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(71) Applicant: **SIEMENS AKTIENGESELLSCHAFT** [DE/DE]; Werner-von-Siemens-Straße 1, 80333 München (DE).

(72) Inventors: **GEISEN, Ole**; Winterfeldstr. 52, 10781 Berlin (DE). **LEBED, Yaroslav**; Rohrdamm 52, 13629 Berlin (DE).

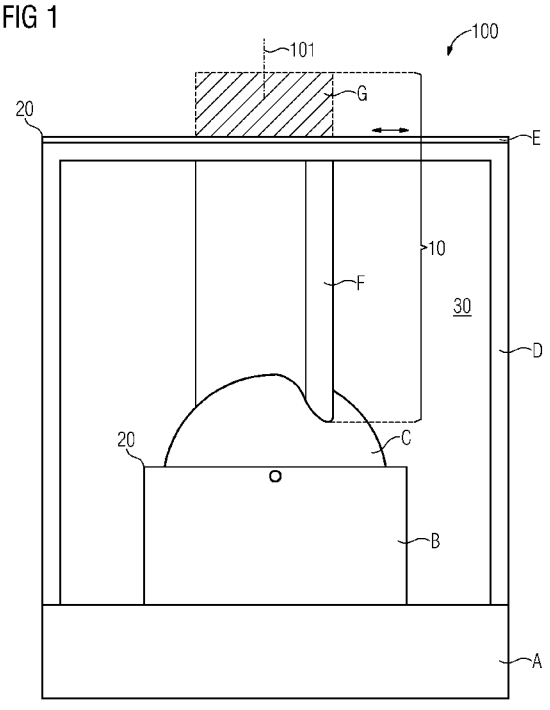
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(54) **Title:** METHOD FOR ADDITIVELY MANUFACTURING A TIP STRUCTURE ON A PRE-EXISTING PART

FIG 1



(57) **Abstract:** A method for additively manufacturing a tip structure (G) on a pre-existing part (H) is presented, the method comprising: - a) placing the part (H) in a build space (30) of a beam- assisted additive manufacturing setup (100) and below a transparent aligning plate (E), - b) engraving a top contour (H) of the part (F) onto the aligning plate (E) with an energy beam (101) of the setup (100), - c) aligning a top surface (11) of the part (F) such that the top surface coincides with the engraved contour (H), - d) removing the aligning plate (E) from the setup (100), and - e) additively manufacturing the tip structure (G) according to a predefined geometry on the top surface (11).

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Description

Method for additively manufacturing a tip structure on a pre-existing part

The present invention relates to a method of additively manufacturing a tip structure on a pre-existing part, e.g. to an according hybrid additive manufacturing method. Further, an according apparatus is presented.

Additive manufacturing techniques comprise e.g. powder bed methods, such as selective laser melting (SLM) or selective laser sintering (SLS) or electron beam melting (EBM).

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

EP 3 124 140 A2 further describes powder bed additive manufacturing devices and methods.

US 2016/167303 A1 describes a method for forming a three-dimensional article through successive fusion of parts of a powder bed.

US 2015/314403 A1 describes an arrangement for laser deposition repair of a gas turbine engine component.

Additive manufacturing methods have proven to be useful and advantages in the fabrication of prototypes or complex and filigree components, such as lightweight design or cooling components comprising mazelike internal structures. Further, additive manufacture stands out for its short chain of process steps, as a manufacturing step can be carried out directly based on corresponding CAD/CAM and/or construction data.

Powder bed manufacturing methods such as selective laser melting or selective laser sintering are relatively well

known methods for fabricating, prototyping or manufacturing parts or components from powder material, for instance. Conventional apparatuses or setups for such 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 the energy of a laser beam and subsequently solidified. The layer thickness is determined by a wiper that moves, e.g. automatically, over the powder bed and removes excess material. Typical layer thicknesses amount to 20 µm or 40 µm. During the manufacture, said laser 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.

A problem which regularly occurs especially in the hybrid additive manufacture, i.e. the powder-bed-based manufacture of a deposit or (tip) structure on an already existing (pre-existing) or pre-manufactured part, is that an accurate alignment of the manufacturing setup or beam hardware to a top surface of the part has to be managed. Particularly a program to be scanned e.g. by an energy beam according to the geometry of the tip structure - which is e.g. predetermined by a CAD model - has to be aligned to a top surface or upper section of the part. The tip structure to be established from a powder bed onto an already existing substrate always requires a stable and accurate alignment, e.g. after the substrate or existing section is placed in to a build space and the respective powder bed.

For the mentioned accurate alignment, usually optical recognition systems are applied in the prior art. After the existing part is placed anywhere on a build plate or platform, the setup' optical recognition system particularly recognises the position of the part and aligns a 3D- or CAD model to it. However, the machine laser or electron beam system is usually calibrated relative to mounting dowels provided on the build plate. After this calibration, it is

still required to accurately machine respective dowel holes in the plate from its top and in the structure to be manufactured.

This process is extremely difficult and sophisticated, including many machining operations and requires accurate machining steps. Further, accuracy of this method is not sufficient due to tolerance stacking effects.

It is an object of the present invention to provide means suitable to improve alignment accuracy in hybrid selective melting methods, particularly positional calibration of a tip structure to be manufactured of an already pre-existing part.

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 for additively manufacturing a tip structure on a pre-existing part as described. The method comprises placing the part in a build space of a beam-assisted additive manufacturing setup and below an aligning plate.

The setup can be selective laser melting setup or electron beam melting setup, for example.

The aligning plate is preferably releasably attachable to the setup. The part is preferably placed on the substrate or build plate of the setup.

The method further comprises engraving a mating or top contour or cross section of the part onto or in the aligning plate with an energy beam of the setup, such as a laser or electron beam. Expediently, the part is mounted to the setup below the aligning plate and the energy beam is then exposed to the aligning plate from the top. The engraving from the top and placing of the part below the aligning plate is

particularly expedient, due to the process inherent build direction of powder bed based additive processes.

The step of placing may as well be performed after the step of engraving as mentioned, e.g. in case that the top contour of the part is already present in a digital form. In this case, the part does not necessarily need to be measured or gauged by an optical system.

The method further comprises aligning a top surface, such as a manufacturing or mating surface, of the part such that said top surface (spatially) coincides or mates with the engraved contour. This step allows for the described accurate alignment for the whole additive manufacturing process.

The method then further comprises removing the aligning plate from the setup and additively manufacturing the tip structure according to its predefined geometry - which may be present in form of a CAD-data file - on the top surface.

The method may further comprise fixing or clamping the part after the step of aligning, e.g. with a separate clamping mechanism.

With the presented method and/or the presented apparatus (see below) a very high alignment accuracy of the geometry of the part to be build on top of the already existing substrate is facilitated. In other words, the engraving or corresponding imaging allows projecting the contour of the tip of the part into the aligning plate in order to ease a later alignment with a beam or manufacturing tooling, such as a laser tooling of the setup or manufacturing device.

In contrast to an alignment as being performed in the prior art, namely an alignment which possibly aligns the laser tooling to the component, the present method allows to adapt or take geometric settings of the laser tooling and then align the pre-existing part to the tooling.

The given alignment process is very simple and very accurate, allowing for repeatable high-quality refurbishment or completion of the part or component. The presented method is further suitable to be adapted to almost any physical part geometry. The presented means further allow for placing the pre-existing part anywhere on the build plate thus allowing for increasing flexibility and simplicity of the manufacturing process.

A further aspect of the present invention relates to an apparatus for aligning a tip structure to be additively manufactured on a pre-existing part, as described. The apparatus comprises a frame defining a build space for the additive manufacture and a clamping mechanism of fixture suitable for rotationally and/or translationally aligning and fixing the part in the build space. The apparatus further comprises the aligning plate, wherein the aligning plate is preferably removably attachable to a top of the frame and further suitable for imaging a top contour of the tip structure to be manufactured onto the part (cf. above).

In an embodiment, the top contour mates with the top surface.

The term “mate” may describe that the respective geometries or spatial dimensions of e.g. the (virtual) top contour and the physical top surface are congruent and/or similar or may be placed one over the other in a congruent way.

In an embodiment, the top contour mates with an initial layer of the tip structure.

In an embodiment the pre-existing part is a pre-machined part.

In an embodiment an extent of pre-machining is adjusted to the predetermined or pre-defined geometry of the tip structure.

This allows for expediently and advantageously exploiting the described method for hybrid additive manufacturing applied for service applications. Particularly, the given embodiments are beneficial for the refurbishment of wear and/or spare parts, e.g. of or applied in a hot gas path of turbo machines.

In an embodiment the top surface of the part is an even surface, preferably as even that it may be placed in a powder bed of an SLM setup.

In an embodiment, the top surface is aligned horizontally with the given method.

In an embodiment, the tip structure is manufactured by selective laser melting or electron beam melting. According to this embodiment, the aligning plate is expediently susceptible to be engraved, preferably accurately engraved with a fine resolution, by the respective laser or electron beam.

In an embodiment the part constitutes a section of a component, such as wear component, spare part of a gas turbine blade or a burner root of a gas turbine.

In an embodiment, the tip structure constitutes a tip to be manufactured for the refurbishment of said component.

The mentioned terms “part” or “components” as used herein may describe any ceramic, metallic components or plastic components. Preferably, the components represent components of a turbine, such as a gas turbine. Most preferably, the component denotes a component applied in a turbo machine, e.g. in the flow path hardware of a gas turbine. The component is, thus, preferably made of a superalloy or nickel-based alloy, particularly a precipitation, dispersion or age hardened alloy.

In an embodiment, the aligning plate of the apparatus has a thickness of less than 5 mm.

Minimizing thickness of the aligning plate is important to avoid inaccuracies which arise due to a vertical offset the aligning plate provides between the top surface of the part and the engraving e.g. on a top surface of the aligning plate.

In an embodiment the aligning plate is made of an optically permeable or translucent material being susceptible to be engraved by the energy beam in order to image the top surface or its contour of the part in the plate as a reference.

In an embodiment, the apparatus comprises a build plate as described above, wherein the build plate carries the frame. According to this embodiment, a dimension of the build plate preferably coincides with the build space as described.

Advantages relating to the described method may as well pertain to the apparatus, or vice versa.

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

Figure 1 shows a schematic side view of an apparatus according to the present invention.

Figure 2 shows a schematic perspective view of the apparatus in a different state.

Figure 3 shows a further schematic perspective view of the apparatus.

Figure 4 shows a further schematic perspective view of the apparatus.

Figure 5 indicates 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.

Figure 1 shows an additive manufacturing setup 100. The setup is preferably a beam-assisted setup or device suitable for performing a selective laser melting or electron beam melting process.

The setup 100 comprises a build plate A. On top of the build plate A, a component or part to be manufactured can be placed for its manufacture.

The setup 100 further comprises an apparatus 20. Instead of the setup, the build plate A may be comprised by the apparatus 20.

The apparatus 20 further comprises a frame D which is arranged on top of the build plate A, thereby defining a build space 30 for an additive build process. In a top view of the setup 100 and/or the apparatus 20, the frame D preferably fully spans a covers the build plate A.

The frame may be any stable metal frame, preferably being open at an upper end such that an energy beam (see numeral 101) from the setup 100 can enter the build space 30 without any hindrance (cf. as well Figure 2).

The build plate A preferably carries the frame D. The frame D may as well be rigidly fixed to the build plate A.

The setup 100 further comprises an aligning plate E. The aligning plate E is attachable to the top of the frame D. The aligning plate E is preferably even in shape and further removable from the setup 100, i.e. easily attachable to and

removable from e.g. the frame D of the setup 100 as indicated by the double arrow in Figure 1.

The aligning plate E is preferably made of glass or plastics and configured to image paths of a laser or electron beam 101 for the presented method. The aligning plate E is particularly configured such that it is susceptible to be engraved by the mentioned radiation, e.g. to image a contour or cross-section of a manufacturing plane of a part F the additive manufacture shall start from.

In case of a laser beam-assisted additive manufacturing method the aligning plate E is preferably suitable for imaging a region of it which has already been exposed with a laser beam. The same holds mutatis mutandis for a process assisted by an electron beam, i.e. electron beam melting.

The part F preferably represents a pre-machined part, wherein an extent of pre-machining is adjusted to the predefined geometry of the tip structure G, as shown in Figure 1. The part F may further constitute a section of a component 10, such as a turbine blade or vane or a root of a turbine burner, wherein the tip structure G constitutes a tip to be manufactured onto the part F e.g. for a refurbishment of the component 10.

The mentioned contour H may represent or indicate a junction line between the part F and the tip structure G in overall component 10, wherein this contour junction mates with the top surface 11, as well as with an initial layer of the tip structure G (see Figure 1).

The aligning plate E is preferably constructed very thin in thickness, e.g. with a thickness of at most 5 mm.

The aligning plate E has preferably a uniform thickness.

Its thickness may as well amount to more than 5 mm, however preferably less than 5 mm, such as 3 mm, 2 mm, 1 mm or even less.

The apparatus 20 further comprises a clamping mechanism comprising a clamping fixture B and a clamping fixture C. The clamping fixture B is, preferably, a translational clamping fixture, e.g. suitable for fixing the part F and vary its position in the build space 30 along e.g. the vertical or build-up direction. The clamping fixture C is preferably a rotational clamping fixture, i.e. suitable for fixing a part, such as the part F and vary and the orientation of the part according to any spatial direction or angle i.e. preferably along and a azimuth angle and an elevation or declination angle in the build space 30 (see angles α and β in Figures 2 and 4 below).

In Figure 1, a situation is shown, in which the pre-existing part F is placed in the build space 30. The part F is particularly placed below the aligning plate E.

Besides the presentation of the mentioned apparatus 20, an inventive method of additively manufacturing a tip structure on the pre-existing part F is described by means of the Figures. The method comprising placing the part F in the build space 30 and below the transparent aligning plate E as described above (cf. step a) in Figure 5).

The method further comprises engraving the contour H of the part F onto the aligning plate E with an energy beam 101 of the setup 100 (cf. Figure 1 and step b) in Figure 5).

The method further comprises aligning the top surface 11 of the part F such that the top surface 11 coincides or mates with the engraved contour H (cf. and step c) in Figure 5). This is further explained by means of Figures 2 to 4.

Figure 2 shows a perspective schematic view of the setup 100, wherein the aligning plate E is shown to be partly optically permeable or translucent, such that the engraved contour H and the top surface (cf. dashed line referenced with numeral 11 in Figure 2) shining through the at least partly transparent aligning plate E, are shown. Thus, the mentioned alignment of the top surface 11 with the engraved contour, namely such that the top surface coincides with the contour, can be easily facilitated. Therefore, the clamping mechanism B, C has to be adjusted such that the shown azimuth or separation angle α by which the contour H and the part F are misaligned, vanishes. This may be performed manually or automatically.

Preferably, the top surface 11 of the part F has an even surface.

A result of such alignment is shown in Figures 1 and 3. In the perspective view of Figure 3, the dashed line disappeared in contrast to the indication of Figure 2, due to the congruence of the part F or - as the case may be - its top surface 11 with the engraved contour H.

As mentioned above, said aligning has preferably been performed by a respective adjustment of the clamping mechanism B, C.

As described above, the top surface 11 is preferably aligned horizontally and/or parallel to a surface of the alignment plate E. The top surface is, preferably, aligned such that a single recoating step in the SLM process or setup 100 covers said surface with a powdery base material (not explicitly indicated).

Figure 4 shows a situation, in which said horizontal alignment has not yet been performed and e.g. a rotational and/or a translational alignment still has to be carried out by adjustment of the respective clamping mechanism as

described above. Said adjustment has to be carried out such that the indicated declination angle β becomes zero.

The method further comprises removing the aligning plate E from the setup 100 (cf. step d) in Figure 5).

The method further comprises additively manufacturing the tip structure G according to a predefined geometry (cf. step e) in Figure 5). A predefined geometry for the tip structure G is indicated in Figure 1 by means of the dashed area. The dashed area may represent a corresponding CAD-model of the tip structure G which inherently matches to the beam tooling and particularly to the engraved contour H. Consequently and necessarily, also the top surface 11 or its contour H coincides or mates with the engraved contour H, such that an accurate alignment has been provided.

Said geometry for the tip structure G is then - according to the present invention - additively manufactured on the top surface 11 of part F. This is preferably done by means of selective laser melting or electron beam melting method and according to the predefined geometry.

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.

Claims

1. Method for the powder-bed-based additive manufacture of a tip structure (G) on a pre-existing part (F) comprising the steps of:
- a) placing the part (F) in a build space (30) of a beam-assisted additive manufacturing setup (100) and below a transparent aligning plate (E),
- b) engraving a top contour (H) of the part (F) onto the aligning plate (E) with an energy beam (101) of the setup (100),
- c) aligning a top surface (11) of the part (F) such that the top surface (11) coincides with the engraved contour (H),- d) removing the aligning plate (E) from the setup (100), and
- e) additively manufacturing the tip structure (G) according to a predefined geometry on the top surface (11), wherein the top contour (H) mates with the top surface (11), and with an initial layer of the tip structure (G).

2. Method according to claim 1, wherein the pre-existing part (F) is a pre-machined part, and wherein an extent of pre-machining is adjusted to the predefined geometry of the tip structure (G).

3. Method according to claim 1 or 2, wherein the top surface (11) of the part (F) is aligned horizontally.

4. Method according to one of the previous claims, wherein the tip structure (G) is manufactured by selective laser melting or electron beam melting.

5. Method according to one of the previous claims, wherein the part (F) constitutes a section of a component (10), such as a turbine blade or burner root, and wherein the tip structure (G) constitutes a tip to be manufactured for the refurbishment of the component (10).

6. Apparatus (20) for aligning a tip structure (G) to be additively manufactured from a powder bed on a pre-existing part (H) comprising:
- a frame (D) defining a build space (30) for the additive manufacture,
- a clamping mechanism (B, C) suitable for rotationally and translationally aligning and fixing the part (H) in the build space (30), and
- an aligning plate (E), wherein the aligning plate is removably attachable to a top of the frame (D) and further suitable for imaging a contour (H) of the tip structure (G) to be manufactured onto the part (H).

7. Apparatus according to claim 6, wherein the aligning plate (E) has a thickness of less than 5 mm.

8. Apparatus according to claim 6 or 7, wherein the aligning plate (E) is made of an optically permeable material being susceptible to be engraved by an energy beam (101) in order to image a contour (H) of the tip structure (G).

9. Apparatus according to one of claims 6 to 8, comprising a build plate (A), wherein the build plate (A) carries the frame (D).

FIG 1

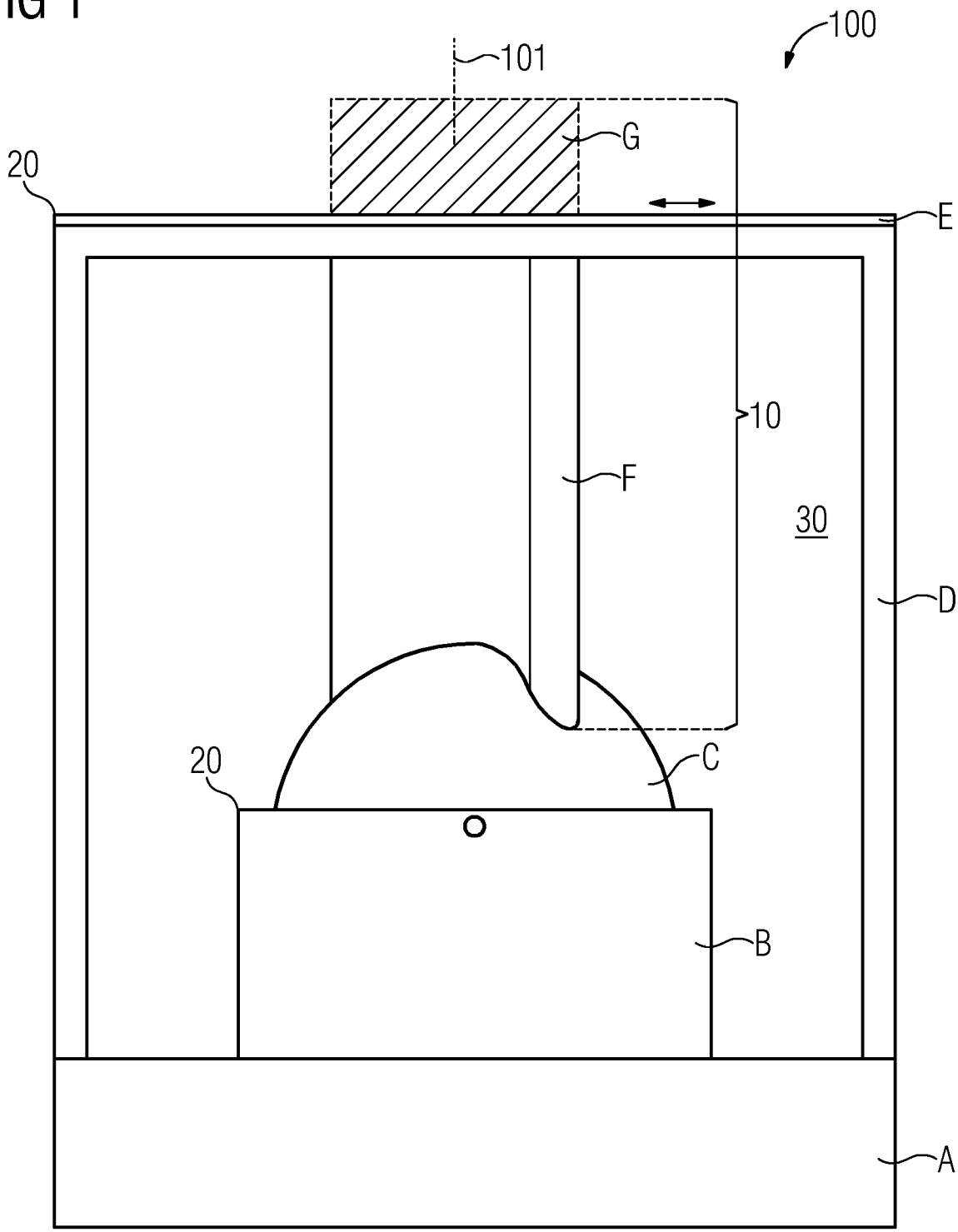


FIG 2

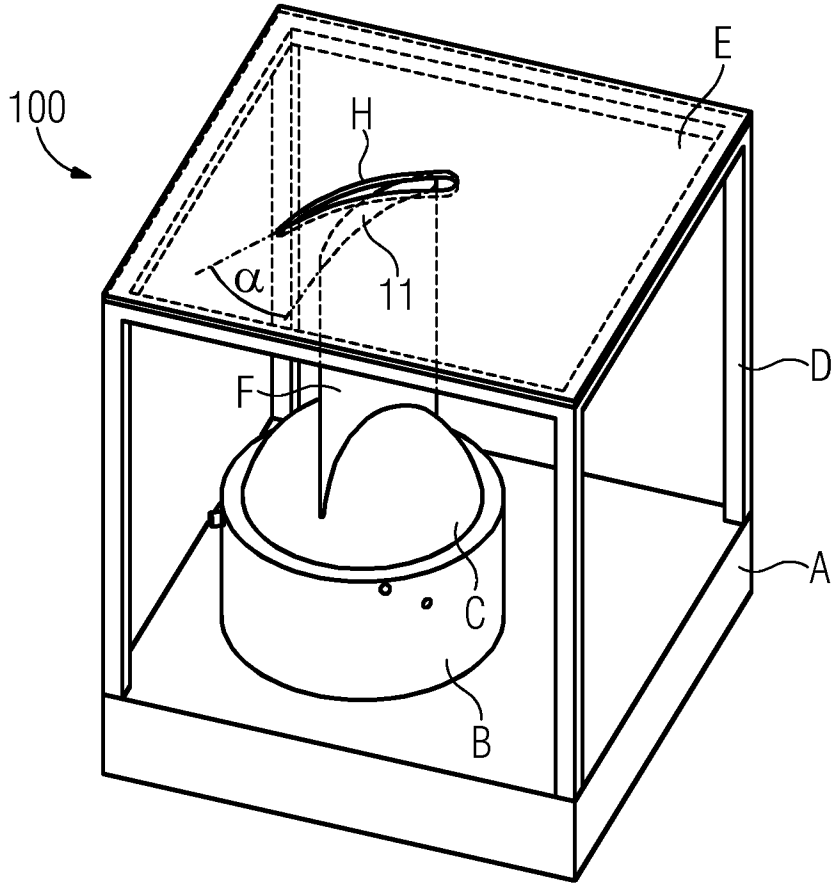


FIG 3

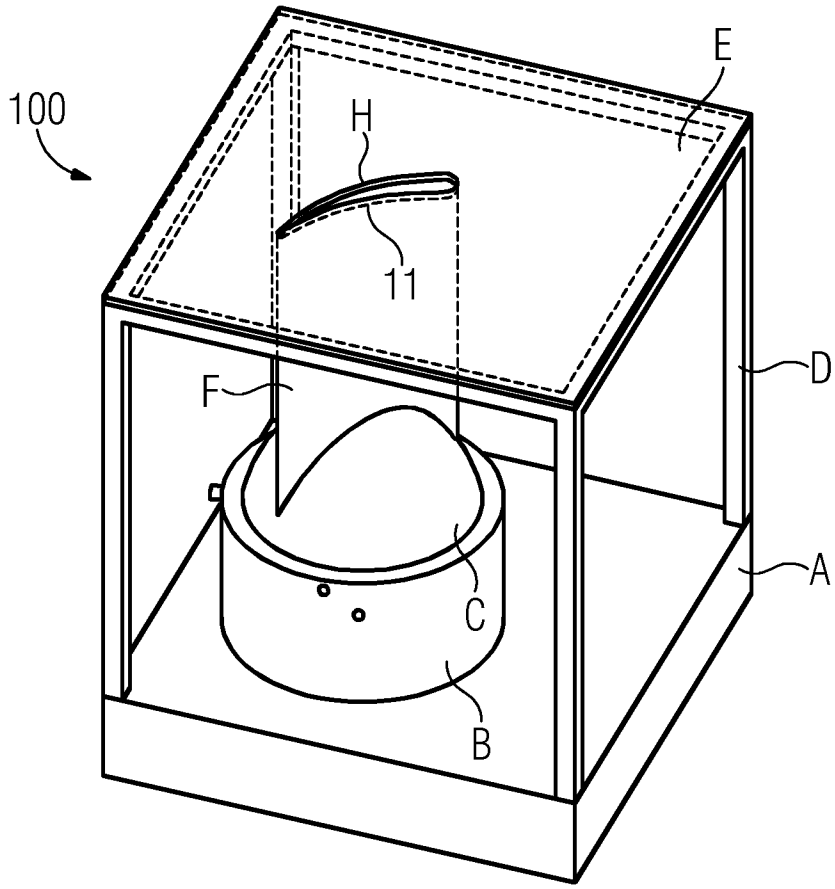


FIG 4

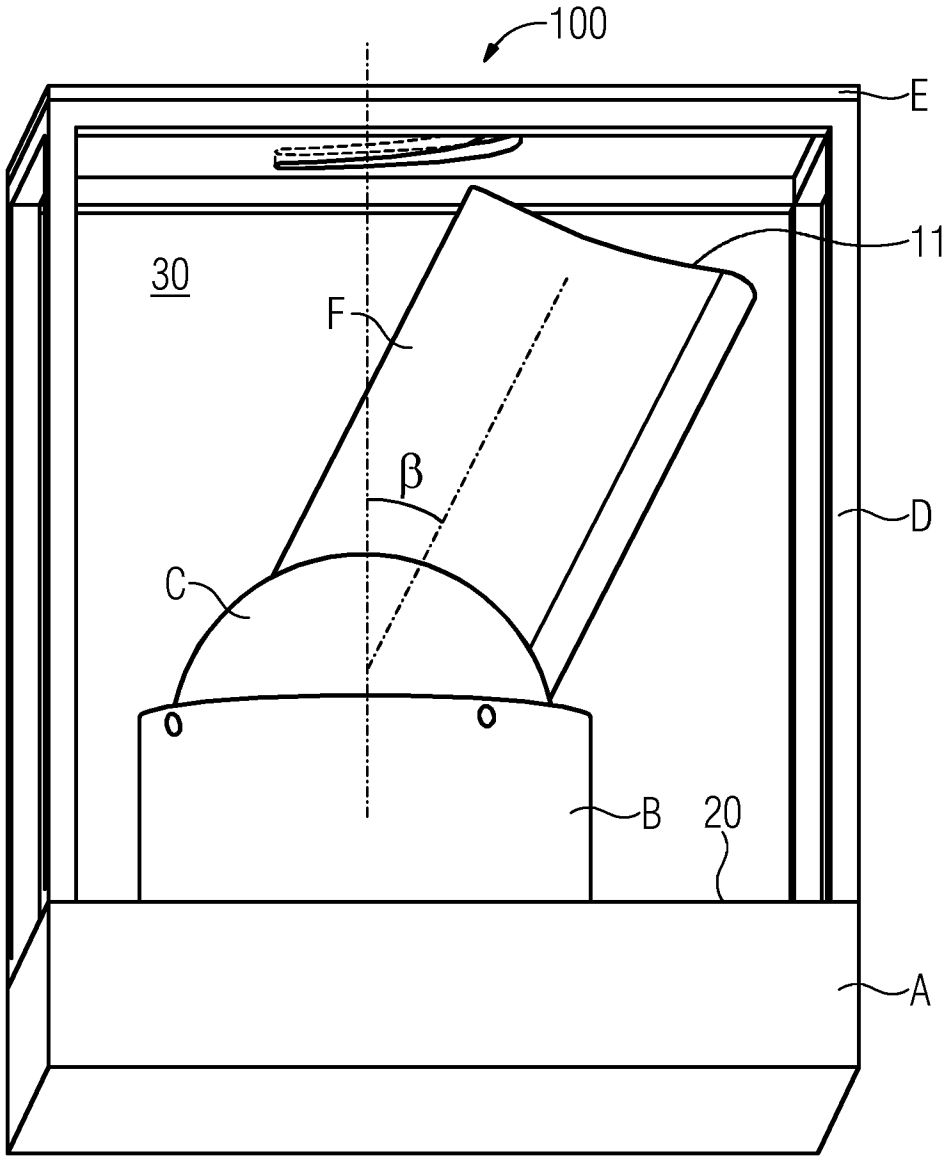
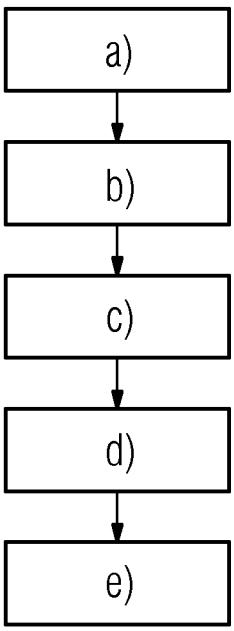


FIG 5



INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
INV. B22F3/105 B33Y10/00 B33Y30/00 B23K26/342 B29C64/153
B29C64/20 F01D5/00 B23P6/00
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 C04B B33Y B23K B29C F01D B23P

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 2015/314403 A1 (BRUCK GERALD J [US] ET AL) 5 November 2015 (2015-11-05)	6,7,9
Y	claim 1	6
A	figures 1, 2 paragraphs [0013], [0015]	1-5,8

Y	US 2016/167303 A1 (PETELET MATTHIEU [GB]) 16 June 2016 (2016-06-16) claim 1 figure 1	6

A	EP 3 135 408 A1 (GEN ELECTRIC [US]) 1 March 2017 (2017-03-01) figures 3-9 claims 1, 11	1-5

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 November 2018	20/11/2018

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	Traon, Nicolas

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/071012

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 3 124 140 A2 (GEN ELECTRIC [US]) 1 February 2017 (2017-02-01) claims 1, 6 paragraph [0013] figures 1, 2 -----	6-9
A	US 2016/158962 A1 (BALISTRERI JOHN [US] ET AL) 9 June 2016 (2016-06-09) figure 3 -----	6-9

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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