luminance average value and a luminance standard deviation.

[0015]

Hereinafter, an embodiment of the present invention will be described with reference to the accompanying drawings. First, a method for predicting a defect (a method for estimating a defect) of an additive-manufactured product will be described with reference to FIGs. 1 to 4, and then a method for manufacturing an additive-manufactured product will be described with reference to FIGs. 5 and 6.

[0016]

<Method for predicting defect of additive-manufactured product>

[0017]

[Luminance data acquisition step (S101)]

First, when a melt pool is formed by irradiating metal powder with a heat source or the like and melting the metal powder, luminance (luminance data) of light emitted from the melt pool is acquired. A laser beam or the like can be used as the heat source.

[0018]

Light used in the embodiment can be, for example, reflection light when a laser beam is irradiated, light generated due to an increase in temperature of a melt pool or a heat affected zone, plasma light made by irradiating a laser beam to metal vapor generated by melting a metal and turning the metal into plasma, or the like. Preferably, it is better to detect luminance with high detection sensitivity. Specifically, it is better to detect light emitted from the melt pool and the vicinity thereof, in other words, light with a wavelength in a range of 600 nm or more and 1100 nm or less.

[0019]

As a method for acquiring (detecting) luminance (luminance data) of light, for example, a sCMOS camera can be used. As for specifications of the sCMOS camera, for example, the number of pixels may be 50,000 pixels or more, and a photographing speed may be about 1

frame per second. More specifically, EOSTATE Exposure OT (manufactured by EOS Company) can be used. The EOSTATE Exposure OT photographs surroundings of the melt pool using the sCMOS camera, in which luminance generated from a manufacturing area irradiated with a laser from just above is provided obliquely above. While the sCMOS camera is installed obliquely above a manufacturing surface, it is possible to compensate for the distance and the angle through software and convert them to an observation image from above. The luminance (OT luminance) acquired by the sCMOS camera may be luminance of a near infrared area during manufacturing. In order to acquire the luminance of the near infrared area, for example, a band pass filter may be provided on the sCMOS camera.

[0020]

[Evaluation data extraction step (S103)]

Next, evaluation data is extracted from the luminance data obtained in the luminance data acquisition step (S101). The evaluation data includes a luminance average value and a luminance standard deviation.

[0021]

The luminance average value is an average value in which a unit of luminance is expressed with Gv, blue indicates zero, red gradually indicates a maximum value of 4.5×10^4, and luminance (color degree) is integrated every 100 msec (photographing speed: 100 msec) during manufacturing. That is, the luminance average value is an average value of pixel luminance values of a luminance image (an average value of luminance acquired in 1 pixel of the image). In addition, the luminance standard deviation indicates evaluation of variation of each pixel luminance of the image in each layer.

[0022]

[Evaluation step (S105)]

Then, the presence/absence of a defect of an additive-manufactured product is estimated by comparing the luminance average value range and the luminance standard deviation range

[0033]

<Method for manufacturing additive-manufactured product>

So far, while the method for predicting a defect of the additive-manufactured product has been described, according to the method for predicting a defect of the present invention, it is possible to manufacture the additive-manufactured product while evaluating the defect of the additive-manufactured product during additive manufacturing.

[0034]

As the embodiment of the method for manufacturing the additive-manufactured product, the method has a additive manufacturing process including a powder supply step of supplying metal powder, a manufacturing step of irradiating the metal powder with a heat source and manufacturing the additive-manufactured product by melting and solidifying the metal powder, and a luminance data acquisition step of acquiring luminance data of light emitted from the melt pool formed when the metal powder is melted, and an inspection process including an evaluation data extraction step of extracting evaluation data from the luminance data and an evaluation step of estimating the presence/absence of the defect of the additive-manufactured product using the evaluation data, and the evaluation data includes a luminance average value and a luminance standard deviation. Hereinafter, each step will be described in detail with reference to FIG. 5 and FIG. 6.

[0035]

FIG. 5 is a view schematically showing an additive manufacturing device 100 configured to manufacture the additive-manufactured product. The additive manufacturing device 100 includes a stage 102, a base plate 103, a powder supply container 104 configured to supply a metal powder 105 to the base plate 103, a recoater 106 configured to form a powder layer 107 on the base plate 103, a laser oscillator 108, a galvanometer mirror 110, a non-melted powder collecting container 111 configured to collect the metal powder 105 that was not melted, a sCMOS camera 113 configured to detect light emitted from a melt pool formed when the metal

powder 105 is melted in a solidified layer 112 obtained by melting and solidifying the metal powder 105 with a laser beam 109 irradiated from the laser oscillator 108, and a luminance data acquisition device and an evaluation data extraction device 114 configured to convert the light detected by the sCMOS camera into luminance data and extract evaluation data. In addition, FIG. 6 shows a flow of the method for manufacturing the additive-manufactured product.

[0036]

(Additive manufacturing process)

[Powder supply step: S201]

First, the stage 102 is lowered to an extent of a 1-layer thickness (for example, about 20 to 50 μm) of an additive-manufactured product 101, which will be manufactured. Next, the metal (raw material) powder 105 is supplied from the powder supply container 104 to the base plate 103 of the upper surface of the stage 102, and the metal powder 105 is flattened by the recoater 106 to form the powder layer 107.

[0037]

[Manufacturing step: S203]

Next, the additive-manufactured product 101 is built in a desired geometry on the basis of geometry information of the additive-manufactured product 101, which will be manufactured, for example, 2-D slice data converted from 3D-CAD data. Specifically, a micro melt pool is formed by irradiating the metal powder 105 on the non-melted powder layer 107 spread over the base plate 103 with the heat source irradiated from the laser oscillator 108, for example, the laser beam 109 irradiated from the laser oscillator 108 through the galvanometer mirror 110. Then, the metal powder 105 is melted and solidified to form the solidified layer 112 having a 2-D slice geometry by scanning the laser beam 109 while irradiating it. Further, the non-melted metal powder 105 may be collected in the non-melted powder collecting container 111.

[0038]

[Luminance data acquisition step: S205]

In the manufacturing step (S203), at the same time powder of an $(n+1)^{th}$ layer of the additive-manufactured product is melted and solidified, the luminance data upon melding of the powder to an n^{th} layer of the solidified layer is acquired using the sCMOS camera 113, the luminance data acquisition device and the evaluation data extraction device 114. Here, as for the specifications of the sCMOS camera 113, as described above, for example, the number of pixels may be 4,000,000 pixels or more and a photographing speed may be about 10 frames per second. More specifically, the sCMOS camera 113, the luminance data acquisition device and the evaluation data extraction device 114 can use, for example, the EOSTATE Exposure OT (manufactured by EOS Company). The EOSTATE Exposure OT photographs surroundings of the melt pool with the sCMOS camera installed obliquely above the luminance generated in the manufacturing area irradiated with a laser from vertically above. While the sCMOS camera is installed obliquely above the manufacturing area, it is possible to compensate a distance and an angle on the software and convert it like an observation image from above. The luminance (OT luminance) acquired by the sCMOS camera may be a luminance of a near infrared area during manufacturing. In order to acquire the luminance of the near infrared area, for example, a band pass filter may be provided in the sCMOS camera.

[0039]

When building to the extent of one layer is terminated, the stage 102 is lowered and new metal powder 105 is supplied on the solidified layer 112 to form a new powder layer 107. The newly formed powder layer 107 is irradiated with the laser beam 109 to be melted and solidified, thereby forming a newly solidified layer. Then, the desired additive-manufactured product 101 can be manufactured by repeating the powder supply step (S201) and the manufacturing step (S203) and forming the solidified layer 112. In addition, an inspection process may be executed after manufactured by repeating the powder supply step (S201) and the manufacturing step (S203), or may be repeated including, for example, an evaluation data extraction step (S207).

for the above-mentioned steps.

[0046]

Accordingly, since the presence/absence of the defect can be estimated for each part, each layer of 1 batch (1 plate) of the additive manufacturing, i.e., in-process (real time), it is possible to manufacture the additive-manufactured product while inspecting the additive-manufactured product.

[0047]

Upon completion of the above-mentioned step, in all the solidified layers (the melted and solidified layers) of the additive-manufactured product, the presence/absence of the defect generated in the additive-manufactured product can be estimated (evaluated) by recording and storing the luminance signal intensity from the melt pool as the luminance average value and the standard deviation upon melting and solidifying.

[0048]

Since the additive-manufactured product 101 is built on the base plate 103 to be fabricated integrally and covered with the non-melted metal powder 105, upon taking out, after cooling the metal powder 105 and the additive-manufactured product 101, the non-melted metal powder 105 may be collected, and the additive-manufactured product 101 and the base plate 103 may be taken out of the powder additive manufacturing device 100. After that, the additive-manufactured product can be obtained by separating (cutting or the like) the additive-manufactured product 101 from the base plate 103.

[0049]

Further, as the additive manufacturing method of the embodiment, powder bed method can be used. As the powder bed method, there is a method of spreading the metal powder to prepare the powder layer, and radiating a laser beam or an electron beam that is thermal energy to melt, solidify or sinter only the manufactured area. The method of melting and solidifying the manufacturing area of the powder layer using a laser beam as a heat source is referred to as

selective laser melting (SLM), and a method of sintering the manufacturing area of the powder layer without melting it is referred to as selective laser sintering (SLS). In the method of using the laser beam as the heat source, in general, the additive manufacturing can be performed under an inert atmosphere such as nitrogen or the like. In addition, the powder layer method can use the electron beam as the heat source, and is referred to as selective electron beam melting (SEBM) or electron beam melting (EBM). In the method of using the electron beam as the heat source, the additive manufacturing can be performed under high vacuum.

[0050]

Hereinabove, while the embodiment of the method for manufacturing the additive-manufactured product has been described, since the presence/absence of the defect of the additive-manufactured product can be estimated in-process and the additive-manufactured product can be manufactured by immediately applying a new additive manufacturing condition using the evaluation results, the effect of reducing a defect rate of the additive-manufactured product can also be expected. In addition, for example, evaluation of the defect by a non-destructive inspection X ray CT is eliminated, and reduction in manufacturing cost of the parts can also be expected.

Examples

[0051]

Hereinafter, examples will be described.

The additive-manufactured product is manufactured using a powder additive manufacturing device (EOS M290 manufactured by EOS Company) and a monitoring instrument (EOSTATE Exposure OT (Optical Tomography)), and the presence/absence of the defect is estimated.

[0052]

The metal powder used in the additive manufacturing is Ni-Cr-Mo-based alloy shown in Table 1.

deviation range are greater than those of the test piece of No.1, and defects were also found in the evaluation using the X ray CT.

[0060]

Hereinabove, for example, in the manufacturing geometry and the manufacturing condition in the example, when the luminance average value and the luminance standard deviation obtained from the additive-manufactured product are less than the maximum value of the luminance average value and within the luminance standard deviation range of the test piece of No. 2, the evaluation can be performed when there is no defect in the additive-manufactured product. In addition, like the case in which the coefficient of variation CV is used, when the calculated coefficient of variation CV is within the coefficient of variation CV range of the test piece of No. 2, the evaluation can be performed when there is no defect in the additive-manufactured product.

[0061]

Further, the above-mentioned embodiment or example is described to assist understanding of the present invention, and the present invention is not limited only to the specific configuration described above.

[Reference Signs List]

[0062]

100: Additive manufacturing device

101: Additive-manufactured product

102: Stage

103: Base plate

104: Powder supply container

105: Metal powder

106: Recoater

107: Powder layer

108: Laser oscillator

109: Laser beam

110: Galvanometer mirror

111: Non-melted powder collecting container

112: 2-D slice-shaped solidified layer

113: sCMOS camera

114: Luminance data acquisition device and evaluation data extraction device

200: Region 1

210: Specimen 1

220: Powder layer position 1

300: Region 2

310: Specimen 2

320: Powder layer position 2

400: Flow gas

[CLAIMS]

[Claim 1]

A method for predicting a defect of an additive-manufactured product manufactured by melting and solidifying metal powder, the method comprising:

a luminance data acquisition step of acquiring luminance data of light emitted from a melt pool formed when the metal powder is melted and solidified;

an evaluation data extraction step of extracting evaluation data from the luminance data; and

an evaluation step of estimating the presence/absence of a defect of the additive-manufactured product using the evaluation data,

wherein the evaluation data includes a luminance average value and a luminance standard deviation.

[Claim 2]

The method for predicting a defect of an additive-manufactured product according to claim 1, wherein, in the evaluation data extraction step,

a coefficient of variation CV is calculated from the luminance average value and the luminance standard deviation, and

in the evaluation step,

the presence/absence of a defect of the additive-manufactured product is estimated using the coefficient of variation CV.

[Claim 3]

A method for manufacturing an additive-manufactured product, the method comprising:

An additive manufacturing process including: a powder supply step of supplying metal powder, a manufacturing step of irradiating the metal powder with a heat source, melting and solidifying the metal powder, and manufacturing the additive-manufactured product, and a luminance data acquisition step of acquiring luminance data of light emitted from a melt pool

formed when the metal powder is melted; and

an inspection process including an evaluation data extraction step of extracting evaluation data from the luminance data and an evaluation step of estimating the presence/absence of a defect of the additive-manufactured product using the evaluation data,

wherein the evaluation data includes a luminance average value and a luminance standard deviation.

[Claim 4]

The method for manufacturing an additive-manufactured product according to claim 3, wherein, in the evaluation data extraction step,

a coefficient of variation CV is calculated from the luminance average value and the luminance standard deviation, and

in the evaluation step,

the presence/absence of the defect of the additive-manufactured product is estimated using the coefficient of variation CV.

[Claim 5]

The method for manufacturing an additive-manufactured product according to claim 3 or 4, further comprising, in the inspection process, a selection step of determining whether to continue the additive manufacturing process.