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(54) Steam turbine part including ceramic matrix composite (CMC)

(57) A steam turbine (10) part includes a ceramic matrix composite (CMC (110)). The part may be made wholly or partially of CMC (110). The CMC (110) eliminates the possibility of oxidation and thus increases steam turbine (10) availability and reliability.

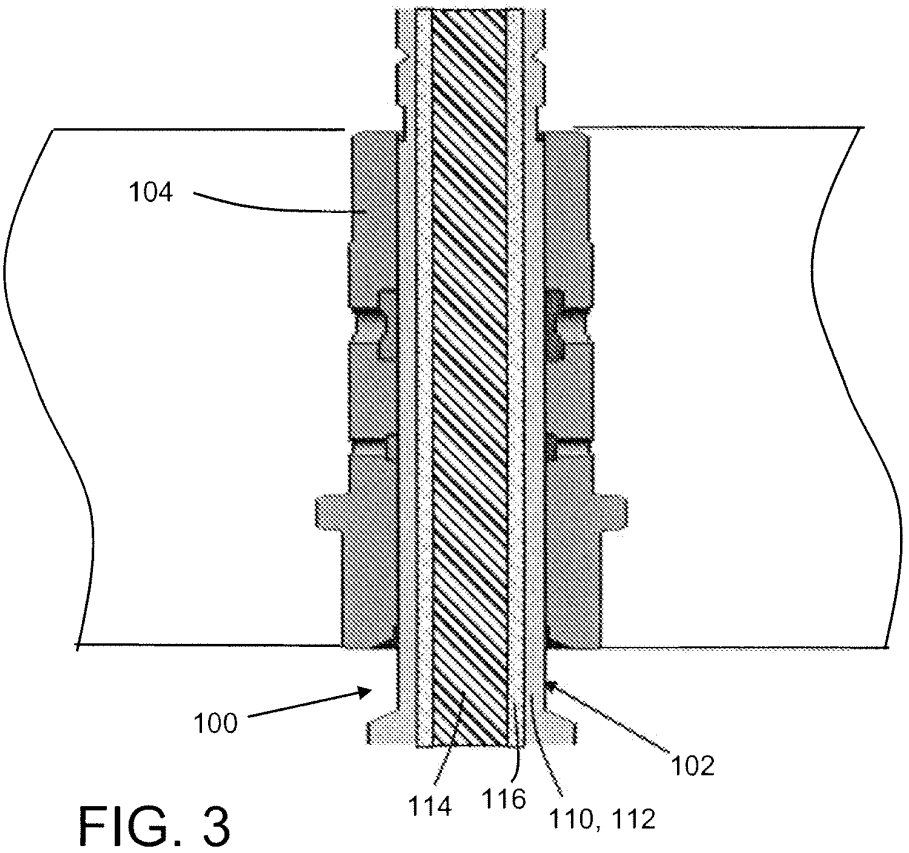


FIG. 3

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Description

BACKGROUND OF THE INVENTION

[0001] The invention relates generally to steam turbines. More particularly, the invention relates to a steam turbine part including ceramic matrix composite (CMC).

[0002] In steam turbines, valves open and close openings between sections of the turbine and are exposed to steam under pressure. One of the design criteria for any steam turbine is reliability, followed by availability and operability. Valve stems, which are typically made of a Nickel alloy, are subjected full steam pressure and temperatures. These pressure and temperatures can reach up to 24.8 mega Pascals (MPa) (3600 pounds per square inch (psi)) and 621 °C (1150 °F) in current designs. Next generation steam turbines, however, are expected to reach up to 29.6 MPa (4300 psi) and 760 °C (1400 °F). Under these latter conditions, Nickel alloy valve stems will oxidize and build up oxide. The valve stem is expected to have up-down motion in a bushing made of similar material. Thus, both valve stem and bushing may develop oxide. To maintain reliability, it is necessary to sustain sufficient clearance at the design and manufacturing stage, so as to allow the stem to work smoothly until major overhaul and/or replacement of the stem (typically 5-10 years) can be performed. One approach to solve this solution is providing additional clearance for the oxide. Unfortunately, providing excessive clearance results in steam leakage which impairs performance. In addition, at high steam temperatures, any reasonable engineering clearance (e.g. 10 millimeter radial) will disappear due to oxide build-up on Nickel based super-alloys in probably 2-4 years, thus potentially resulting in valve stem binding, making the valve non-functional. If a stem binds in its normal, valve open condition, such an event may result in an inability to shut off steam flow and over-speeding of the turbine.

BRIEF DESCRIPTION OF THE INVENTION

[0003] A steam turbine part includes a ceramic matrix composite (CMC). The part may be made wholly or partially of CMC. The CMC eliminates the possibility of oxidation under which a layer of partially or fully oxide based ceramic/fiber combination is applied, and thus increases steam turbine availability and reliability.

[0004] A first aspect of the disclosure provides a steam turbine part for a steam turbine, the stationary part comprising: a ceramic matrix composite.

[0005] A second aspect of the disclosure provides a steam turbine comprising: a part including a ceramic matrix composite.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006]

FIG. 1 is a perspective partial cut-away illustration of a steam turbine.

FIG. 2 is a cross-sectional view of a steam turbine part in the form of a valve stem made completely of ceramic matrix composite (CMC).

FIG. 3 is a cross-sectional view of a steam turbine part in the form of a valve stem made partially of CMC.

FIG. 4 is a cross-sectional view of a steam turbine part in the form of a valve stem having only surfaces exposed to steam made of a CMC.

FIG. 5 is a cross-sectional view of a steam turbine part in the form of a valve stem made of a CMC having a textured exterior surface.

DETAILED DESCRIPTION OF THE INVENTION

[0007] At least one embodiment of the present invention is described below in reference to its application in connection with and operation of a steam turbine. However, it should be apparent to those skilled in the art and guided by the teachings herein that the present invention is likewise applicable to any suitable turbine and/or engine. Embodiments of the present invention provide a steam turbine part where the stationary part includes a ceramic matrix composite (CMC).

[0008] Referring to the drawings, FIG. 1 shows a perspective partial cut-away illustration of a steam turbine 10. Steam turbine 10 includes a rotor 12 that includes a rotating shaft 14 and a plurality of axially spaced rotor wheels 18. A plurality of rotating blades 20 are mechanically coupled to each rotor wheel 18. More specifically, blades 20 are arranged in rows that extend circumferentially around each rotor wheel 18. A plurality of stationary vanes 22 extends circumferentially around shaft 14, and the vanes are axially positioned between adjacent rows of blades 20. Stationary vanes 22 cooperate with blades 20 to form a stage and to define a portion of a steam flow path through turbine 10.

[0009] In operation, steam 24 enters an inlet 26 of turbine 10 and is channeled through stationary vanes 22. Vanes 22 direct steam 24 downstream against blades 20. Steam 24 passes through the remaining stages imparting a force on blades 20 causing shaft 14 to rotate. At least one end of turbine 10 may extend axially away from rotor 12 and may be attached to a load or machinery (not shown) such as, but not limited to, a generator, and/or another turbine.

[0010] In one embodiment of the present invention as shown in FIG. 1, turbine 10 comprises five stages. The five stages are referred to as L0, L1, L2, L3 and L4. Stage L4 is the first stage and is the smallest (in a radial direction) of the five stages. Stage L3 is the second stage and is the next stage in an axial direction. Stage L2 is the

third stage and is shown in the middle of the five stages. Stage L1 is the fourth and next-to-last stage. Stage L0 is the last stage and is the largest (in a radial direction). It is to be understood that five stages are shown as one example only, and each turbine may have more or less than five stages. Also, as will be described herein, the teachings of the invention do not require a multiple stage turbine.

[0011] As understood, steam turbine 10 includes a number of parts. For purposes of description, the invention may be described relative to a stationary valve stem 102, as shown in FIGS. 2-4. Other stationary parts may include, for example, a stationary valve bushing 104 (FIGS. 2-3), a nozzle, casings, etc. It is also understood that the teachings of the invention may also be applied to moving parts such as a valve head or rotor blade. Part 100 includes a ceramic matrix composite (CMC). CMC may include any ceramic material, perhaps including reinforcing fiber or fabric weave, capable of resisting oxidation. In one embodiment, CMC includes an oxide based matrix, which acts to eliminate oxidation. For example, CMC 110 may include an aluminum oxide (Al_2O_3) matrix. In an alternative embodiment, CMC 110 may also include silicon carbon (SiC) fibers to increase hardness. In another embodiment, CMC 110 includes an oxide based matrix and a ceramic based fiber. For example, the oxide based matrix may include (Al_2O_3), titanium boride (TiB) and silicon carbon (SiC). In another example, the oxide based matrix may include Al_2O_3, titanium diboride (TiB_2), platinum carbon (PtC) or silicon carbon (SiC). The ceramic based fiber may include any of the above-listed oxide-based matrices or a ceramic based material such as silicon carbon (SiC). Other matrices may include, for example, zirconium carbide (ZrC), hafnium carbon (HfC), titanium carbon (TiC), tantalum carbon (TaC), and niobium carbon (NbC) and mixed carbides such as zirconium silicon carbon (Zr-Si-C), hafnium silicon carbon (Hf-Si-C) or titanium silicon carbon (Ti-Si-C). Other fibers may include, for example, silicon carbon (SiC), carbon (C), alpha-Al_2O_3 with yttrium oxide (Y_2O_3) and zirconium oxide (ZrO_2) additives, or variations thereof. In any event, CMC 110 should act to increase the ductility or energy absorption in the material system for part 100 and the capability to resist steam corrosion and wearing which in certain cases may include layers on the CMC 110 or fibers.

[0012] In one embodiment, shown in FIG. 2, part 100 may be made entirely of CMC. In an alternative embodiment, shown in FIG. 3, part 100 may be made partially of CMC. In the example shown, part 100 includes a CMC layer 112 over a metal core 114, e.g., of steel. In this case, a thermal matching interface 116 may be necessary between CMC layer 112 and metal core 114 to aid in matching the different thermal expansion rates. Thermal matching interface 116 may include, for example, a compliant layer between CMC layer 112 and metal core 114. Alternatively, as shown in FIG. 4, only surfaces 118 of a part 100 that are exposed to steam may include CMC 110. As understood, a variety of configurations may be employed within the scope of the invention.

[0013] Part 100 may be formed using any now known or later developed technique, e.g., creating a pre-preg of reinforcing material as a freestanding part or mounted to a metal core 114 (FIG. 3), repeatedly infusing the prepreg with a ceramic and curing the ceramic.

[0014] Referring to FIG. 5, in one alternative embodiment, an exterior surface 120 of part 100 may include a textured surface 120. Textured surface 120 may be formed, for example, by providing a woven textile fabric as an outer portion of a pre-preg such that the fabric creates the textured surface 120. The increased surface area for the steam path created by textured surface 120 may increase efficiency by reducing leakage.

[0015] Although embodiments of the invention have been described relative to a valve stem for a steam turbine, the teachings should not be so limited. In particular, the invention can be applied to practically any part of a steam turbine for which oxidation is a limiting factor. For example, the teachings of the invention may be applied to nozzles, casings, etc.

[0016] The above-described invention increases steam turbine availability for next generation steam turbines through reduction of oxide growth rates.

[0017] The terms "first," "second," and the like, herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another, and the terms "a" and "an" herein do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item. The modifier "about" used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context, (e.g., includes the degree of error associated with measurement of the particular quantity). The suffix "(s)" as used herein is intended to include both the singular and the plural of the term that it modifies, thereby including one or more of that term (e.g., the metal(s) includes one or more metals). Ranges disclosed herein are inclusive and independently combinable (e.g., ranges of "up to about 25 wt%, or, more specifically, about 5 wt% to about 20 wt %", is inclusive of the endpoints and all intermediate values of the ranges of "about 5 wt% to about 25 wt%," etc).

[0018] While various embodiments are described herein, it will be appreciated from the specification that various combinations of elements, variations or improvements therein may be made by those skilled in the art, and are within the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

Claims

1. A steam turbine (10) part comprising:

   a ceramic matrix composite.

2. The steam turbine (10) part of claim 1, wherein the CMC (110) is a layer over a metal core (114).

3. The steam turbine (10) part of claim 2, further comprising a thermal matching interface (116) between the CMC (110) and the metal core (114).

4. The steam turbine (10) part of claim 1, wherein the CMC (110) includes an oxide based CMC (110).

5. The steam turbine (10) part of claim 4, wherein the oxide based CMC (110) includes aluminum oxide (Al_2O_3).

6. The steam turbine (10) part of claim 5, wherein the CMC (110) further includes silicon carbon (SiC).

7. The steam turbine (10) stationary part of claim 1, wherein the CMC (110) includes an oxide based matrix and a ceramic based fiber.

8. The steam turbine (10) stationary part of claim 7, wherein the oxide based matrix includes aluminum oxide (Al_2O_3), titanium boride (TiB) and silicon carbon (SiC).

9. The steam turbine (10) part of claim 7, wherein the oxide based matrix includes aluminum oxide (Al_2O_3), titanium di-boride (TiB_2), platinum carbon (PtC) and silicon carbon (SiC).

10. The steam turbine (10) part of claim 1, wherein the CMC (110) includes:

    a matrix selected from the group consisting of: zirconium carbide (ZrC), hafnium carbon (HfC), titanium carbon (TiC), tantalum carbon (TaC), niobium carbon (NbC), zirconium silicon carbon (Zr-Si-C), hafnium silicon carbon (Hf-Si-C) and titanium silicon carbon (Ti-Si-C); and
    a fiber selected from the group consisting of: silicon carbon (SiC), carbon (C) and alpha-Al_2O_3 with yttrium oxide (Y_2O_3) and zirconium oxide (ZrO_2).

11. The steam turbine (10) part of claim 1, wherein an exterior surface of the part includes a textured surface (120).

12. The steam turbine (10) part of claim 1, wherein the part includes a stationary part.

13. The steam turbine (10) part of claim 12, wherein the stationary part is selected from a group consisting of: a valve stem (102), a nozzle, and a bushing.

14. A steam turbine comprising a part according to any of the preceding claims.

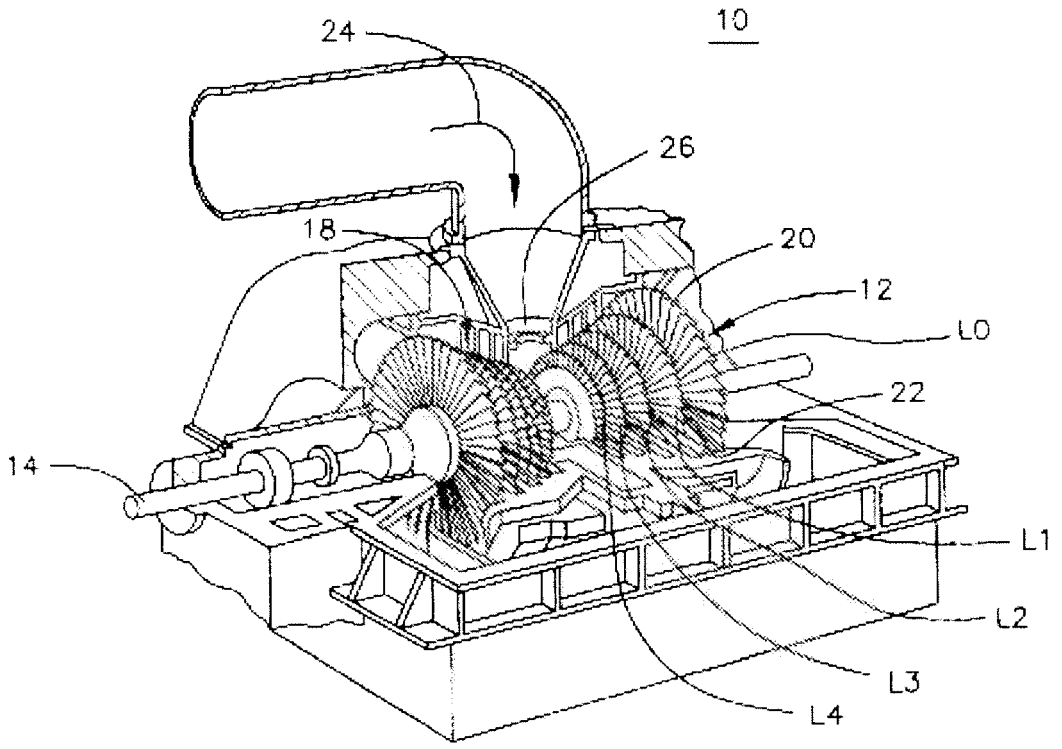


FIG. 1

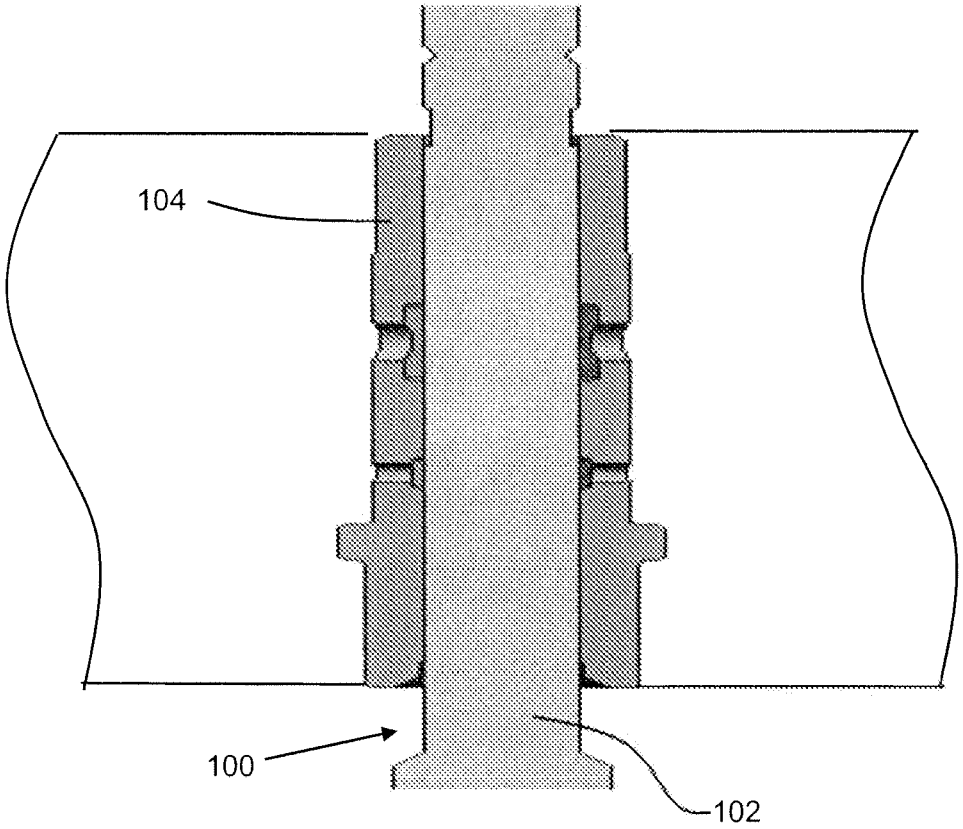


FIG. 2

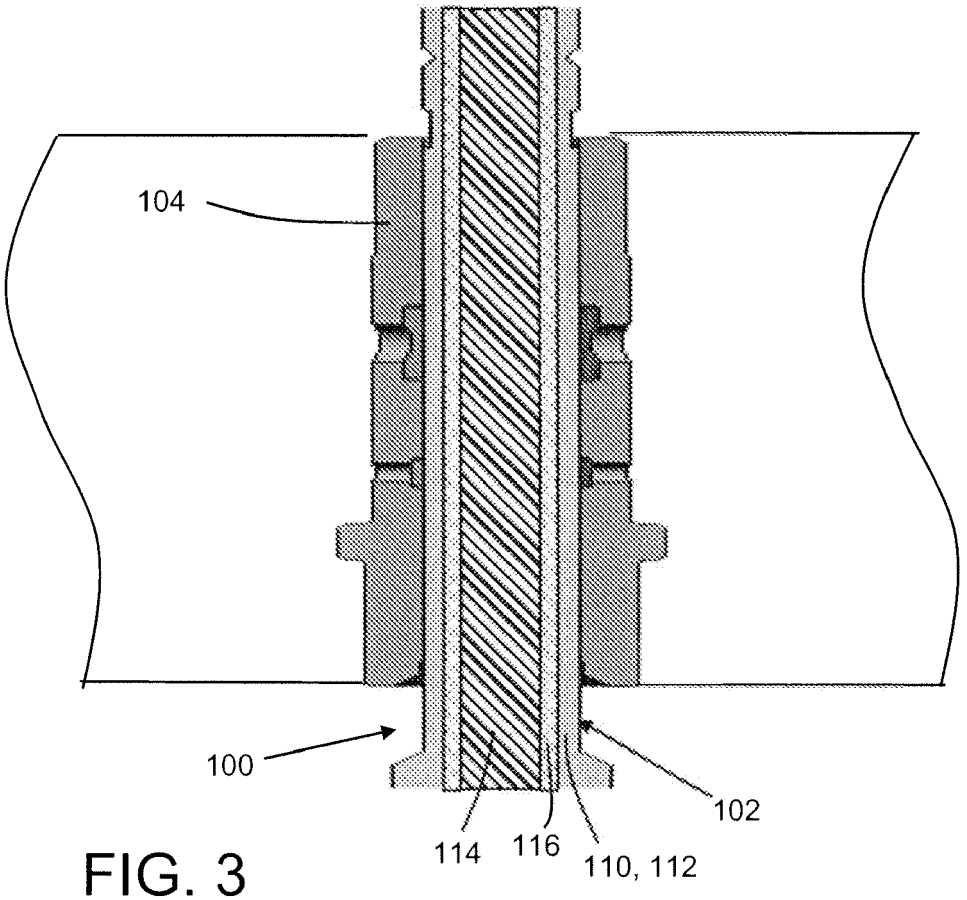


FIG. 3

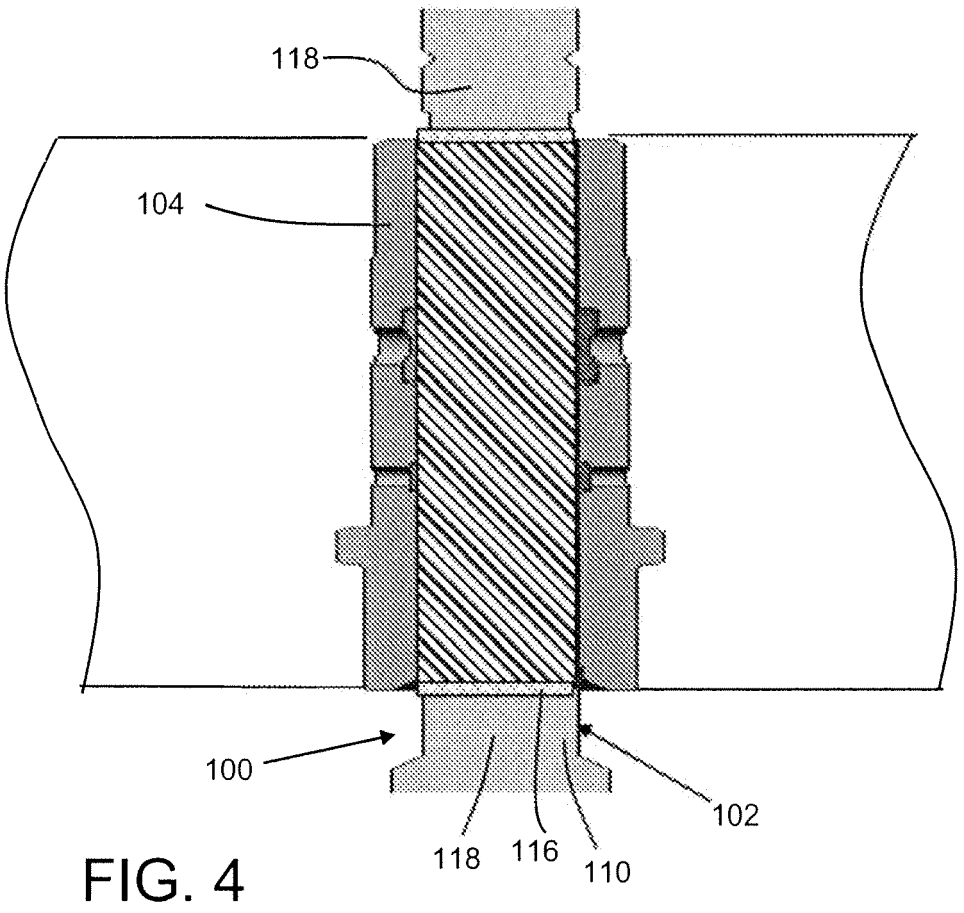


FIG. 4

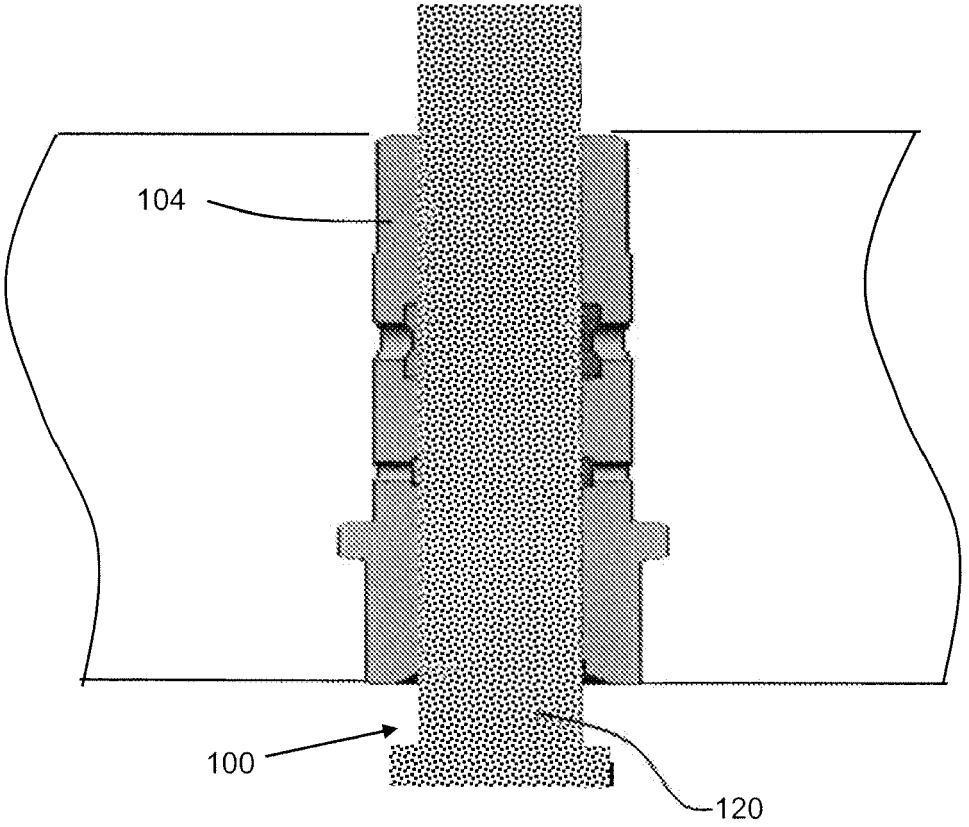


FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 09 16 9335

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F01D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	16 December 2009	Chatziapostolou, A

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 09 16 9335

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