**Claims**

1. A crack suppression method for high entropy alloy powder bed fusion additive manufacturing process, characterized by comprising the following steps:

S1: powder composition design: conduct composite microalloying composition design on high entropy alloy powder;

S2: powder surface amorphous alloy coating treatment: modify the surface of the high entropy alloy powder obtained in S1 and coat it with a layer of amorphous alloy coating;

S3: process parameter optimization and thermo mechanical coupling simulation: based on the composite powder characteristics obtained in S2, establish a thermo mechanical coupling finite element model to simulate and optimize the laser powder bed melting forming process parameters;

S4: real time control of the melt pool: under the optimized process parameters in S3, preliminary forming of high entropy alloy is carried out, and a dynamic sensor monitoring system for the melt pool is synchronously implemented to adaptively adjust the process parameters and obtain a single-layer alloy overlay entity;

S5: inter-layer ultrasonic treatment: after each deposition layer is melted and before laying the next layer of powder, high-energy ultrasonic impact treatment is applied to the surface of the solidified layer;

S6: multi level heat treatment: perform three-layer serialized heat treatment on the additive manufacturing parts that have undergone ultrasonic impact treatment to obtain the final high entropy alloy parts.

2. The crack suppression method for high entropy alloy powder bed fusion additive

manufacturing process according to claim 1, characterized in that: the powder composition design in S1: performing theoretical composition design based on a crack sensitivity index model, requiring a CSI value ≤ 0.15, and preparing the following raw materials in atomic percentage: 18.5%-20.5% iron, 18.5%-20.5% cobalt, 18.5%-20.5% nickel, 18.5%-20.5% chromium, 14.5%-16.5% manganese, as well as composite micro-alloying additive elements comprising 1.0%-1.2% titanium, 0.08%-0.10% boron, 0.15%-0.25% silicon, and 0.04%-0.06% yttrium rare-earth element.

3. The crack suppression method for high entropy alloy powder bed fusion additive manufacturing process according to claim 2, characterized in that: the powder composition design in S1: weigh the raw materials in the designed proportion and prepare them using vacuum induction melting combined with gas atomization method, the preparation process is as follows:

S1.1 place the raw materials in a vacuum induction melting furnace, evacuate to below $4.5\times10^{-3}$Pa, and then fill with high-purity argon gas of ≥ 99.999% to a pressure of 0.05-0.10MPa, using high-purity argon gas as a protective and atomizing medium;

S1.2 heat the raw materials to 1600-1650 ℃ and keep them at a medium frequency electromagnetic stirrer with a rated stirring power of 60% -80% for 10-14 minutes;

S1.3 atomization powder production: the alloy melt with uniform composition is guided to the atomization nozzle through a bottom guide tube, and the tightly coupled gas atomization method is used to crush and solidify the melt into liquid droplets under high-purity argon gas pressure of 6.5-7.5 MPa;

S1.4 powder collection and screening: the atomized powder is cooled in a closed settling chamber and then screened using a graded screening system, spherical powders with a particle size range of 10-50μm are selected as additive manufacturing raw materials, with a powder sphericity of ≥ 96% and an oxygen content of ≤ 200ppm.

4. The crack suppression method for high entropy alloy powder bed fusion additive manufacturing process according to claim 1, characterized in that: the powder surface amorphous alloy coating treatment in S2: mixing the high entropy alloy powder obtained in S1 with coating raw material powders comprising zirconium, titanium, nickel, copper, and aluminum in predetermined proportions, wherein the atomic percentages of the coating raw materials are: zirconium 50%-55%; titanium 4%-6%; nickel 8%-12%; copper 20%-25%; aluminum 8%-12%.

5. The crack suppression method for high entropy alloy powder bed fusion additive manufacturing process according to claim 4, characterized in that: the powder surface amorphous alloy coating treatment in S2: employing a high energy ball milling mechanical alloying process, wherein the high entropy alloy powder and the coating raw materials are processed under the following parameters: ball-to-powder ratio of 12:1, rotational speed of 350-450 rpm, and processing duration of 5-8 hours, the entire process is conducted under the protection of argon gas with a purity greater than 99.99%, causing the coating raw materials to undergo a solid-state reaction on the surface of the matrix powder, thereby forming a Zr-based amorphous alloy coating with a thickness of 90-120 nm.

6. The crack suppression method for high entropy alloy powder bed fusion additive manufacturing process according to claim 1, characterized in that: the process parameter optimization and thermo mechanical coupling simulation in S3:

S2.1 based on the properties of the composite powder with a surface amorphous coating prepared in S2, establish a three-dimensional transient finite element model that comprises the powder layer, melt pool, solidified entity, and substrate.

S2.2 introduce the critical crack driving force C into the three-dimensional transient finite element model as a key quantitative indicator for evaluating hot-cracking tendency, its calculation formula is:C= (dσ/dt) / (dT/dt), where σ is the local thermal stress, T is the temperature at the corresponding point, and dσ/dt and dT/dt represent the stress rate and temperature rate respectively within the brittle temperature range during solidification, the objective of simulating and optimizing the process parameters is to ensure that the maximum value of C throughout the entire process does not exceed 1.4MPa/℃.

S2.3 based on the model from S2.1 and the criterion from S2.2, perform iterative simulation calculations by inputting historical data into the model, finally, determine the optimal process parameter window for laser powder bed fusion to suppress solidification cracks as follows: laser power: 200-250 W, scan speed: 1100-1400 mm/s, scan spacing: 100-110 μm, layer thickness: 30-35 μm, substrate preheating temperature: 175-180 °C.

7. The crack suppression method for high entropy alloy powder bed fusion additive manufacturing process according to claim 1, characterized in that: the real time control of

the melt pool in S4 employs a coaxially integrated high-speed photodiode and infrared thermal imager to monitor in real time the radiation intensity signal and brightness temperature distribution of the melt pool, the monitored signals are compared in real time with an ideal melt pool characteristic map extracted from the model in S3, when the monitored values deviate continuously from the ideal range for more than three scanning tracks, the control system adaptively fine-tunes the laser power or scanning speed for the next region within the process window determined in S3 based on a preset PID algorithm, thereby achieving dynamic and stable control over the melt pool size and solidification behavior.

8. The crack suppression method for high entropy alloy powder bed fusion additive manufacturing process according to claim 1, characterized in that: the inter-layer ultrasonic treatment in S5 comprises:

S5.1 after the closed-loop control system in S4 confirms completion of the scanning of the current layer, the system automatically triggers a non-contact ultrasonic generator, which is interlocked with the powder-spreading device, before the recoater spreads a new powder layer, the generator emits high-energy ultrasonic shockwaves at a frequency of 50-60 kHz onto the surface of the formed layer according to a preset program.

S5.2 based on calculations using the Hall-Petch relationship and the dislocation-density strengthening model, the ultrasonic amplitude is precisely controlled within the range of 20-40 μm, and each region is treated for 0.5-1.0 seconds, this ensures that the shockwave energy density E transmitted to the material surface reaches 10-16J/cm², refining the average grain size by more than

30% at a depth of 60-180 μm below the surface.

9. The crack suppression method for high entropy alloy powder bed fusion additive manufacturing process according to claim 1, characterized in that: the multi level heat treatment in S6: placing the formed part in a vacuum heat-treatment furnace and implementing a three-step heat-treatment protocol.

10. The crack suppression method for high entropy alloy powder bed fusion additive manufacturing process according to claim 9, characterized in that: the three-step heat-treatment protocol is executed in the following sequence:

(1) first step: heat to 600-650 °C at a rate of 5-10 °C/min, hold for 2-3 hours, then furnace-cool to below 300 °C.

(2) second step: rapidly heat to 1150-1200 °C, perform solution treatment for 1-1.5 hours, followed by water quenching.

(3) third step: carry out aging treatment at 750-800 °C for 4-6 hours, then air-cool, assisted by Thermo-Calc thermodynamic software, the uniform precipitation of nanoscale Ti- and Ni-rich L12 ordered phases is controlled.