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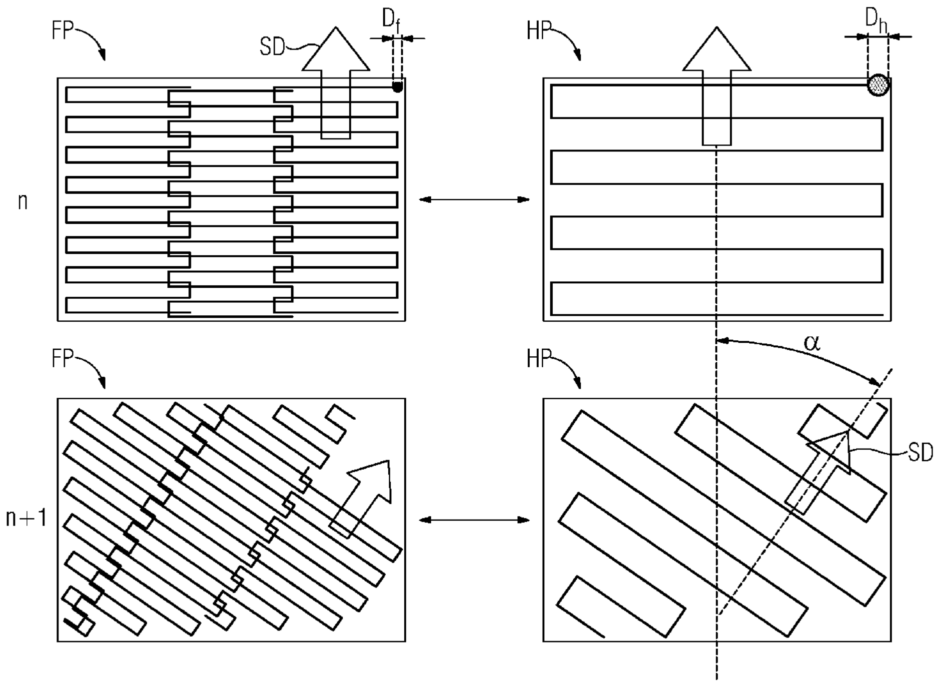
(54) Title: METHOD FOR HEATING A BASE MATERIAL IN ADDITIVE MANUFACTURING

FIG 3



(57) Abstract: A method for heating a base material (P) in additive manufacturing is provided. The method comprises, a), providing an energy beam (21) for the heating of the base material (P), wherein the base material (P) is arranged to at least partly form a manufacturing plane (MP), and, b), irradiating the manufacturing plane (MP) for the heating with the energy beam (21) under scaled irradiation parameters, wherein the scaled irradiation parameters are derived in that irradiation parameters for fusing the base material (P) are scaled by a scaling factor (s), and wherein the scaling factor (s) comprises a quotient of a heating beam diameter (Dh) and a fusion beam diameter (Df). Furthermore, a method of additive manufacturing, a method of providing an according irradiation pattern and a corresponding computer program product are provided.

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Description

Method for heating a base material in additive manufacturing

The present invention relates to a method for heating, preferably pre-heating or post-heating, a base material for the additive manufacture of a component. Further, an according additive manufacturing method is provided. Furthermore, a method of providing an irradiation pattern, and a corresponding computer program or computer program product are provided.

Preferably, the component denotes a component applied in a turbo machine, e.g. in the flow path hardware of a gas turbine. The component and/or the base material is preferably made of a nickel- or cobalt-based superalloy, particularly a precipitation hardened alloy.

Turbo machines, particularly those for power generation purposes, are subject to steady development in order to increase efficiency. This development is actually gaining significance in view of restrictions which are to be implemented to comply with climate change and global warming mitigation. Further progress in turbine efficiency is e.g. complicated as operation temperatures of the hot gas path of gas turbines, would yet have to be increased. At the same time there is a stringent demand to apply the turbo machines in a less steady operational mode, e.g. on demand in peaker plants when there is a high demand for electricity, for example. This poses significant challenges particularly for the materials applied in the given machines, as for example the discontinuous (on demand) use highly increases material fatigue due to the involved warming and cooling cycles and therewith the number of the so-called “equivalent operating hours”. Thermo-mechanical fatigue and creep behaviour are here the dominant issues which pose the main challenges for the turbo machine materials.

Additive manufacturing, particularly powder-bed-fusion (PBF) methods, such as selective laser melting (SLM), selective laser sintering (SLS) or electron beam melting (EBM) have proven to be useful and advantageous in the fabrication of prototypes or complex components, such as components with a maze-like or convoluted structure or functionally cooled components. Further, the additive manufacture stands out for its short chain of process steps which in turn enables material economization and a particularly low lead time.

A method of selective laser melting is described in EP 2 601 006 B1, for example.

The given approaches are suitable for fabricating, prototyping or manufacturing parts or components of complex shapes from a, preferably powdery, base material with a huge freedom of design.

Apparatuses or devices for such PBF-methods usually comprise a manufacturing or build platform on which the component is built layer-by-layer after the feeding of a layer of base material which may then be melted, e.g. by an energy beam, such as a laser, and subsequently solidified. The layer thickness is determined by a recoater or deposition apparatus that moves, e.g. automatically, over the powder bed and removes excess material from a manufacturing plane or build space. Typical layer thicknesses amount to between 20 µm and 40 µm. During the manufacture, said energy beam scans over the surface and melts the powder on selected areas which may be predetermined by a CAD-file according to the geometry of the component to be manufactured. Said scanning or irradiation is preferably carried out in a computer-implemented way or via computer aided means, such as computer-aided-manufacturing (CAM) instructions, which may be present in the form of a dataset. Said dataset or CAM-file may be or refer to a computer program or computer program product.

A computer program (product) as referred to herein may relate to a computer program means constituting or comprising a storage medium like a memory card, a USB-stick, a CD-ROM, a DVD or a file downloaded or downloadable from a server or network. Such program or product may also be provided by a wireless communication network or via transfer of the corresponding information by the given computer program (product) or computer program means.

The information or data defined e.g. defined by said computer program product or CAM-file preferably relates to a tool path or irradiation pattern according to which an additive manufacturing processor or device may perform or execute the irradiation. Said irradiation may pertain to a pre-heating, post-heating and, of course, as well to the actual solidification of the base material for the component.

The term "pre-heating" as referred to herein shall mean that the base material for the component is only prepared or heated for the actual subsequent solidification step, e.g. in order to avoid excessive thermal gradients during the melting/welding process. This may also be expedient for each layer of the component in order to limit thermal gradients in the additive process which may otherwise easily exceed 10^5 K/s.

Conventionally, such pre-heating may be carried out via a laser or electron beam of the corresponding manufacturing device, wherein this beam is scanned over the base material or manufacturing plane in a defocused way. Alternatively, induction coils can be conducted for the preheating of the base material.

The term "post-heating" as referred to herein shall denote a process which is preferably carried out after a solidification of the base material has already occurred and a structure for the component is established. Besides the limitation of thermal gradients, post-heating may be very helpful for mitigating or healing defects in the component's structure. It is apparent that the post-heating relates to the already solidified structure of the component formed of the base material, rather than to the base material in the loose or powdery state.

The mentioned thermal gradients are of course adverse for the resulting material structure and chemistry in terms of weld cracks and e.g. disproportionation of chemical constituents in the hardened and specialized alloys of the base materials.

In the face of industrialised additive manufacturing processes for complex shaped components, there is the stringent need to improve not only the actual solidification or welding process, but also to further develop preparation steps, such as pre-heating and/or post-heating in a reliable and as possible automated way.

It is, thus, an object of the present invention to provide means which help to solve the given problems or tasks, particularly to provide for a solution to scale or tailor a heating process in an expedient way, e.g. with respect to a subsequent or prior fusion step.

The mentioned object is achieved by the subject-matters of the independent claims. Advantageous embodiments are subject-matter of the dependent claims.

An aspect of the present invention relates to a method, such as an irradiation method for heating, such as pre- and/or post-heating, of the base material in additive manufacturing.

The method comprises providing an energy beam, such as a laser or electron beam, for the heating of the base material, wherein the base material is arranged to at least partly form a manufacturing plane. Accordingly, said manufacturing plane is, preferably, at least partly formed of the base material. Additionally, said manufacturing plane may at least partly be formed by an already solidified portion or structure of the component. In an initial state of the additive build-up process of the component, the manufacturing plane may even be formed by an underlying build plate.

The method further comprises irradiating the manufacturing plane, such as exposing the manufacturing plane for the heating with the energy beam under scaled irradiation parameters. In other words, the energy beam may be scanned over the manufacturing plane for heating purposes or may be exposed with the energy beam in an according way.

The scaled irradiation parameters are derived or rendered in that irradiation parameters for fusing the base material, e.g. for the solidification or the buildup of the component, are scaled, such as multiplied, by a scaling factor. The irradiation parameters for fusing may pertain to a conventional or known parameter set or irradiation pattern. To this effect said (given) irradiation pattern may be copied into a processor or processed in that the scaling factor is applied accordingly.

The scaling factor comprises a quotient of a heating beam diameter and a fusion beam diameter.

Said fusion beam diameter and/or said heating beam diameter, preferably both, pertain to the energy beam. Further, both diameters preferably constitute characteristic, specific or preset values.

The irradiation is, preferably, carried out according to an irradiation pattern. Said pattern may be predefined or the result of a CAM-file.

It is likely or preferred that the energy beam diameter in a heating mode (heating beam diameter) shall be or is usually chosen to be greater than the energy beam diameter in a fusion mode (fusion beam diameter), as the fusion or melting of the base material usually requires a greater spatial resolution; whereas for the heating - such as a pre-heating - the spatial energy density to be applied to the manufacturing plane shall be smaller. Further, the heating is desired to be carried out more efficiently or in a shorter time.

The present solution provides an automated, scaled and/or tailored heating procedure applicable for any component which is promising to be manufactured additively, wherein, the pre-heating is e.g. correlated with a given irradiation parameter set for the actual fusing process. Thus, important technical improvements are provided for the industrialisation and automation of additive manufacturing as a whole, without the need to individually adapt a heating strategy in a time-consuming and/or manually way, e.g. prior to any given build job.

The present invention is particularly important for high-performance materials, which require sophisticated thermal management prior to, during and/or after the respective additive buildup in order to provide the required structural or thermo-mechanical properties.

In an embodiment, the irradiation parameters for fusing at least comprise a hatch distance and a stripe width for the irradiation, wherein said hatch distance and/or said stripe width are scaled by the scaling factor. Additionally or alternatively, further parameters, such as a beam offset, or further irradiation parameters as listed herein below may be scaled by the scaling factor.

In an embodiment, the scaling factor amounts to values between 1 and 10.

In an embodiment, the scaling factor amounts to values between 2 and 5.

In an embodiment, a beam offset is defined for the irradiation and/or the heating which is chosen to about half of the heating beam diameter or a defocused beam diameter. According to this embodiment, the beam offset may not only be defined for the actual fusing, but also for any heating, such as a pre- or post-heating process. Thereby, accuracy and reproducibility of the manufacturing process can be improved as a whole, particularly in the manufacture of thermally or mechanically heavily stressed components for gas turbines. Particularly, the definition of the beam offset allows to provide and/or improve a contour irradiation strategy or corresponding heating cycles applied to the contour of the component.

In an embodiment, an idle or spare mode operation is selected for (vector) turns in the irradiation pattern resulting from the irradiation of the manufacturing plane. According to this embodiment, heat applied by the energy beam can advantegeously be controlled such that it does not exceed a maximum or upper limit above which heat may e.g. cause irreversible structural defects. Of course the vector turns in the irradiation pattern are particularly prone to such defects because the heat applied to these sites (turns between two hatching vectors) is increased due to an increased energy density, a given area of the base material is exposed to through the beam turn. For instance, such excessive heat input may result in an adverse material structure, e.g. pores. Nevertheless, an insufficient heat input may as well result in adverse material properties, such as un-melted regions.

In an embodiment the irradiation power or power density is reduced to 0 (zero) for regions or areas of the turns in the irradiation pattern only.

In an embodiment the irradiation power or power density is reduced to a lower value for regions or areas of the turns in the irradiation pattern only.

In an embodiment, the irradiation power or power density and/or an idle time for the heating is selected based on data, information or input from a thermal simulation or a monitoring means, such as a monitoring process or system.

Similar monitoring means are e.g. described in WO 2018/189301 A1.

In an embodiment, the irradiation of the manufacturing plane is carried out for preheating the base material.

In an embodiment, the irradiation of the manufacturing plane is carried out for post-heating of the base material or, as the case may be, a solidified structure of the component.

In an embodiment the irradiation of the manufacturing plane is repeated, such as repeated once or several times, prior to and/or after the additive buildup of the component. According to this embodiment, customised or specific heating cycles or heating ramps may be applied to the overall additive process also in a pre-heating or post-heating step. Thereby, in turn, a structural or compositional quality, such as a hardness, rigidity, thermo-mechanical fatigue or high cycle-fatigue behaviour, may be improved for the final component.

The latter advantages do not only apply for this embodiment but are rather valid for any embodiment of the present invention.

A further aspect of the present invention relates to a method of additive manufacturing a component comprising the method as described above, wherein the energy beam is a laser or electron beam of or on duty in an additive manufacturing device, wherein the method further comprises additively building up the component under the irradiation parameters for fusing the base material.

A further aspect of the present invention relates to a component manufactured by the method of additive manufacturing as described above.

A further aspect of the present invention relates to a method of providing an irradiation pattern or corresponding dataset comprising said pattern for additive manufacturing. Said method comprises irradiating the manufacturing plane for the heating as described above, wherein the irradiation pattern defines a tool path (e.g. comprising further irradiation parameters) for powder-bed-fusion or powder bed based additive manufacturing, and wherein said irradiation pattern can be processed in an additive manufacturing device. Said processing may relate to e.g. reading in, reading out or executing a CAM-file comprising the irradiation pattern.

A further aspect of the present invention relates to a computer program or computer program product comprising instructions which, when executed by a computer or a data processing device, cause the computer to carry out the steps of irradiating the manufacturing plane as described above. Said computer program product may particularly constitute or comprise the CAM-file as mentioned above, or corresponding program instructions.

In an embodiment, the irradiation of the manufacturing plane is carried out computer-implemented.

Advantages and embodiments relating to the described method for heating, method of additive manufacturing, method of providing the irradiation pattern and/or the described computer program (product) may as well pertain or be valid with regard to the other respective categories and/or the described component.

Further features, expediencies and advantageous embodiments become apparent from the following description of the exemplary embodiments in connection with the Figures.

Figure 1 indicates in a schematic sectional view an additive powder-bed-fusion manufacturing process.

Figure 2 indicates a simplified irradiation (vector) pattern for heating in additive manufacturing.

Figure 3 opposes fusion patterns and heating patterns in schematic illustrations for consecutive layers of a component to be manufactured according to the present invention.

Figure 4 indicates a simplified irradiation pattern according to another embodiment.

Figures 5 and 6 indicate a simplified irradiation pattern for still further embodiments.

Figure 7 indicates another embodiment of the presented method of heating according to the present invention.

Figure 8 shows a schematic flow chart of method steps of the present invention.

Like elements, elements of the same kind and identically acting elements may be provided with the same reference numerals in the figures. The figures are not necessarily depicted true to scale and may be scaled up or down to allow for a better understanding of the illustrated principles. Rather, the described Figures are to be construed in a broad sense and as a qualitative base which allows a person skilled in the art to apply the presented teaching in a versatile way.

The term „and/or" as used herein shall mean that each of the listed elements may be taken alone or in conjunction with two or more of further listed elements.

Figure 1 shows an additive manufacturing device 100. Said device 100 is, preferably, a conventional device for manufacturing any type of components by powder-bed-fusion. Such techniques employ a bed of a powder or base material P which is selectively and layerwise exposed to or irradiated by an energy beam 21, such as a laser or an electron beam of an irradiation apparatus or energy beam source 20. Accordingly, the given powder-bed-fusion method may relate to selective laser sintering, selective laser melting or electron beam melting. Said processes have in common that the component (cf. reference numeral 10) is established or build up on top of a build platform 1. In other words, the component 10 is fused onto said platform 1 and consecutively established by selectively solidifying the base material according to its predefined geometry which may be present in form of a CAD-file. After the irradiation or fusing of each layer (cf. reference numeral L), the build platform 1 is usually lowered according to the measure of a layer thickness and a new base material layer is deposited on a manufacturing plane MP via a deposition apparatus 30.

The component 10 as referred to herein may particularly relate to a steam or gas turbine component, such as component of flow path hardware of a gas turbine. Thus, the component 10 may be or relate to a blade, vane, shroud, shield, such as heat shield, tip, segment, insert, injector, seal, transition, burner, nozzle, strainer, orifice, liner, distributor, dome, boost, cone, lance, plate, resonator, piston or any corresponding retrofit kit. Alternatively, said component may relate to another or similar component.

Figure 2 shows in the left part a pattern (cf. reference numerals HP and FP below) according to which a base material P or manufacturing plane MP is irradiated when selective sintering or melting methods are applied. An overall tool path or scanning direction is indicated with arrow SD. This direction SD is modulated by a meander-like pattern or trajectory which shall resemble the path of the corresponding energy beam 21 e.g. for the fusing of the base material.

Said pattern or tool path as shown on the left in Figure 2 preferably denotes or defines a fusion pattern or geometric irradiation parameters for fusing the base material MP. The irradiation parameters which may actually define the pattern comprise - inter alia – a hatch distance h and a stripe width w for the irradiation, as indicated on the left. Such a pattern provides for an expedient solidification result, for which an area-wide irradiation with a focused energy beam is required as possible.

According to the present invention, scaled irradiation parameters or a scaled irradiation pattern is provided which is derived or rendered in that the irradiation parameters for fusing the base material are scaled, such as e.g. multiplied by a scaling factor s as shown on the right in Figure 2. The scaling factor comprises a quotient of a heating beam diameter Dh and a fusion beam diameter Df (s = Dh/Df). Consequently, said scaling factor s may not be equivalent to said quotient, but may have a further variables or constants affecting the value of the factor s.

The scaling factor s may e.g. amount to values between 1 and 10, such as between 2 and 5. Said scaling factor s may particularly amount to 2, 3, 4 or 5. Alternatively and e.g. depending on the particular heating strategy, said factor may deviate from the given values.

The hatch distance h and/or the stripe width w of the respective irradiation pattern are, according to the present invention, scaled or multiplied by the scaling factor s in order to provide for an expedient heating pattern (cf. Figure 3 below). By the given scaling, the heating pattern is correlated to the fusing pattern which allows to automatically tailor a heating strategy for or subsequent to the corresponding fusing process.

In addition to the hatch distance h and the stripe width w, the scaling can, according to the present invention, as well apply to further process parameters, such as an energy impact per volume or areal unit, energy wavelength, beam offset, beam speed, geometry of beam spot, beam angle of further ones.

Figure 3 illustrating aspects of the present invention is composed of four partial images, wherein the upper ones (upper left and upper right) relate to a given layer n in the additive manufacturing process of the component 10; n being a natural number.

The lower images (lower left and lower right) pertain to a subsequent layer n+1 in the additive manufacturing process of the component 10.

For both layers n and n+1, the left part of Figure 3 shows a fusion pattern FP, while the right part of Figure 3 indicates in an example a scaled heating pattern HP which was e.g. derived from the respective fusion pattern by the provided scaling strategy.

The upper images of Figure 3 illustrate that the corresponding scaling factor s by which the hatch distance h and the stripe width w (not explicitly indicated in Figure 3) are scaled according to the presented method amounts to roughly two ($s \approx 2$). The stripe width w is, however, set to infinity (∞) or to a measure corresponding to the width of the manufacturing plane MP, e.g. such that no separate stripe is defined.

This upscaling of the geometry of the heating pattern (originating from a given or set fusion pattern) allows for providing an expedient, efficient and advantageous heating process, be it for pre- or post-heating in additive manufacturing.

In contrast to the corresponding (fusion and heating) patterns for layer n, said patterns for layer n+1, which shall succeed layer n in the manufacturing process, the whole patterns (cf. FP and HP in the lower part of figure 3) are tilted by an angle α. This may be expedient or advantageous for the resulting weld structure of the component. When, particularly, the irradiation pattern is tilted or rotated slightly, the weld seam or beads do not exactly overlap in the resulting structure. This in turn improves the heat put into the manufacturing plane MP as well as the structural constitution of the component 10.

Depending on the actual fusion pattern, the heating pattern may of course be scaled or derived such that also the stripe width w of the heating pattern HP is finite and e.g. chosen twice or 3 times greater than that one of the fusion pattern FP (cf. left part of Figure 3).

Aside from the described upscaling the heating pattern HP, also a downscaling, e.g. with a value of the scaling factor s of equal to or below 1 ($s \leq 1$) are contemplated in the present invention. This particular embodiment may be advantageous particularly when a post-heating shall be carried out e.g. for healing certain defects in the built structure by a dedicated thermal treatment.

The coordinate system in the middle of Figure 3 indicates spatial directions x and y of a corresponding manufacturing plane (cf. reference numeral MP in Figure 1).

Figure 4 illustrates in a schematic comparable to the ones of Figure 2 and 3 an embodiment of the heating pattern HP which may, according to the present invention, be applied to a preheating as well as to a post-heating for additive manufacturing (cf. above).

It is shown in Figure 4 that - similar to known fusion patterns or corresponding tool path’s – a beam offset BO as an irradiation parameter can be defined. A default value can e.g. be set to half of a defocused beam diameter or heating beam diameter Dh (cf. side of Figure 4). By way of this example, it is illustrated that important aspects of a fusion irradiation strategy can be transferred to a corresponding heating strategy. As stressed above, on one side, the heating, such as pre- or post-heating, can be significantly improved. On the other hand, the overall additive manufacturing process chain, comprising computer-aided-manufacturing (CAM) means are improved or at least implemented in a more automated, efficient and/or reliable way.

Figures 5 and 6 each indicate partial views of heating patterns HP as described above. Further, it is shown that an idle or spare mode operation can be selected for (vector) turns T in the irradiation or heating pattern HP according to the present invention. Said idle or spare mode operation may comprise definition of an idle time, such as a beam-off time which results in a reduction of energy applied at the turns T.

Figure 5 indicates that such a functionality may be carried out according to a “skywriting” function which may be applied in the corresponding fusion pattern in order to avoid high or excessive energy input between two hatch vectors, for instance. The boldly indicated turns T shall illustrate that a full idle is defined at the turns T, at which e.g. the energy beam 21 is completely switched off. For the realisation of this embodiment, a specific idle time may be defined. If, however, the power of the energy beam can be controlled reliably and precisely and reduced in the curved U-turn regions, said “skywriting” or (laser-off-)function for preheating can be dispensed with.

Additionally or alternatively the embodiment illustrated in Figure 6 is contemplated, wherein the irradiation power or power density in the vicinity of the turns T is only reduced to a lower value which also results in the aerial or spatial energy input to be reduced to a compatible extent.

Said selection of the power of power density of the energy beam and/or the idle or beam-off time can be based either on an input from (pre-)heating simulation, e.g. including an x-y-thermographic map of every layer to be manufactured, or on a monitoring means or system which outputs an information on the local temperature distribution in the given layer L.

Figure 7 indicates a further embodiment of the presented solution, wherein the irradiation of the manufacturing plane MP is repeated, such as repeated once or several times, prior to and/or after an additive buildup of the component 10.

The respective heating patterns HP1, HP2 and HP3 listed from left to right illustrate that any heating exposure or irradiation can be repeated, such as repeated three times. Thereby, further degrees of freedom are provided, by which any heating process can be improved and dedicated to the requirements of the given material and process conditions.

Figure 8 further outlines how the presented irradiation solution or a corresponding product is embedded in the overall additive manufacturing process. Some method steps of the present invention are illustrated, wherein step a) denotes providing of the energy beam 21 for the heating of the base material P.

Step b) denotes the presented heating step or as the case may be the irradiating of the manufacturing plane MP for the heating with the energy beam 21 under the scaled irradiation parameters, wherein the scaled irradiation parameters are derived in that irradiation parameters for fusing the base material P are scaled by the scaling factor s, as described above.

Step c) denotes additively building-up the component 10 under the irradiation parameters (cf. fusion patterns FP above) for fusing the base material P. Thus, the given method for heating the base material and/or the manufacturing plane MP is part of the overall additive manufacturing process which may be performed in the additive manufacturing device 100 as shown in Figure 1.

According to the present invention, step b) may be employed succeeding step a). According to this embodiment, the irradiation or heating is expediently a pre-heating step (cf. above).

Additionally or alternatively, as further shown by way of the dashed contour in Figure 8, the present invention also contemplates the heating or irradiation of step b) to be succeeding step c). According to this embodiment, the irradiation or heating is expediently a post-heating step (cf. above).

The heating step b) is in either way indicated by the reference numeral CPP for computer program product, and CAM in order to emphasise that the irradiation step may be implemented by a computer or executed or be part of a CAM process or CAM-file.

As stressed above, the present invention further relates to a method of mere providing the irradiation pattern HP, wherein the irradiation is carried out as described above, whereby a tool path for powder-bed-fusion or a corresponding dataset is provided or defined and wherein, the irradiation pattern HP can e.g. be processed in the additive manufacturing device 100. In other words, the technical advantages and the technical solution of the present invention yet manifest in a corresponding computer program, CAM-file or corresponding dataset, which can be processed or executed in any given additive manufacturing device.

The scope of protection of the invention is not limited to the examples given hereinabove. The invention is embodied in each novel characteristic and each combination of characteristics, which particularly includes every combination of any features which are stated in the claims, even if this feature or this combination of features is not explicitly stated in the claims or in the examples.

Patent claims

1. Method of additive manufacturing a component (10) comprising, heating a base material (P) in additive manufacturing comprising the steps of:

- a) providing an energy beam (21) for the heating of the base material (P), wherein the energy beam (21) is a laser or electron beam of an additive manufacturing device (100), and wherein the base material (P) is arranged to at least partly form a manufacturing plane (MP),
- b) irradiating the manufacturing plane (MP) for the heating with the energy beam (21) under scaled irradiation parameters, wherein the scaled irradiation parameters are derived in that irradiation parameters for fusing the base material (P) are scaled by a scaling factor (s), wherein the scaling factor (s) comprises a quotient of a heating beam diameter (Dh) and a fusion beam diameter (Df), wherein the irradiation parameters at least comprise a hatch distance (h) and a stripe width (w) for the irradiation, wherein said hatch distance (h) and/or said stripe width (w) are scaled by the scaling factor (s), and
- additively building up (c)) the component (10) under the irradiation parameters for fusing the base material (P).

2. Method according to claim 1, wherein the scaling factor (s) amounts to values between 2 and 5.

3. Method according to one of the previous claims, wherein a beam offset (BO) is defined for the irradiation which is chosen to about half of the heating beam diameter (Dh).

4. Method according to one of the previous claims, wherein an idle operation is selected for turns in the irradiation pattern (HP) resulting from the irradiation (b)) of the manufacturing plane (MP).

5. Method according to claim 4, wherein an irradiation power and/or an idle time for the heating is selected based on da-

ta, information, or input from a thermal simulation or a monitoring means.

6. Method according to one of the previous claims, wherein the irradiation (b)) of the manufacturing plane (MP) is carried out for pre-heating the base material (P).

7. Method according to one of the previous claims, wherein the irradiation (b)) of the manufacturing plane (MP) is carried out for post-heating.

8. Method according to one of the previous claims, wherein the irradiation (b)) of the manufacturing plane (MP) is repeated, such as repeated once or several times, prior to and/or after an additive buildup of a component (10).

9. Method of providing an irradiation pattern (HP) for additive manufacturing, the method comprising irradiating (b)) the manufacturing plane (MP) for the heating according to one of the previous claims, wherein the irradiation pattern (HP) defines a tool path for powder-bed-fusion additive manufacturing, and wherein said irradiation pattern (HP) can be processed in an additive manufacturing device (100).

10. Computer program product (CPP) comprising instructions which, when executed by a computer, cause the computer to carry out the steps of irradiating (b)) the manufacturing plane (MP) according to one of the previous claims.

FIG 1

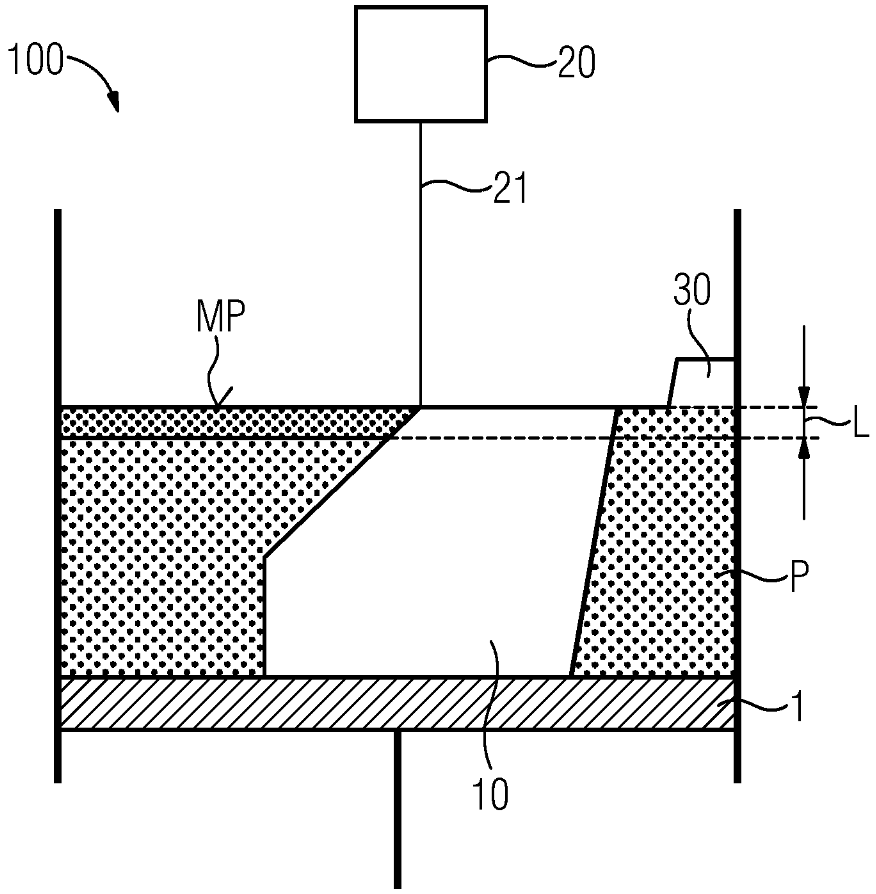
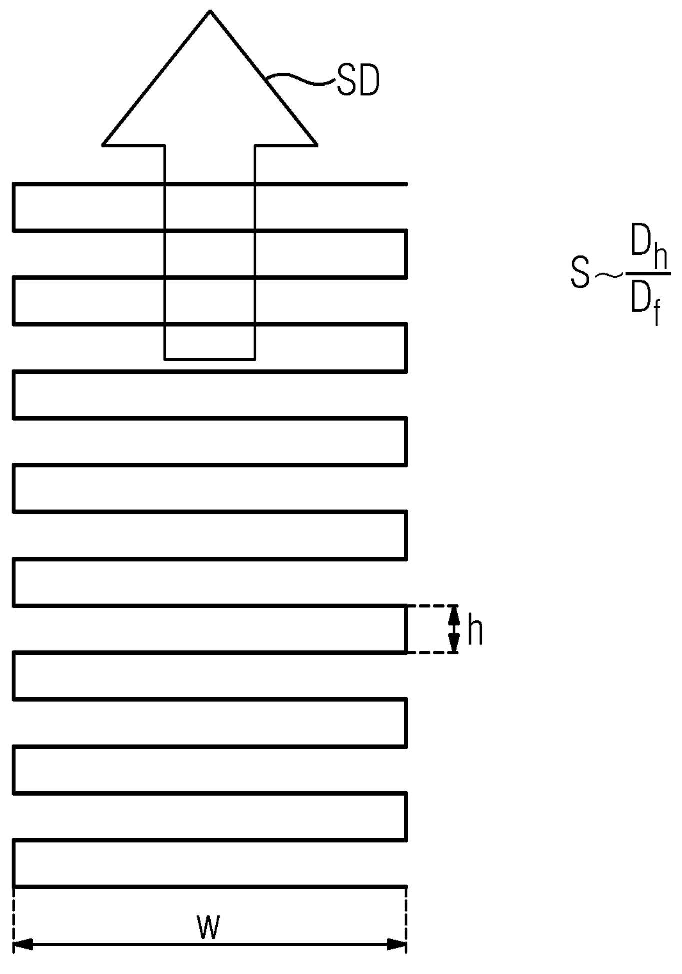


FIG 2



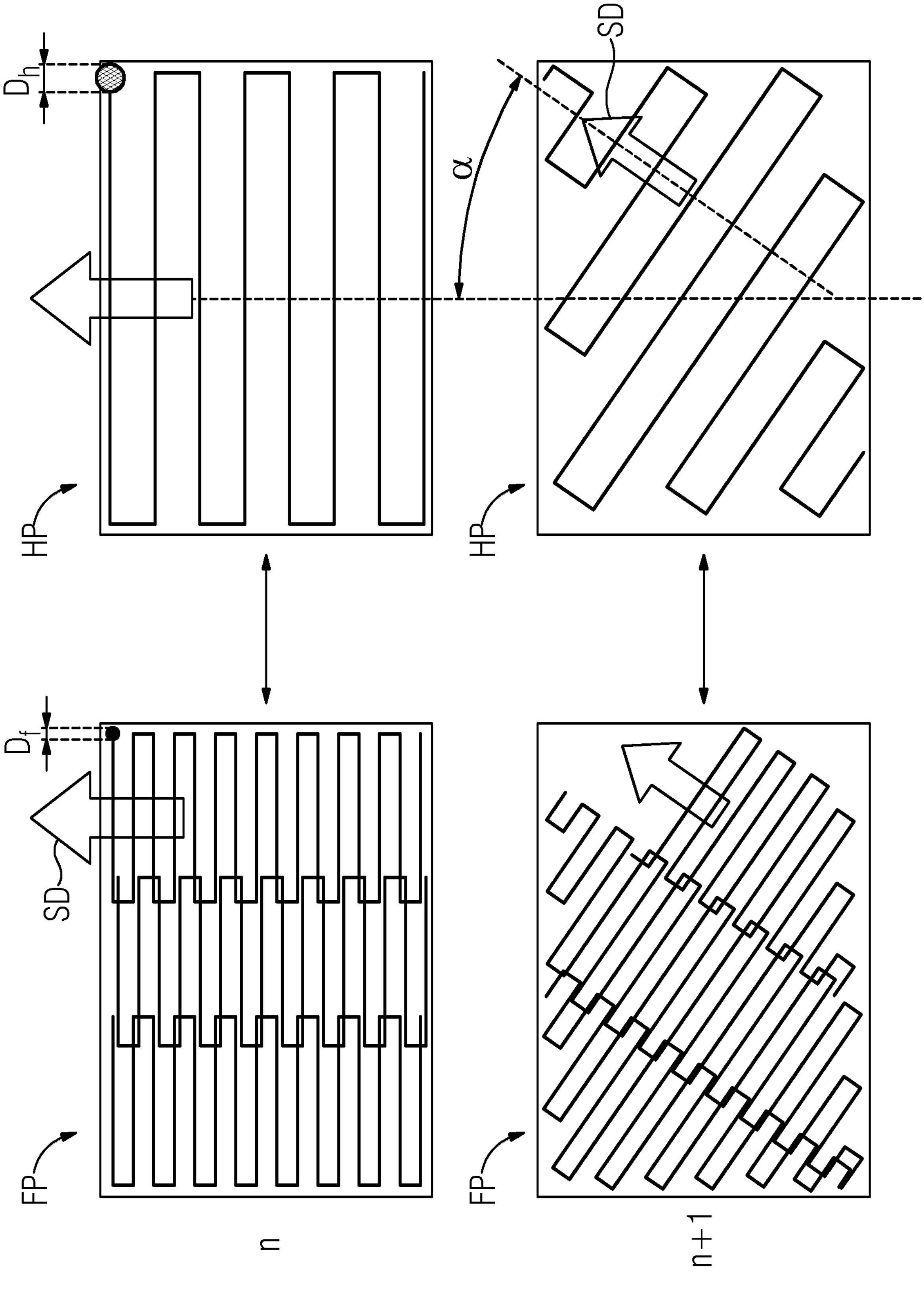


FIG 3

FIG 4

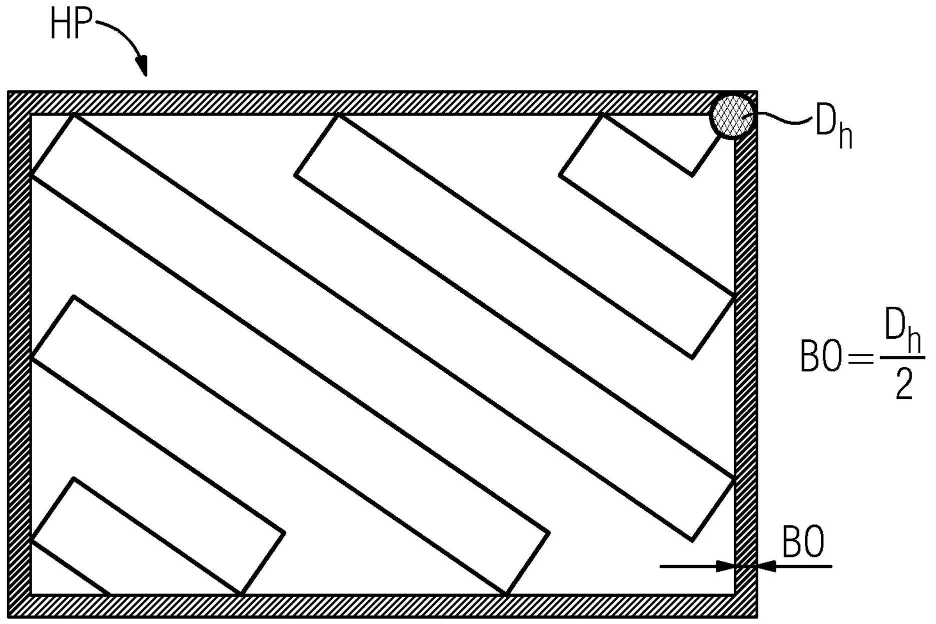


FIG 5

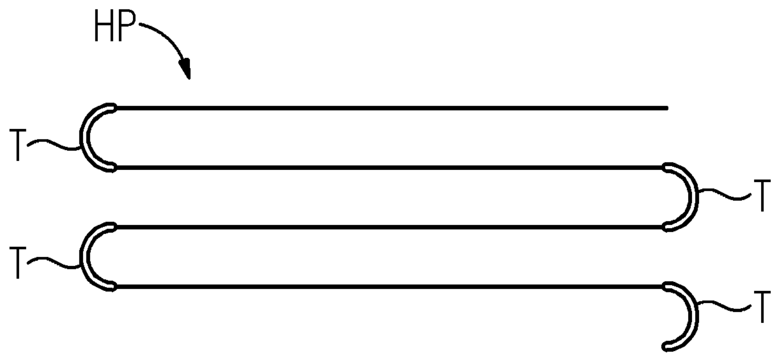


FIG 6

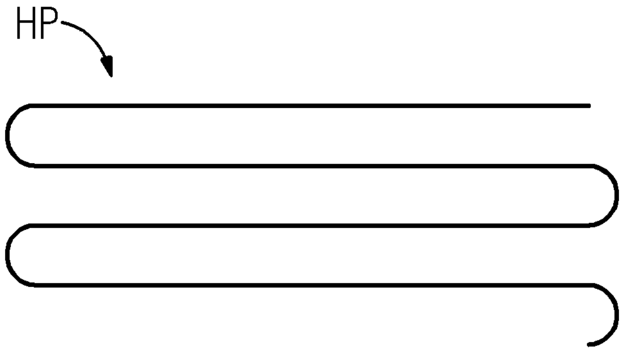


FIG 7

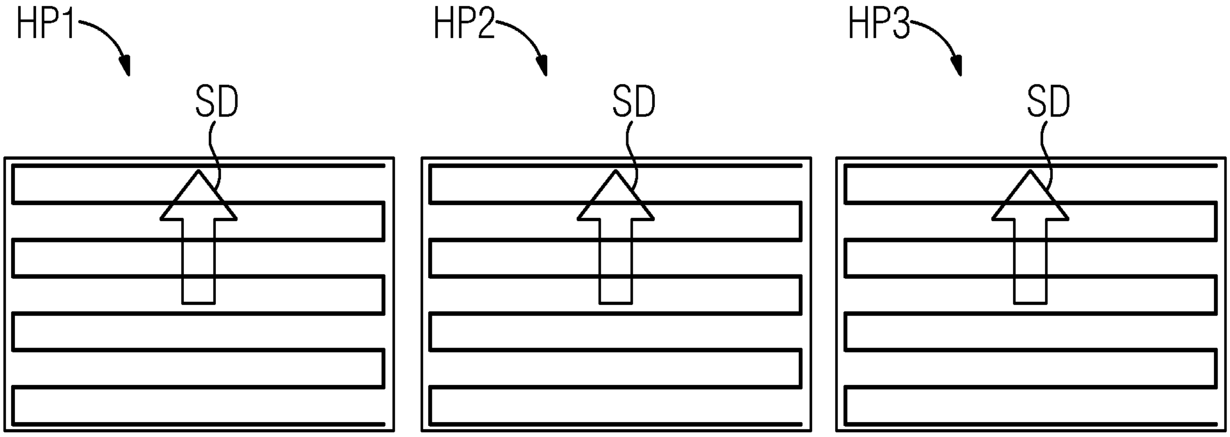
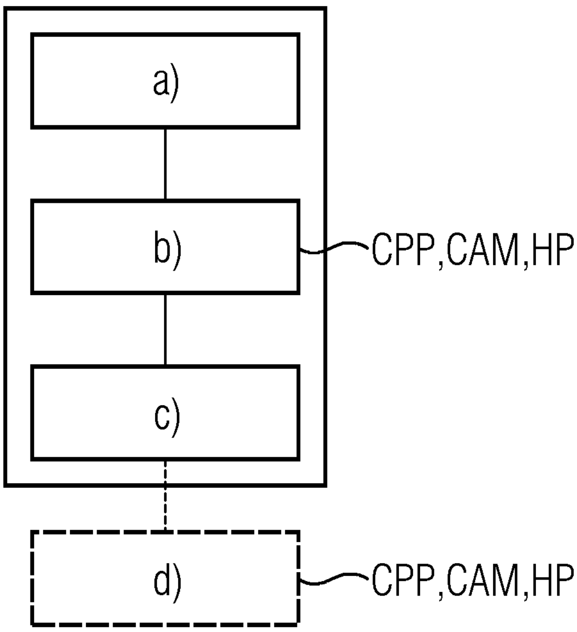


FIG 8



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/054199

A. CLASSIFICATION OF SUBJECT MATTER
INV. B22F3/105 B29C64/386 B33Y10/00 B33Y50/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B22F B29C G06T G05B B33Y

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2018/264598 A1 (MAMRAK JUSTIN [US]) 20 September 2018 (2018-09-20) claims; figures	1-10
X	US 5 776 409 A (ALMQUIST THOMAS A [US] ET AL) 7 July 1998 (1998-07-07) column 49, line 63 - column 50, line 7 figures	1-10
A	EP 3 388 907 A1 (SIEMENS AG [DE]) 17 October 2018 (2018-10-17) paragraph [0001] claims	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
24 April 2020	08/05/2020

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Morra, Valentina

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2020/054199

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