molten metal and form in the metal structure.

3.2 Spatter Phenomenon

Electron beam is one of the important parameters affecting surface forming, which directly affects the size of the input energy of the electron beam. When the beam is too small, the powder fusion is not enough to produce spheroidization phenomenon, and the surface is uneven, affecting the thickness of the next powder layer, resulting in pore defects. However, when the beam is too large, it is easy to cause sputtering, overburning and other phenomena. Scanning speed is another important factor affecting the quality of SEBM. It controls the energy input of the electron beam obtained by the powder bed at the same volume per unit time. If the scanning speed is too slow, the electron beam will be kept in the molten pool for a long time, and the accumulation of the molten pool will be unstable, which is prone to spatter phenomenon. However, when the scanning speed is too fast, the powder in the unit volume is not completely melted, and the spherodization phenomenon occurs to form pore defects, resulting in a decrease in the density of the formed parts [7-10].

3.3 Surface Topography Study

In the printing process, powder is spread on the entire printing platform. Based on the scanning strategy of the printing equipment, the energy of the electron beam is concentrated in the specified area, and the energy is dispersed in the nearby area. There is CuCrNb powder in the shape of droplet and unmelted bulge at the scanning boundary. There are no warping edges, a small number of spattered metal particles, and nodular defects. When the energy is further increased, although the surface scan line is clear, there is a large amount of bulge phenomenon, the bulge phenomenon is caused by the fact that when the energy input is too large and the scanning speed is fast, the life of the molten pool is longer, and a large amount of liquid phase is generated, and the scanning line will play a stirring role in the molten pool, resulting in the instability of the molten pool. Therefore, under the combined action of thermal capillary force, surface tension and melting pool agitation, the melt in the molten pool flows violently, and the melt cannot spread evenly along the surface of the sample, and it is easy to form a bulge in the place with high surface tension. In the subsequent layer-to-layer melting process, the surface bulge accumulates continuously, and the surface bulge eventually forms a phenomenon of surface bulges. As shown in Figure 4, when the linear energy input is too large, there are many macroscopic pores on the surface, and the surface has obvious overmelting phenomenon and obvious bulging. However, sample No. 2 with the lowest energy is significantly different from other samples, mainly in that the surface is relatively flat, the hole aperture is an order of magnitude lower than that of other samples, and the printing scan line is not clear. This indicates that the existing defects will be further deepened, and the failure to control the parameters will lead to increased defects of the sample, affecting the density and other mechanical properties.

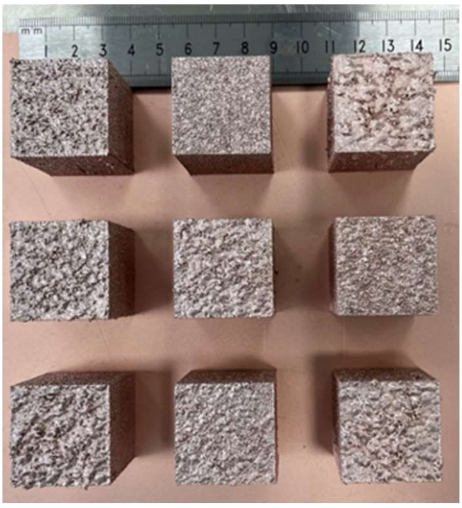

Figure 4. Surface morphology of CuCrNb alloy SEBM printed form.

4. Conclusion

I In this study, the preparation of Cu-8Cr-4Nb alloy and the effect of process parameters on the density and pore formation were studied, and the micro-morphology of the fracture at different linear energy densities was determined, which provided a reference for the subsequent development of the process window of SEBM additive manufacturing of more than 99.9% of the alloy.

(1). Excessive line energy in electron beam printing will lead to the formation of irregular pores, and excessive line energy density will also increase sputtering, further affecting the surface topography and reducing the printing density.

(2). In the process of electron beam printing, if the linear energy density is too small, there are mainly prototype pores in the alloy, and the amount of unmelted powder is more, but the surface is relatively flat, and the splash phenomenon of the melt pool is not obvious.

(3).The process window of copper alloy is very small, and the surface pores are immediately reduced when adjusted to the appropriate parameters, while the scan line is clearly visible, and the density is also greatly improved.s.

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