allow a lower frame rate for image capture and therefore generates less image data. A profile of the cooling of the consolidated powder layer is used to infer the build quality of each level. However, by monitoring the cooling characteristics of the solidified powder, there is already an inherent delay in feedback control to the laser.

[0007] Any reference herein to a patent document or other matter which is given as prior art is not to be taken as an admission that that document or matter was known or that the information it contains was part of the common general knowledge as at the priority date of any of the claims.

Summary of the Invention

[0008] One aspect of the present invention provides an additive manufacturing system for fabricating 3D objects from successive layers of material, the additive manufacturing system comprising:

an energy projection assembly for inputting energy into a specified area within the layer to consolidate the material;

a plurality of image sensors, each of the image sensors having a corresponding field of view covering at least part of the layer of material, such that each of the fields of view at least partially overlap with the field of view of at least one other of the image sensors; and,

an image processor to capture image data from each of the image sensors; wherein during use;

the image processor controls exposure times for each of the image sensors and combines the image data from the image sensors to provide a single, spatially resolved image of the energy being input throughout the specified area for each layer of material respectively for comparison against threshold data values to locate potential consolidation defects in the specified area;

wherein the exposure times are staggered and partially overlapping with each other.

[0009] Throughout the description and claims of the specification, the word "comprise" and variations of the word, such as "comprising" and "comprises", is not intended to exclude other additives, components, integers or steps.

[0010] The additive manufacturing system according to embodiments of the present invention uses relatively long exposure times to capture a single image of the area being melted or sintered in that layer of powder. The overlapping image data from each of the relevant image sensors is combined to generate a single, spatially resolved image of the energy input at all points within the specified area. The pixel data from this single image is compared to a reference image and differences exceeding a predetermined variance are identified as potential defects in that layer of material. Each layer or 'slice' of the 3D object has a corresponding reference image and the single image generated from the image sensors is compared to the reference image for that slice.

[0011] Locating potential defects from a single image rather than a large set of images captured at high frame rates dramatically reduces the amount of data processing. This in turn reduces processing times such that real time feedback control of the fabrication process requires far

[0024] Preferably, the image sensors are positioned directly above the layer of material such that their optical axes are normal to the layer. In this case, the system is integrated into the PBF equipment during assembly. Being directly above the power layer reduces the need to correct for perspective.

[0025] Preferably the image processor is configured to use the image data for the single, spatially resolved image of the specified area for feedback control of the energy projection assembly.

[0026] Preferably the additive manufacturing system is a selective laser sintering (SLS) system, a selective laser melting (SLM) system or an electron beam system and the image sensors are configured to record light emissions from molten material at a point of energy input scanning across the area of interest in the layer. The skilled worker will understand that the term 'light' refers to electro-magnetic radiation including infra-red, visible and ultra violet light.

[0027] In a related aspect of the invention, there is provided an additive manufacturing system for fabricating 3D objects from successive layers of material, the additive manufacturing system comprising:

an energy projection assembly for inputting energy into a specified area within the layer to consolidate the material;

a plurality of image sensors, each of the image sensors having a corresponding field of view covering at least part of the layer of material, such that each of the fields of view at least partially overlap with the field of view of at least one other of the image sensors; and,

a processor configured to control exposure times for each of the image sensors and combine the image data from the image sensors to provide a single, spatially resolved image of the energy being input throughout the specified area for each layer of material respectively for comparison against threshold data values to locate potential consolidation defects in the specified area;

wherein the exposure times are staggered and partially overlapping with each other;

wherein the potential consolidation defects are identified as defect regions of the specified area having insufficient energy input; wherein,

the processor operatively controls the energy projection assembly to selectively apply energy to the defect regions.

[0028] Preferably, the processor is further configured to vary input power to the energy projection assembly to adjust the energy input to the material.

[0029] Preferably the energy selectively applied to the defect regions is controlled by the processor to provide the material with a customised microstructure.

[0030] Preferably customised microstructure differs from the microstructure of the material in the remainder of the specified area.

[0031] In some embodiments, the energy projection assembly has a scanning energy beam (such as a laser or electron beam) and the processor is configured to selectively control one or more of the following process parameters during the application of energy to the defect regions:

scan speed;

scan acceleration;

scan direction;

hatch distance (being the spacing between adjacent scan tracks);

CLAIMS

1. An additive manufacturing system for fabricating 3D objects from successive layers of material, the additive manufacturing system comprising:

an energy projection assembly for inputting energy into a specified area within the layer to consolidate the material;

a plurality of image sensors, each of the image sensors having a corresponding field of view covering at least part of the layer of material, such that each of the fields of view at least partially overlap with the field of view of at least one other of the image sensors; and,

an image processor to capture image data from each of the image sensors; wherein during use;

the image processor controls exposure times for each of the image sensors and combines the image data from the image sensors to provide a single, spatially resolved image of the energy being input throughout the specified area for each layer of material respectively for comparison against threshold data values to locate potential consolidation defects in the specified area;

wherein the exposure times are staggered and partially overlapping with each other.

2. An additive manufacturing system according to claim 1 wherein the image data from the single, spatially resolved image is resolved into scan vectors with associated intensity values corresponding to individual laser tracks followed the laser scan head.

3. An additive manufacturing system according to claim 1 wherein the image sensors are CCD (charge-coupled device) arrays, CMOS (complementary metal oxide semi-conductor) arrays, or sCMOS (scientific-CMOS) arrays.

4. An additive manufacturing system according to claim 1 wherein the image processor is configured to selectively activate and deactivate the image sensors when the point of energy input is within areas of overlap between the corresponding fields of view.

5. An additive manufacturing system according to claim 1 wherein the energy projection assembly is configured to deactivate between successive layers for a predetermined deactivation period, and the image processor is configured to activate and deactivate the image sensors to capture the single spatially resolved image within a capture period that is less than half the

predetermined deactivation period such that the image processor is able to detect the end of the energy input process for each of the successive layers.

6. An additive manufacturing system according to claim 1 further comprising a build chamber for housing a build platform to support the layer of material, the build chamber having one or more viewing windows for observing the build process wherein the image sensors are mounted outside the build chamber and view the build platform through the one or more of the viewing windows.

7. An additive manufacturing system according to claim 6 wherein the image sensors are positioned to view the layer of material on the build platform at an angle inclined to the normal of the layer, and the image processor is configured to manipulate the image data from each of the image sensors to correct for perspective.

8. An additive manufacturing system according to claim 1 wherein the image sensors are positioned directly above the layer of material such that their optical axes are normal to the layer.

9. An additive manufacturing system according to claim 1 wherein the image processor is configured to use the image data for the single, spatially resolved image of the specified area for feedback control of the energy projection assembly.

10. An additive manufacturing system according to claim 1 wherein the system is a selective laser sintering (SLS) system, a selective laser melting (SLM) system, or a laser powder bed fusion (L-PBF) system and the image sensors are configured to record light emissions from molten material at a point of energy input scanning across the area of interest in the layer.

11. An additive manufacturing system according to claim 1 wherein the system is an electron beam melting system.

12. An additive manufacturing system according to claim 1 wherein the system is a masked energy projection system, in which the entire area of interest is simultaneously exposed to an energy beam of corresponding shape.

13. An additive manufacturing system according to claim 12 wherein the system is a stereolithography (STL) system or a digital light projection (DLP) system.

14. An additive manufacturing system for fabricating 3D objects from successive layers of material, the additive manufacturing system comprising:

an energy projection assembly for inputting energy into a specified area within the layer to consolidate the material;

a plurality of image sensors, each of the image sensors having a corresponding field of view covering at least part of the layer of material, such that each of the fields of view at least partially overlap with the field of view of at least one other of the image sensors; and,

a processor configured to control exposure times for each of the image sensors and combine the image data from the image sensors to provide a single, spatially resolved image of the energy being input throughout the specified area for each layer of material respectively for comparison against threshold data values to locate potential consolidation defects in the specified area;

wherein the exposure times are staggered and partially overlapping with each other;

wherein the potential consolidation defects are identified as defect regions of the specified area having insufficient energy input; wherein,

the processor operatively controls the energy projection assembly to selectively apply energy to the defect regions.

15. An additive manufacturing system according to claim 14 wherein the processor is further configured to vary input power to the energy projection assembly to adjust the energy input to the material.

16. An additive manufacturing system according to claim 15 wherein the energy selectively applied to the defect regions is controlled by the processor to provide the material with a customised microstructure.

17. An additive manufacturing system according to claim 16 wherein the customised microstructure differs from the microstructure of the material in the remainder of the specified area.

18. An additive manufacturing system according to claim 14 wherein the energy projection assembly has a scanning energy beam and the processor is configured to selectively control one or more of the following process parameters during the application of energy to the defect regions:

scan speed;

scan acceleration;

scan direction;

hatch distance being the spacing between adjacent scan tracks;

offset distance being a difference, if any, between an area scanned by the energy beam and the defect region;

beam focus in which the energy beam input spot size is altered; and

beam input power modulation to alter the energy beam power.

19. An additive manufacturing system according to claim 16 wherein the processor selects one or more of the following scan patterns during the application of energy to the defect regions:

directional rastering in which energy beam scan tracks extend back and forth in a regular hatching style pattern;

point exposure in which the energy beam is held at a fixed location proximate the defect region for a specified period of time;

nested contour loops in which the energy beam path is a contour-wise, nested rastering of discrete loops corresponding to the defect region shape; and,

spiral winding in which the energy beam path is a contour-wise, nested rastering of continuous loops corresponding to the defect region shape.

20. An additive manufacturing system according to claim 16 wherein the processor is configured to divide the defect region into a number of sub-regions and applies the energy to each of the sub- regions using different process parameters.

21. An additive manufacturing system according to claim 16 wherein the processor is configured to apply the energy to the defect region if the defect region is sufficiently proximate defect regions detected in at least one previous layer of the material.

22. An additive manufacturing system according to claim 21 wherein the processor is configured to control one or more of the process parameters during the energy input such that consolidation occurs in the previous layer as well.

23. An additive manufacturing system according to claim 16 wherein the processor is configured to detect excess energy input into the specified area and adjust process parameters for inputting energy into a specified area of a subsequent layer of the material.

24. An additive manufacturing system according to claim 16 wherein the processor is configured to access a database with the process parameters used during previous corrections of consolidation defects, and use information from the database to select the process parameters for the application of energy to the defect region.

25. An additive manufacturing system according to claim 24 wherein a plurality of like additive manufacturing systems record process parameter data into the database.

26. An additive manufacturing system according to claim 14 wherein the processor is configured to generate a record of build quality for each of the fabricated 3D objects in a two-dimensional slice form, or three-dimensional volume form, showing locations of the defect regions.

27. An additive manufacturing system according to any one of claims 24 to 26 wherein the processor is further configured to use information from the database to automatically identify regions with higher propensity for defects from recorded defects in previously built components or particular structures, and pre-emptively vary the process parameters to avoid defect formation.