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(54) **A METHOD OF SINTERING**

(57) A method of sintering a metal injection-moulded, green aerofoil component. The method includes providing a setter having a stationary support arranged to support an aerofoil part of the component and a moveable platform arranged to support an end part of the component, the moveable platform being independently moveable relative to the stationary support. The method further

includes locating the green component on the setter such that the aerofoil part and the end part are supported by respectively the stationary support and the moveable platform. The supported green component is then sintered, the moveable platform moving during the sintering relative to the stationary support to accommodate sintering-induced shrinkage of the component.

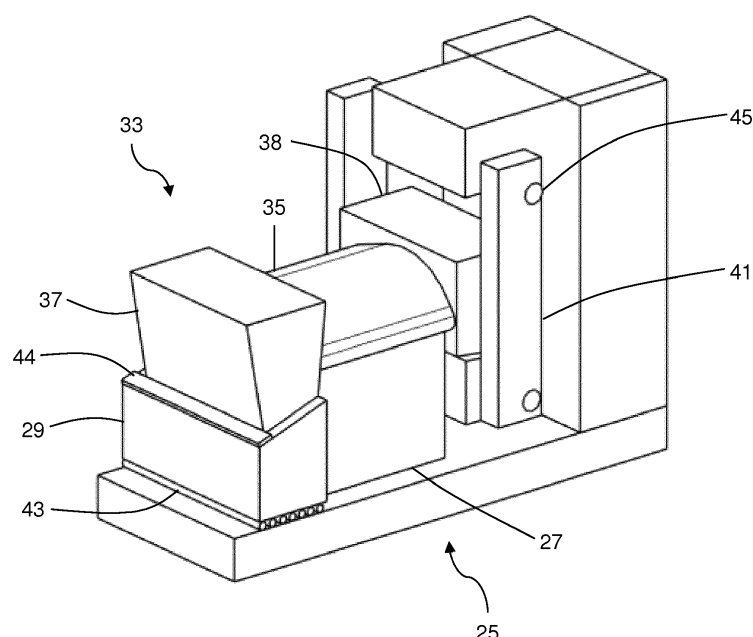


Fig. 3(b)

Description

[0001] The present disclosure relates to a method of sintering a metal injection-moulded, green aerofoil component.

[0002] Metal Injection Moulding (MIM) is a metalworking process which produces components from a range of materials including steel, molybdenum, nickel, titanium and copper. The MIM process involves mixing a metal powder with a plasticising binder and injecting the resulting feedstock into a mould. The mould is then removed to leave a metal powder "green" component held together by the binder. The green component may undergo some intermediate processing but eventually undergoes sintering, sometimes with the application of additional pressure, to fuse the powder particles into a single solid mass and to burn-off the binder.

[0003] The fusing of the powder particles during sintering results in the green component shrinking. If the entire component or isolated areas of the component are prevented from moving freely, the component can become distorted as it shrinks. However, the component also needs to be supported during sintering to prevent it being distorted under its own weight. This can be especially important for thin overhanging structures.

[0004] Support methods may involve placing the green component on a bed of zirconium oxide beads. However the beads may move unevenly as they slide over each other or even seize up at high temperature, locally preventing free movement of the green component and leading to unwanted distortion of the component. Further, the beads may not provide sufficient support to prevent deformation of thin sections under their own weight. Alternatively, US 2008/0075619 A1 proposes a setter which supports the green component during sintering and is formed from a feedstock of molybdenum powder and a binder such that it shrinks at a similar rate to the green component during sintering. EP 0633440 A1 also proposes a setter which supports the green component during sintering and is formed from a feedstock of powder and binder which shrinks together with the green component it supports during sintering. However, both of these setters are made from a powder and a binder which undergo sintering, thus they can only be used in a single sintering operation.

[0005] In general terms, the present invention provides a method of sintering a metal injection-moulded, green aerofoil component such that a setter can move with and support the green component as it shrinks during sintering.

[0006] Accordingly, the present disclosure provides a method of sintering a metal injection-moulded, green aerofoil component, the method including:

providing a setter having a stationary support arranged to support an aerofoil part of the component and a moveable platform arranged to support an end part of the component, the moveable platform being

independently moveable relative to the stationary support,

locating the green component on the setter such that the aerofoil part and the end part are supported by respectively the stationary support and the moveable platform, and

sintering the supported green component, the moveable platform moving during the sintering relative to the stationary support to accommodate sintering-induced shrinkage of the component.

[0007] Advantageously, because the moveable platform is independently moveable relative to the stationary support, the method can thus reduce or eliminate unwanted distortion of components during sintering.

[0008] Optional features of the invention will now be set out. These are applicable singly or in any combination with any aspect of the invention.

[0009] The stationary support may have a shaped surface which contacts an aerofoil surface of the aerofoil part when the green component is located on the setter, the shaped surface conforming to the shape of the aerofoil surface at the final stages of sintering. Additionally or alternatively, the moveable platform may have a further shaped surface which contacts a surface of the end part when the green component is located on the setter, the further shaped surface conforming to the shape of the end part.

[0010] The aerofoil component may be a vane or a rotor blade of a gas turbine engine. For example the aerofoil component may be a variable inlet guide vane, a variable stator vane or a compressor blade.

[0011] The method may further include: removing the sintered aerofoil component from the setter, and repeating the locating and sintering steps with another metal injection-moulded, green aerofoil component. Advantageously, the setter can thus be reused and the method can reduce the amount of waste material generated during MIM and reduce the amount of variation between separately sintered aerofoil components.

[0012] The method may further include applying a friction reducing agent to the stationary support and/or the moveable platform at points of contact between the setter and the green component. The friction reducing agent may include ceramic beads, such as zirconium oxide beads, mixed with a binder which burns off during the sintering.

[0013] The setter may have rollers or wheels which support the moveable platform to enable the independent movement of the platform relative to the stationary support. Similarly, the moveable platform may be hinged or pivoted to enable the independent movement of the platform relative to the stationary support.

[0014] More generally, the moveable platform may be constrained to move in a plane or along a path defined by a line or curve. This can reduce unwanted distortion of components during sintering.

[0015] The setter may have a stopper against which

the green component is located. This can help to ensure that the green component is correctly positioned on the setter.

[0016] The green aerofoil component may have first and second end parts at respective ends of the aerofoil part, and the setter may have corresponding first and second moveable platforms.

[0017] Embodiments will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 shows schematically a longitudinal cross-section through a ducted fan gas turbine engine;

Figure 2 shows schematically (a) a setter, (b) a green aerofoil component, and (c) the green aerofoil component located on the setter;

Figure 3 shows schematically (a) a further setter with a first and a second moveable platform, and (b) a green aerofoil component located on the further setter; and

Figure 4 shows schematically a green aerofoil component located on another setter with a first and a second moveable platform.

[0018] With reference to Figure 1, a ducted fan gas turbine engine is generally indicated at 10 and has a principal and rotational axis X-X. The engine comprises, in axial flow series, an air intake 11, a propulsive fan 12, an intermediate pressure compressor 13, a high-pressure compressor 14, combustion equipment 15, a high-pressure turbine 16, an intermediate pressure turbine 17, a low-pressure turbine 18 and a core engine exhaust nozzle 19. A nacelle 21 generally surrounds the engine 10 and defines the intake 11, a bypass duct 22 and a bypass exhaust nozzle 23.

[0019] During operation, air entering the intake 11 is accelerated by the fan 12 to produce two air flows: a first air flow A into the intermediate-pressure compressor 13 and a second air flow B which passes through the bypass duct 22 to provide propulsive thrust. The intermediate-pressure compressor 13 compresses the air flow A directed into it before delivering that air to the high-pressure compressor 14 where further compression takes place.

[0020] The compressed air exhausted from the high-pressure compressor 14 is directed into the combustion equipment 15 where it is mixed with fuel and the mixture combusted. The resultant hot combustion products then expand through, and thereby drive the high, intermediate and low-pressure turbines 16, 17, 18 before being exhausted through the nozzle 19 to provide additional propulsive thrust. The high, intermediate and low-pressure turbines respectively drive the high and intermediate-pressure compressors 14, 13 and the fan 12 by suitable interconnecting shafts.

[0021] One option for manufacturing aerofoil compo-

nents of the engine, such as variable inlet guide vanes, variable stator vanes or compressor blades in the compressor section of the engine, is Metal Injection Moulding (MIM). Accordingly, the gas turbine engine 10 may have components manufactured according to the methods described and/or claimed herein.

[0022] Figure 2 shows schematically (a) a setter 25, (b) a green aerofoil component 33, and (c) the green aerofoil component located on the setter. The setter has a stationary support 27, a moveable platform 29 which is independently moveable relative to the stationary support, and a fixed platform 30 which is fixed relative to the stationary support. The green aerofoil component has an aerofoil part 35, a first end part 37 and a second end part 38, all produced by MIM. As shown in Figure 2(c), the green aerofoil component is located on the setter such that the stationary support supports the aerofoil part, the moveable platform supports the first end part, and the fixed platform supports the second end part.

[0023] The stationary support 27 has a shaped surface 31 which contacts the aerofoil surface of the aerofoil part 35 when the green component 33 is located on the setter, the shaped surface conforming to the shape of the aerofoil surface at the final stages of sintering. The movable platform 29 has a further shaped surface 32 which contacts a surface of the first end part 37 when the green component is located on the setter, the further shaped surface conforming to the shape of the first end part at the final stages of sintering. Similarly the fixed platform 30 has a shaped surface 34 which contacts a surface of the second end part 38 when the green component is located on the setter, the shaped surface conforming to the shape of the second end part at the final stages of sintering. Advantageously, such shaped surfaces provide better support for the green aerofoil component and encourage component shape conformity, thus reducing the likelihood of unwanted distortion of the green aerofoil component occurring during sintering.

[0024] When sintering the supported green aerofoil component 33, the moveable platform 29 moves relative to the stationary support 27 to accommodate sintering-induced shrinkage of the component. Advantageously, the setter can thus provide sufficient support to prevent sagging of the component during sintering. By accommodating the shrinkage-induced movement of the first end part 37 relative to the aerofoil part 35, friction between the aerofoil component and the setter 25 can be reduced, thereby decreasing unwanted distortion of the aerofoil component during sintering. This can be particularly important when producing components such as double ended vanes (as illustrated in Figure 2(b)), which have two end parts, both of which can require support as they shrink.

[0025] The moveable platform 29 is shown supported by rollers 43 which enable the independent movement of the platform relative to the stationary support 27. The rollers constrain the moveable platform to move along a straight line that is parallel to the length direction of the

aerofoil component. Another option is to use wheels to support the moveable platform. The use of wheels can similarly constrain the platform to move in a line. Advantageously, the rollers or wheels allow the moveable platform to move freely in the length direction of the aerofoil component 33, while preventing any undesired lateral movement, thereby reducing the likelihood of the moveable platform inhibiting sintering induced shrinkage and helping to prevent unwanted distortion of the green aerofoil component.

[0026] Further, the moveable platform 29 has a stopper 44. The stopper 44 ensures the green aerofoil component 33 is located in the correct position on the setter 25 and helps to prevent the component falling off the platform. Advantageously, the amount of variation between sintered components can thus be reduced. Stoppers may also be attached to the stationary support 27 and/or the fixed platform 30.

[0027] A friction reducing agent can be applied to the stationary support 27, the fixed platform 30 and/or the moveable platform 29 at points of contact between the setter 25 and the green aerofoil component 33. Advantageously, this further reduces the frictional force between the green aerofoil component and the setter. An example of a suitable friction reducing agent is a paste of ceramic beads, such as zirconium oxide beads, mixed with a binder. A possible composition of a friction reducing agent is 85-90% by weight of ceramic beads and 10-15% by weight of binder. Preferably, the ceramic beads are larger than the roughness of the materials used in the setter, and typically are about 300 microns in diameter. It is also preferable that the binder used in the friction reducing agent burns-off at a comparable rate to the binders in the green component. This results in the ceramic beads in the friction reducing agent being released before sintering-induced shrinkage of the component begins. A friction reducing agent may be applied between the moveable platform 29 and the adjacent support surface (e.g. in addition to or as an alternative to the rollers or wheels) to promote the movement of the moveable platform.

[0028] After sintering, the aerofoil component 33 is removed from the setter 25. Another green aerofoil component can then be located on the setter for subsequent sintering. Advantageously, the setter can thus be reused. Unlike setters which need to be disposed of or recycled after a single sintering operation, a re-usable setter reduces the amount of waste material. Further, due to potential non-uniformities between single-use setters, the parts produced using a re-usable setter may exhibit less variation than those produced using single-use setters.

[0029] Figures 3 and 4 each show schematically a respective setter which has a first 29 and a second 41 moveable platform. Green aerofoil components, each having an aerofoil part 35, a first end part 37 and a second end part 38, are located on the setters such that the first and second moveable platforms support the first 37 and

second 38 end parts respectively. More particularly, Figure 3 shows (a) its setter alone, and (b) a green aerofoil component located on the setter, while Figure 4 shows just a green aerofoil component located on the setter. In both cases the moveable platforms have shaped surfaces 32, 34 to better support the respective end parts as well as stoppers 44 to ensure that components are correctly located on the setters. Further, the setters each have a stationary support 27 with a shaped surface 31 to support the aerofoil part 35 of the green aerofoil components.

[0030] The first moveable platforms 29 shown in Figures 3 and 4 are both supported by rollers 43 which constrain the platforms to move in the length direction of the respective aerofoil components. The second moveable platform 41 shown in Figure 3 is hinged about a hinge 45 and the second moveable platform shown in Figure 4 is pivoted about a pivot 47. The hinge and pivot constrain the second movable parts to move in an arc about the respective hinge or pivot. Having both first and second moveable platforms (as opposed to just one moveable platform, as shown in Figure 2) improves the accommodation of movement of both of the end parts, reducing friction between the aerofoil component and the setter. Advantageously, this further reduces the amount of unwanted distortion of the aerofoil component during sintering. The setter may have other combinations of moveable platforms other than those illustrated in Figures 2 to 4. For a setter may have first and second moveable platforms which are both supported by rollers or wheels, or which are both pivoted or hinged.

[0031] Although not shown in the drawings, a setter 25 may have one or more interchangeable parts. For example, a setter may have a permanently attached stationary support which is suitable to support a range of aerofoil parts and a set of interchangeable moveable platforms which can be temporarily and movably attached to the setter, each platform suitable to support a specific type of aerofoil component. One setter can therefore be used to produce a range of aerofoil components and may thus reduce the time taken swapping setters when changing between production of different types of component.

[0032] The setter 25 itself may be produced by injection moulding and sintering. It can then be machined to a final shape. Particularly high precision regions, such as areas in contact with the aerofoil, may be produced by freeze casting.

[0033] While the invention has been described in conjunction with the exemplary embodiments described above, many equivalent modifications and variations will be apparent to those skilled in the art when given the disclosure. Accordingly, the exemplary embodiments of the invention set forth above are considered to be illustrative and not limiting. Various changes to the described embodiments may be made without departing from the scope of the invention.

Claims

1. A method of sintering a metal injection-moulded, green aerofoil component (33), the method including:

providing a setter (25) having a stationary support (27) arranged to support an aerofoil part (35) of the component and a moveable platform (29) arranged to support an end part (37) of the component, the moveable platform being independently moveable relative to the stationary support,

locating the green component on the setter such that the aerofoil part and the end part are supported by respectively the stationary support and the moveable platform, and

sintering the supported green component, the moveable platform moving during the sintering relative to the stationary support to accommodate sintering-induced shrinkage of the component.
2. A method according to claim 1, wherein the stationary support has a shaped surface (31) which contacts an aerofoil surface of the aerofoil part when the green component is located on the setter, the shaped surface conforming to the shape of the aerofoil surface at the final stages of sintering.
3. A method according to claim 1 or 2, wherein the moveable platform has a further shaped surface (32) which contacts a surface of the end part when the green component is located on the setter, the further shaped surface conforming to the shape of the end part.
4. A method according to any one of the previous claims, wherein the aerofoil component is a vane or a rotor blade of a gas turbine engine.
5. A method according to any one of the previous claims, further including:

removing the sintered aerofoil component from the setter, and

repeating the locating and sintering steps with another metal injection-moulded, green aerofoil component.
6. A method according to any of the previous claims, wherein the method further includes applying a friction reducing agent to the stationary support and/or the moveable platform at points of contact between the setter and the green component.
7. A method according to claim 6, wherein the friction reducing agent includes ceramic beads.
8. A method according to any of the previous claims, wherein the setter has rollers (43) or wheels which support the moveable platform to enable independent movement of the platform relative to the stationary support.
9. A method according to any of the previous claims, wherein the moveable platform is hinged or pivoted to enable independent movement of the platform relative to the stationary support.
10. A method according to any of the previous claims, wherein the setter has a stopper (44) against which the the green component is located.
11. A method according to any of the previous claims, wherein the green aerofoil component has first (37) and second (38) end parts at respective ends of the aerofoil part, and the setter has corresponding first (29) and second (41) moveable platforms.

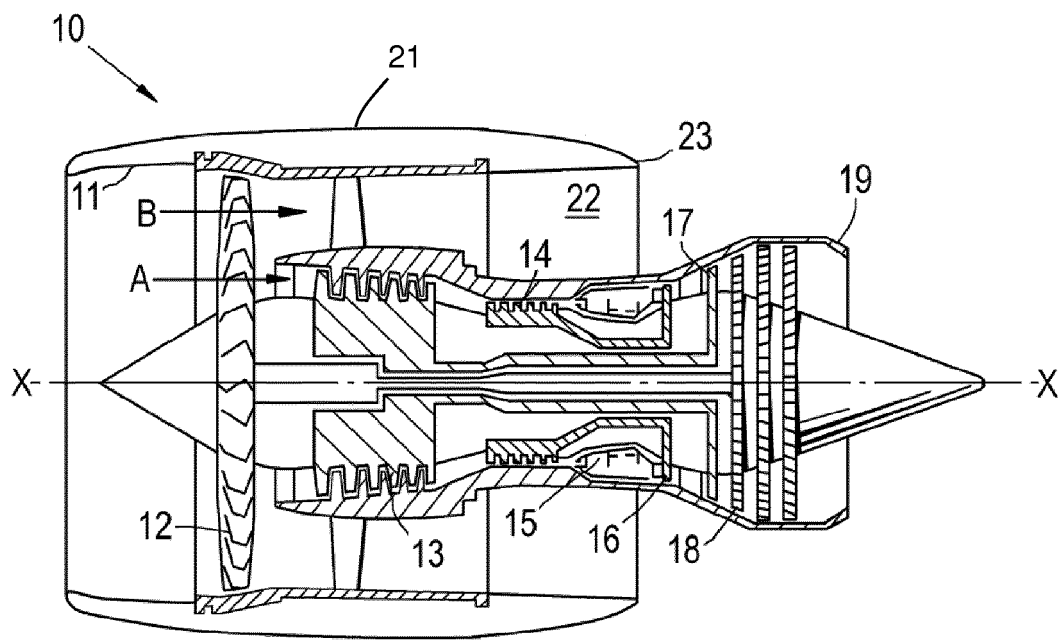


Fig. 1

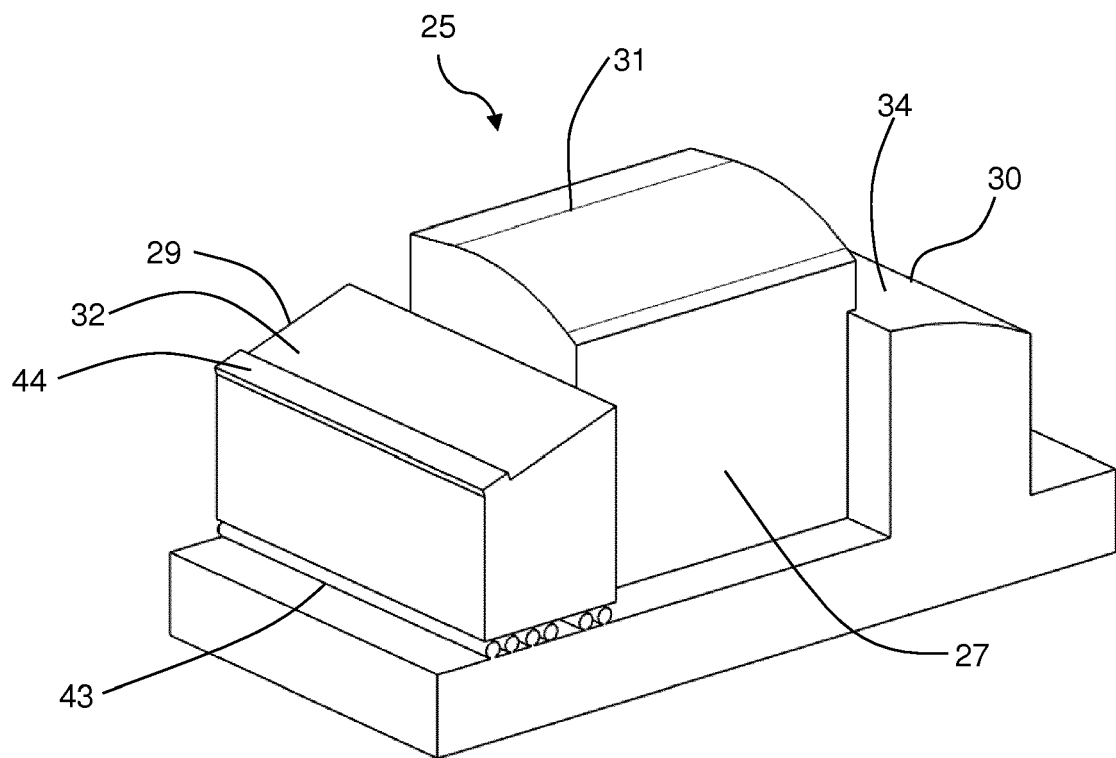


Fig. 2(a)

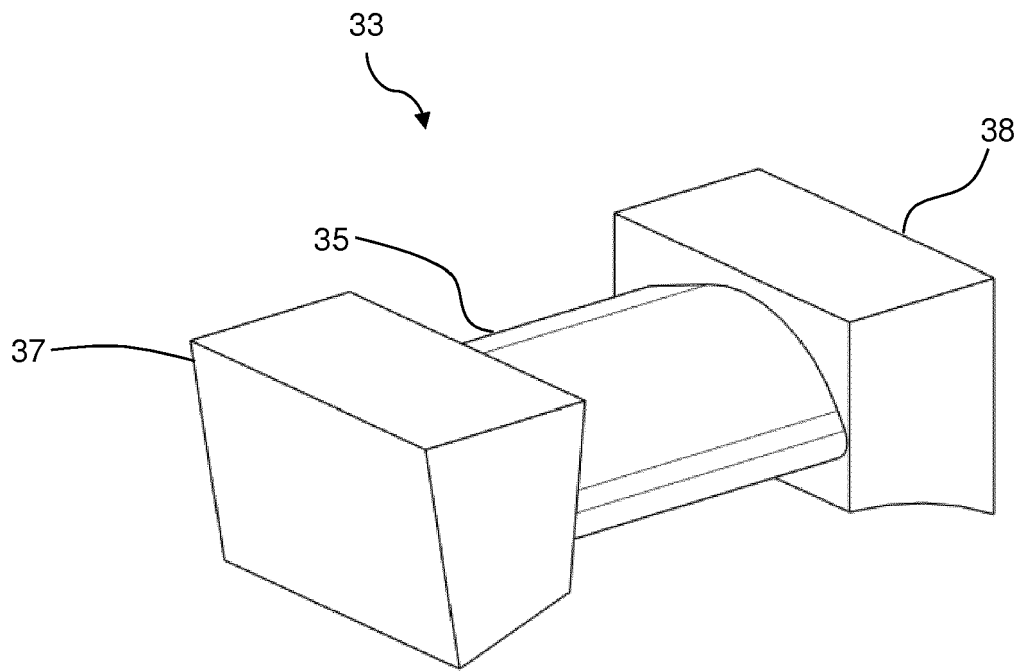


Fig. 2(b)

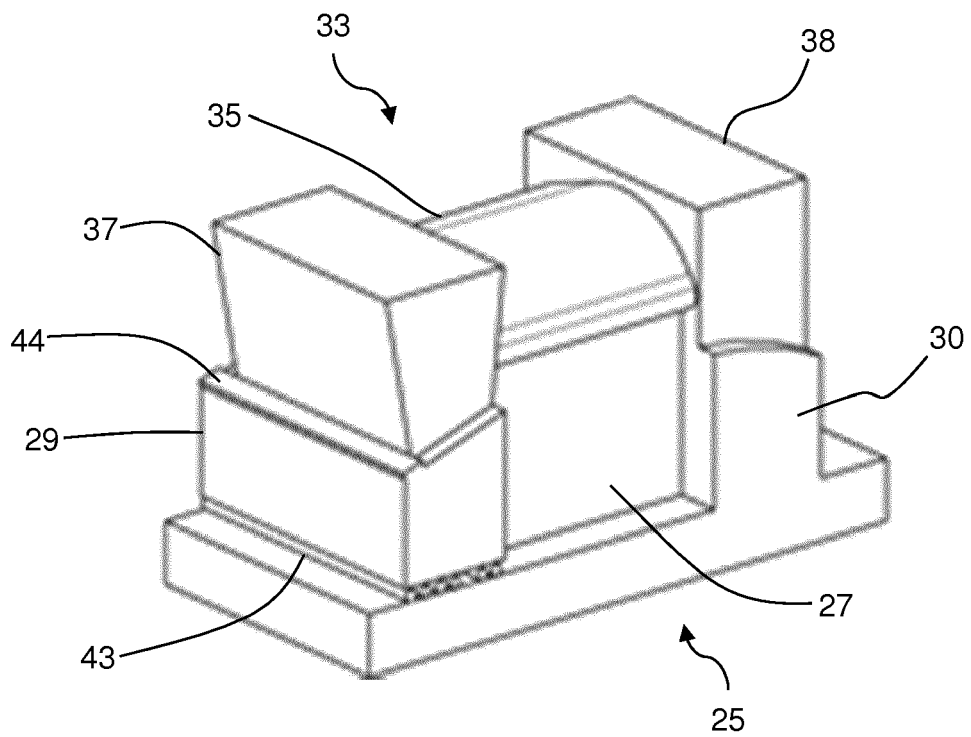


Fig. 2(c)

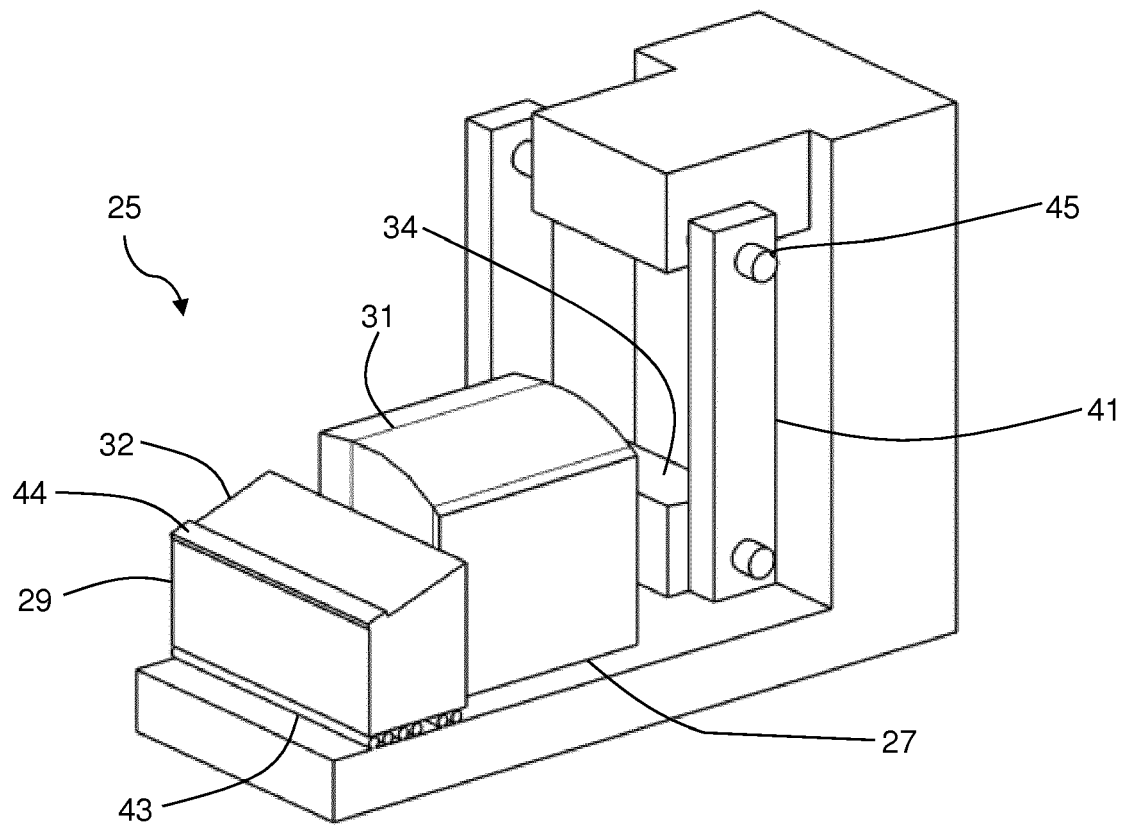


Fig. 3(a)

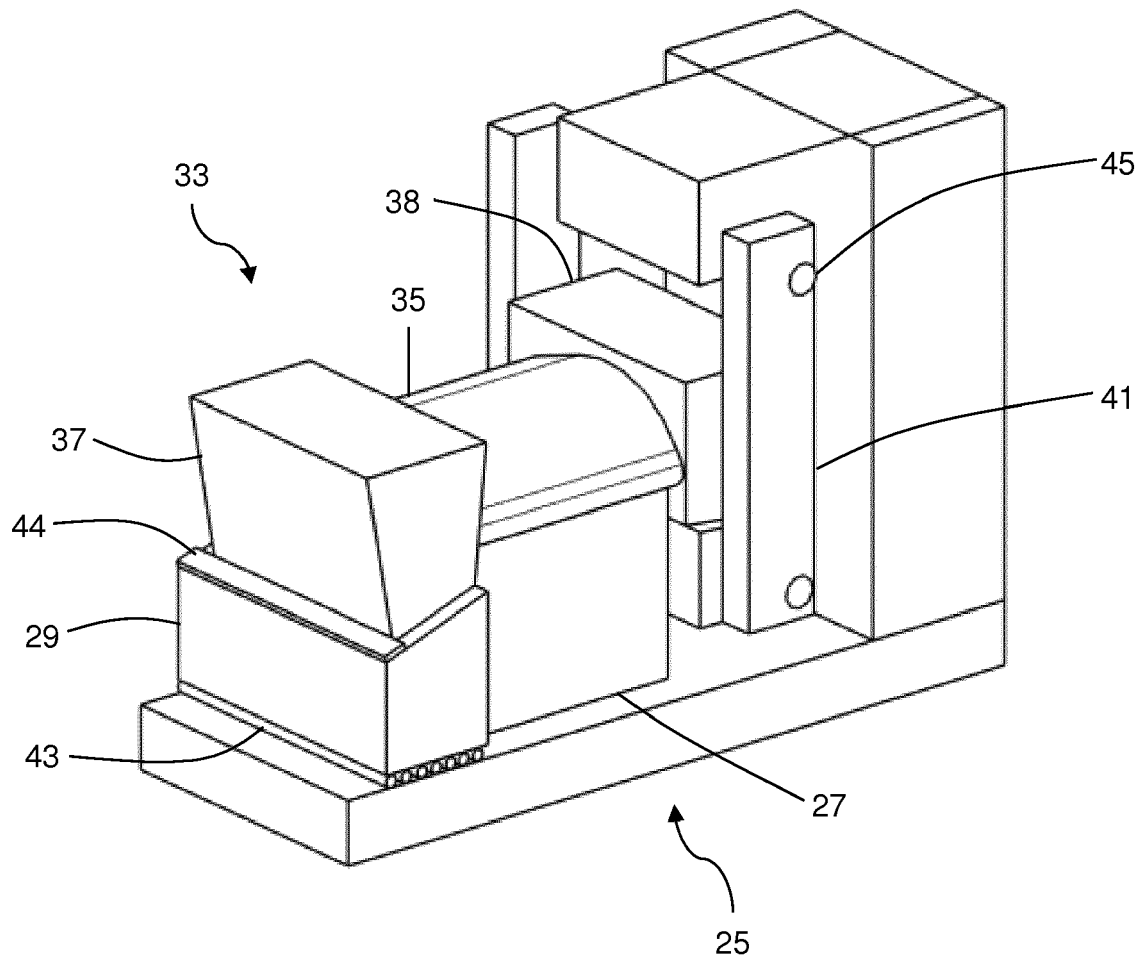


Fig. 3(b)

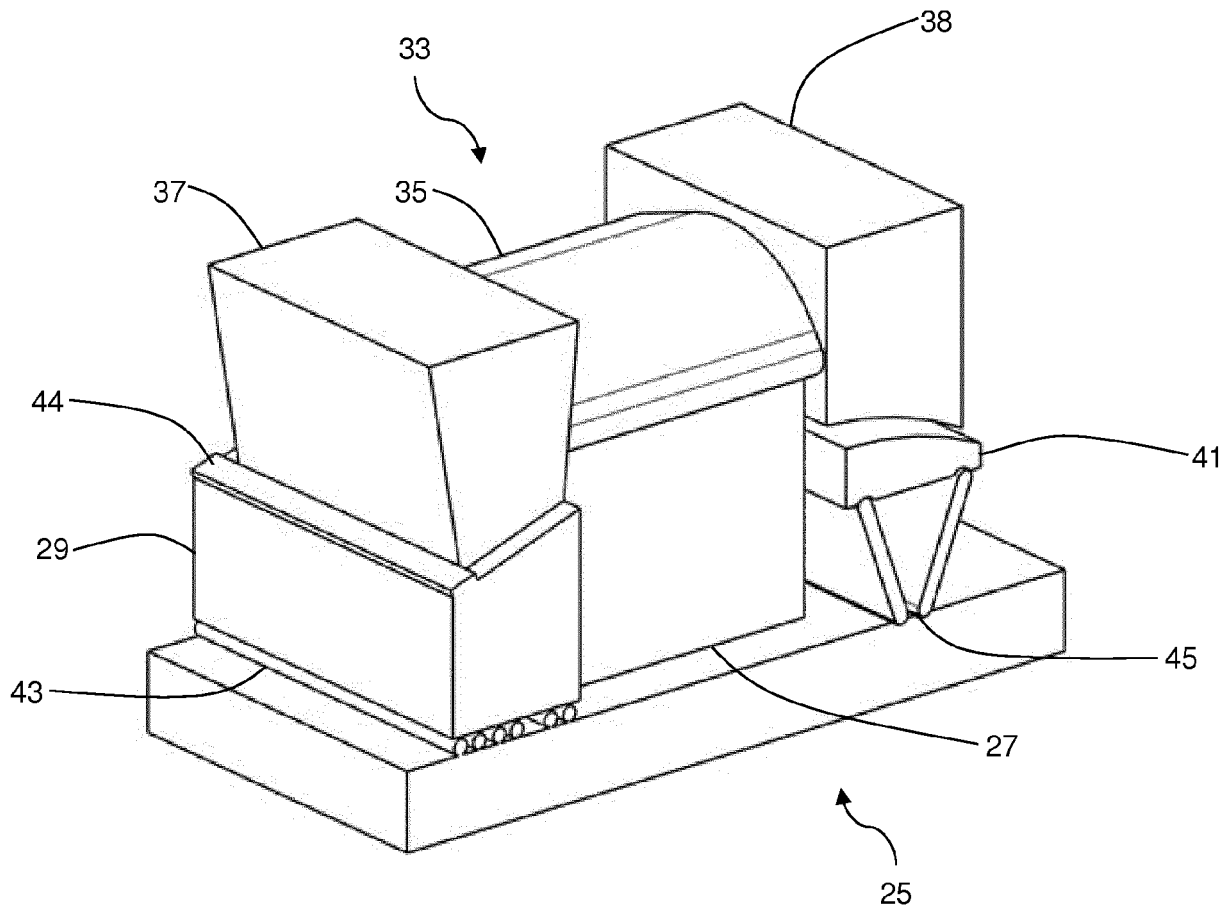


Fig. 4



EUROPEAN SEARCH REPORT

Application Number
EP 16 16 1344

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	FR 2 944 721 A1 (SNECMA [FR]) 29 October 2010 (2010-10-29) * page 3, line 18 - page 7, line 20 * * figures 1-3 * -----	1-7,10, 11 8,9	INV. B22F3/10 B22F3/22 B22F5/04 B22F3/00
			TECHNICAL FIELDS SEARCHED (IPC)
			B22F
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 6 September 2016	Examiner Forestier, Gilles
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR 2944721	A1	29-10-2010	NONE

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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