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(54) Title: BELLY BAND SEAL WITH UNDERLAPPING ENDS

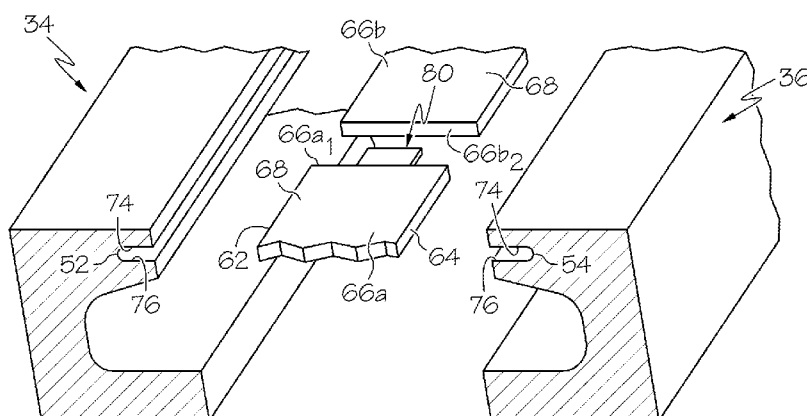


FIG. 2

(57) Abstract: A sealing band for use in a turbomachine having a plurality of stages, each stage comprising a rotatable disk and blades carried thereby. At least one pair of adjacent rotatable disks define an annular gap therebetween and have respective opposing sealing band receiving slots aligned with the annular gap. The sealing band includes a plurality of seal strips located in series adjacent to one another, and adjacent seal strips include opposing end faces located in facing relationship adjacent to one another. An underlap portion is affixed adjacent to an end of at least one seal strip and extends past the end face of an adjacent seal strip, along a radially facing side of the adjacent seal strip.

BELLY BAND SEAL WITH UNDERLAPPING ENDS

FIELD OF THE INVENTION

This invention relates in general to seals for multistage turbomachines and, more particularly, to an optimized baffle seal provided between adjoining disks in a multistage turbomachine.

BACKGROUND OF THE INVENTION

In various multistage turbomachines used for energy conversion, such as turbines, a fluid is used to produce rotational motion. In a gas turbine, for example, a gas is compressed through successive stages in a compressor and mixed with fuel in a combustor. The combination of gas and fuel is then ignited for generating combustion gases that are directed to turbine stages to produce the rotational motion. The turbine stages and compressor stages typically have stationary or non-rotary components, e.g., vane structures, that cooperate with rotatable components, e.g., rotor blades, for compressing and expanding the operational gases.

The rotor blades are typically mounted to disks that are supported for rotation on a rotor shaft. Annular arms extend from opposed portions of adjoining disks to define paired annular arms. A cooling air cavity is formed on an inner side of the paired annular arms between the disks of mutually adjacent stages, and a labyrinth seal may be provided on the inner circumferential surface of the stationary vane structures for cooperating with the annular arms to effect a gas seal between a path for the hot combustion gases and the cooling air cavity. The paired annular arms extending from opposed portions of adjoining disks define opposing end faces located in spaced relation to each other. Typically the opposing end faces may be provided with a slot for receiving a sealing band, known as a "baffle seal" or "belly band seal", which bridges the gap between the end faces to prevent cooling air flowing through the cooling air cavity from leaking into the path for the hot combustion gases. The sealing band may be formed of plural segments, in the circumferential direction, that are typically interconnected at a sealing joint such as at a shiplap joint between the ends to prevent passage of gases past the joint.

SUMMARY OF THE INVENTION

In accordance with one aspect of the invention, a sealing band is provided for use in a turbomachine having a plurality of stages, each stage comprising a rotatable disk and blades carried thereby. At least one pair of adjacent rotatable disks define an annular gap therebetween and have respective opposing sealing band receiving slots aligned with the annular gap. The sealing band comprises a plurality of seal strips located in series adjacent to one another, and adjacent seal strips include opposing end faces located in facing relationship adjacent to one another. An underlap portion is affixed adjacent to an end of at least one seal strip and extends past the end face of an adjacent seal strip, along a radially facing side of the adjacent seal strip.

The underlap portion may have a width, extending across the gap, that is less than a width of the at least one seal strip.

The at least one seal strip may have a width greater than the annular gap, and the underlap portion may have a width no greater than the annular gap.

The underlap portion may have a width less than the annular gap.

The underlap portion may be attached in abutting relation to the end face of the at least one seal strip.

The underlap portion may extend radially away from a radially facing side of the at least one seal strip.

The radially facing side of both the at least one seal strip and the adjacent seal strip may face radially inwardly of the at least one pair of adjacent rotatable disks.

The underlap portion may extend radially beyond the sealing band receiving slots.

The adjacent disks may include opposing disk end faces defining the annular gap therebetween, and the underlap portion may include opposing sides extending adjacent and parallel to the opposing disk end faces.

In accordance with another aspect of the invention, a sealing band is provided in a turbomachine having a plurality of stages, each stage comprising a rotatable disk and blades carried thereby. At least one pair of adjacent rotatable disks define an annular gap therebetween and have respective opposing sealing band receiving

slots aligned with the annular gap. The sealing band comprises a plurality of seal strips located in series adjacent to one another. Adjacent seal strips including opposing end faces located in facing relationship adjacent to one another, each seal strip including opposing radially outwardly and inwardly facing seal strip faces. An underlap portion is affixed adjacent to an end face of at least one seal strip and extends circumferentially past the end face of an adjacent seal strip, along the inwardly facing seal strip face of the adjacent seal strip. The underlap portion comprises opposing radially outwardly and inwardly facing underlap faces, wherein the outwardly facing underlap face is coplanar with the inwardly facing seal strip face.

The sealing band receiving slots may be formed in disk arms associated with each of the adjacent disks, the annular gap being defined between spaced disk arm faces formed on the disk arms, and the underlap portion having opposing sides, each underlap portion side may be located adjacent to a respective disk arm face.

The outwardly facing underlap face may form a planar surface between the underlap portion sides.

A distance between the underlap portion sides may be no greater than a distance between the disk arm faces.

The underlap portion may comprise a separate element attached to the end of the at least one seal strip.

A section of the underlap portion adjacent to the at least one seal strip has a width substantially equal to a width of the seal strip.

The underlap portion includes an underlap element having a width that is less than a width of the annular gap and defining the outwardly facing underlap face.

The underlap portion may extend radially inwardly beyond the sealing band receiving slots, and may define a seal spanning between the pair of adjacent disks and closing a gap between the end face of the at least one seal strip and the end face of the adjacent seal strip.

BRIEF DESCRIPTION OF THE DRAWINGS

While the specification concludes with claims particularly pointing out and distinctly claiming the present invention, it is believed that the present invention will be better understood from the following description in conjunction with the accompanying Drawing Figures, in which like reference numerals identify like elements, and wherein:

Fig. 1 is a diagrammatic section view of a portion of a gas turbine engine including a seal strip assembly in accordance with the present invention;

Fig. 2 is an exploded perspective view illustrating aspects of the present invention;

Fig. 3 is a plan view of a pair of seal strips assembled extending between adjacent disk arms with an underlap portion forming a seal between end faces of the seal strips;

Fig. 4 is a cross-sectional view taken along line 4-4 in Fig. 3;

Fig. 5A is a plan view illustrating an underlap portion on a seal strip prior to movement into underlapping relation to an adjacent seal strip;

Fig. 5B is a side view illustrating the underlapping portion in an assembled position, forming a seal between adjacent seal strips; and

Fig. 6 is a view similar to Fig. 5B illustrating an alternative structure providing an attachment of an underlap portion to a seal strip.

DETAILED DESCRIPTION OF THE INVENTION

In the following detailed description of the preferred embodiment, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration, and not by way of limitation, a specific preferred embodiment in which the invention may be practiced. It is to be understood that other embodiments may be utilized and that changes may be made without departing from the spirit and scope of the present invention.

Referring to Fig. 1, a portion of a turbine engine 10 is illustrated diagrammatically including adjoining stages 12, 14, each stage 12, 14 comprising an array of stationary vane assemblies 16 and an array of rotating blades 18, where the vane assemblies 16 and blades 18 are positioned circumferentially within the engine

10 with alternating arrays of vane assemblies 16 and blades 18 located in the axial direction of the turbine engine 10. The blades 18 are supported on rotor disks 20 secured to adjacent disks with spindle bolts 22. The vane assemblies 16 and blades 18 extend into an annular gas passage 24, and hot gases directed through the gas passage 24 flow past the vane assemblies 16 and blades 18 to remaining rotating elements.

Disk cavities 26, 28 are located radially inwardly from the gas passage 24. Purge air is preferably provided from cooling gas passing through internal passages in the vane assemblies 16 to the disk cavities 26, 28 to cool the blades 18 and to provide a pressure to balance against the pressure of the hot gases in the gas passage 24. In addition, interstage seals comprising labyrinth seals 32 are supported at the radially inner side of the vane assemblies 16 and are engaged with surfaces defined on paired annular disk arms 34, 36 extending axially from opposed portions of adjoining disks 20. An annular cooling air cavity 38 is formed between the opposed portions of adjoining disks 20 on a radially inner side of the paired annular disk arms 34, 36. The annular cooling air cavity 38 receives cooling air passing through disk passages to cool the disks 20.

Referring further to Fig. 2, the disk arms of two adjoining disks 20 are illustrated for the purpose of describing the seal strip assembly 46 of the present invention, it being understood that the disks 20 and associated disk arms 34, 36 define an annular structure extending the full circumference about the rotor centerline. The disk arms 34, 36 define respective opposed disk end faces 48, 50 located in closely spaced relation to each other. A circumferentially extending sealing band receiving slot 52, 54 is formed in the respective disk end faces 48, 50, wherein the slots 52, 54 are radially aligned with an annular gap 56 (Figs. 3 and 4) defined between the disk end faces 48, 50.

As seen in Fig. 4, the seal strip assembly 46 includes a sealing band 60 forming a circumferentially extending belly band seal. The sealing band 60 includes opposing sealing band edges 62, 64 which are positioned within the respective slots 52, 54 defined in the opposed end faces 48, 50. The sealing band 60 spans the annular gap 56 between the end faces 48, 50 and defines a seal for preventing or substantially limiting flow of gases between the cooling air cavity 38 and the disk

cavities 26, 28. Further, the sealing band 60 is comprised of a plurality of segments, typically four segments, referred to herein as seal strips 66 (Fig. 3).

As seen in Figs. 2 and 3, a first seal strip 66a and a second seal strip 66b are located adjacent to each other at respective seal strip end faces 66a₁ and 66b₂. It may be understood that each seal strip 66 is formed as an elongated member extending circumferentially within the engine 10 and includes a first end face, e.g. first end 66a₁ of seal strip 66a, and a second end face, e.g., second end face 66b₂ of seal strip 66b. Referring to Fig. 4, the seal strips 66 also each include a radially outwardly facing seal strip face 68 (hereinafter "outer seal strip face 68") and an opposing radially inwardly facing seal strip face 70 (hereinafter "inner seal strip face 70"). When positioned within the sealing band receiving slots 52, 54, the outer seal strip face 68 is positioned adjacent a radially inwardly facing surface 74 in each of the slots 52, 54, and the inner seal strip face 70 is positioned adjacent a radially outwardly facing surface 76 in each of the slots 52, 54. The thickness of the seal strips 66 is selected such that the dimensional clearance between the seal strip faces 68, 70 and the slot surfaces 74, 76 is minimized to limit leakage past the sealing band 60.

As noted above, a sealing joint, such as a shiplap joint, has typically been provided at the junction between segments of a sealing band. In accordance with an aspect of the invention, it has been observed that the reduced material thickness provided at shiplap joints, i.e., where the ends of the segments are reduced to about half thickness of the sealing band, is a potentially structurally weak location on the sealing band. The thinner material of the sealing band segments at the shiplap location may be subject to fracturing, which may form a breach in the seal with a resulting leakage of cooling air through the belly band.

Further in accordance with an aspect of the invention, an underlap seal 78 is provided to optimize sealing and facilitate durability at the junction between seal strips 66. As may be best seen in Figs. 2, 3 and 5A, the underlap seal 78 is formed by an underlap portion 80 comprising an elongated member that is affixed to the first seal strip 66a at or adjacent to the first seal strip end face 66a₁. It should be understood that the underlap portion 80 may be formed as a separate element that is attached to first seal strip 66a by welding or other attachment technique, or the

underlap portion 80 may be formed integrally at the first end face 66a₁ during a manufacturing process forming the first seal strip 66a. Hence, the term “affixed” as used herein may reference either attachment of the underlap portion 80 provided as a separate element, or integral formation of the underlap portion 80 with the seal strip 66a, such as may be provided during a manufacturing process forming the first end face 66a₁.

The underlap portion 80 described herein has a generally rectangular cross-section, as may be seen in Fig. 4, however other shapes that provide equivalent functional advantages as described herein are equally encompassed by the present description. As seen in Fig. 5B, the underlap portion 80 includes a radially outwardly facing underlap face 82 (hereinafter “outer underlap face 82”) formed as a planar surface, and an opposing radially inwardly facing underlap face 84 (hereinafter “inner underlap face 84”), which may also be a planar surface. The outer and inner underlap faces 82, 84 are connected by opposing underlap portion sides 86, 88. The underlap portion sides 86, 88 extend adjacent and parallel to the respective disk end faces 48, 50. Hence, when the seal strip 66a is positioned within the slots 52, 54, the underlapping portion 80 extends radially inwardly from the inner seal strip face 70, i.e., radially inwardly from the slots 52, 54, into the annular gap 56. It may be noted that the underlap portion 80 may be formed with a radial thickness, i.e., the dimension between the outer and inner underlap faces 82, 84, that is substantially equal to a radial thickness of the seal strips 66, as measured between the outer and inner seal strip faces 68, 70.

In the illustrated embodiment, the outer underlap face 82 is shown as being coplanar with or generally coplanar, i.e., generally lying in a common plane, with the inner seal strip face 70. For example, the underlap portion 80 may be welded in position on the seal strip 66a with a portion of the outer underlap face 82 in contact with the inner seal strip face 70, and with the remainder of the outer underlap face 82 extending outwardly from the first end face 66a₁ of the seal strip 66a.

As may be seen in Fig. 4, the width of the underlap portion 80 is less than the width of the seal strips 66. Referring further to Fig. 3, the underlap portion 80 is dimensioned such that an axial width of the underlap portion 80, as measured by the distance D₂ between the underlap portion sides 86, 88 is no greater than the axial

width of the annular gap 56 as measured by the distance D_1 between the disk end faces 48, 50. Preferably, the axial width D_2 of the underlap portion 80 is slightly less than the axial width D_1 of the annular gap 56 to accommodate variations in the axial width D_1 of the annular gap 56, such as may be caused by relative axial movement of the adjoining disks 20.

In a particular, non-limiting example of the seal strip assembly 46, a nominal distance D_1 between the disk end faces 48, 50 may be about 12.7mm, and a nominal width of the underlap portion 80 may be about 11mm, such that a nominal gap of about 0.85mm may be formed between the disk end faces 48, 50 and each of the respective sides 86, 88 of the underlap portion 80. It may be understood that the exemplary dimensions described above may be measured when the components are cold, and that a dimension of the gap between the underlap portion 80 and the disk end faces 48, 50 may decrease when the components are at a higher or "hot" temperature, such as during operation of the engine 10.

As seen in Figs. 3 and 5B, in an assembled state of the sealing band 60, the underlap portion 80 extends underneath, i.e., underlaps, the second seal strip 66b. In particular, the underlap portion 80 extends past the second seal strip end face 66b₂ and under the second seal strip 66b to position the outer underlap face 82 in engagement with the inner seal strip face 70 of the second seal strip 66b. That is, in a final position of the seal strips 66, a substantial portion of the length of the underlap portion 80 extending beyond the first seal strip end face 66a₁ is located under the second seal strip 66b, and a relatively smaller section of the underlap portion 80 spans a gap 90 that may be formed between the opposing seal strip end faces 66a₁ and 66b₂.

It should be noted that the relative position between adjacent ones of the seal strips 66 may be maintained by anti-rotation structure associated with each of the seal strips 66. For example, an anti-rotation structure such as is disclosed in U.S. Patent No. 7,581,931 may be provided, which patent is incorporated herein by reference. The anti-rotation device provided to each seal strip 66 substantially limits circumferential movement of the seal strips 66 relative to the adjacent disks 20 and relative to each other.

As described above, the underlap portion 80 extends substantially the entire axial width D_1 of the annular gap 56, and substantially prevents or limits passage of cooling air to the seal strips 66a and 66b at the location of the underlap portion 80. In particular, the underlap portion sides 86, 88 extend radially inwardly from the inner seal strip face 70, i.e., radially inwardly from the radially outwardly facing surface 76 of the slots 52, 54, to form a seal with the adjacent disk end faces 34, 36 to prevent or limit passage of air around the underlap portion 80 at the circumferential location of the gap 90 between the seal strip end faces 66a₁, 66b₂.

As noted above, although the underlap portion 80 is illustrated as a separate element attached to the seal strip 66a, the underlap portion 80 may be formed as an integral feature on the seal strip 66a, such as during manufacture of the seal strip 66a. For example, the underlap portion 80 may be formed through use of a combination of forging and machining operations in which the end of the first seal strip 66a is shaped to configure the underlap portion 80 as an integral part of the seal strip 66a.

Alternatively, as is illustrated in Fig. 6, an underlap portion 80' may be provided that forms an end of the first seal strip 66a. In particular, the underlap portion 80' may comprises a seal strip end 81 having a width that is generally the same as an end face 66a₁ of the first seal strip 66a, and further includes an end face 66a₁' having the same width as the seal strip end 81. The underlap portion 80' includes an integrally formed underlap element 83 having a width that is generally the same as the axial width D_2 described above for the underlap portion 80.

The underlap portion 80' may be affixed to the end face 66a₁ of the first seal strip 66a at a butt weld connection 85, such that the underlap portion 80' forms an extension of the seal strip 66a wherein the end face 66a₁' is located in opposing relation to the end face 66b₂ of the second seal strip 66b. The underlap element 83 defines a seal extending in underlapping relation to the second seal strip 66b in the same manner as described above for the underlap portion 80.

It should be understood that, although various structures are described for providing an underlap portion, such as are described for the underlap portions 80, 80', within the spirit and scope of the present invention, any manner of attachment or

formation techniques may be implemented to provide an underlap portion 80, as described herein, for sealing between adjacent seal strips 66.

Further, although the underlap portion 80 is described with particular reference to the end of the first seal strip 66a, it may be understood that in a practical embodiment of the invention, an underlap portion 80 may be provided to an end of each of the segments or seal strips 66 forming the sealing band for underlapping with an adjacent seal strip end.

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this invention.

CLAIMS

What is claimed is:

1. A sealing band for use in a turbomachine having a plurality of stages, each stage comprising a rotatable disk and blades carried thereby, at least one pair of adjacent rotatable disks defining an annular gap therebetween and having respective opposing sealing band receiving slots aligned with the annular gap, the sealing band comprising:

a plurality of seal strips located in series adjacent to one another, and adjacent seal strips including opposing end faces located in facing relationship adjacent to one another; and

an underlap portion is affixed adjacent to an end of at least one seal strip and extending past the end face of an adjacent seal strip, along a radially facing side of said adjacent seal strip.

2. The sealing band of claim 1, wherein said underlap portion has a width, extending across said gap, that is less than a width of said at least one seal strip.

3. The sealing band of claim 1, wherein said at least one seal strip has a width greater than said annular gap, and said underlap portion has a width no greater than said annular gap.

4. The sealing band of claim 3, wherein said underlap portion has a width less than said annular gap.

5. The sealing band of claim 2, wherein said underlap portion is attached in abutting relation to the end face of said at least one seal strip.

6. The sealing band of claim 5, wherein said underlap portion extends radially away from a radially facing side of said at least one seal strip.

7. The sealing band of claim 5, wherein said radially facing side of both said at least one seal strip and said adjacent seal strip faces radially inwardly of said at least one pair of adjacent rotatable disks.
8. The sealing band of claim 1, wherein said underlap portion extends radially beyond said sealing band receiving slots.
9. The sealing band of claim 8, wherein said adjacent disks include opposing end faces defining said annular gap therebetween, and said underlap portion includes opposing sides extending adjacent and parallel to said opposing side faces.
10. A sealing band in a turbomachine having a plurality of stages, each stage comprising a rotatable disk and blades carried thereby, at least one pair of adjacent rotatable disks defining an annular gap therebetween and having respective opposing sealing band receiving slots aligned with the annular gap, the sealing band comprising:
- a plurality of seal strips located in series adjacent to one another, and adjacent seal strips including opposing end faces located in facing relationship adjacent to one another, each seal strip including opposing radially outwardly and inwardly facing seal strip faces; and
 - an underlap portion is affixed adjacent to an end face of at least one seal strip and extends circumferentially past the end face of an adjacent seal strip, along the inwardly facing seal strip face of said adjacent seal strip; and
 - said underlap portion comprises opposing radially outwardly and inwardly facing underlap faces, wherein said outwardly facing underlap face is coplanar with said inwardly facing seal strip face.
11. The sealing band of claim 10, wherein said sealing band receiving slots are formed in disk arms associated with each of said adjacent disks, said annular gap being defined between spaced disk arm faces formed on said disk arms, and said underlap portion having opposing sides, each underlap portion side located adjacent to a respective disk arm face.

12. The sealing band of claim 11, wherein said outwardly facing underlap face forms a planar surface between said underlap portion sides.
13. The sealing band of claim 11, wherein a distance between said underlap portion sides is no greater than a distance between said disk arm faces.
14. The sealing band of claim 10, wherein said underlap portion comprises a separate element attached to said end of said at least one seal strip.
15. The sealing band of claim 14, wherein a section of said underlap portion adjacent to said at least one seal strip has a width substantially equal to a width of said seal strip.
16. The sealing band of claim 15, wherein said underlap portion includes an underlap element having a width that is less than a width of said annular gap and defining said outwardly facing underlap face.
17. The sealing band of claim 10, wherein said underlap portion extends radially inwardly beyond said sealing band receiving slots, and defines a seal spanning between said pair of adjacent disks and closing a gap between said end face of said at least one seal strip and said end face of said adjacent seal strip.

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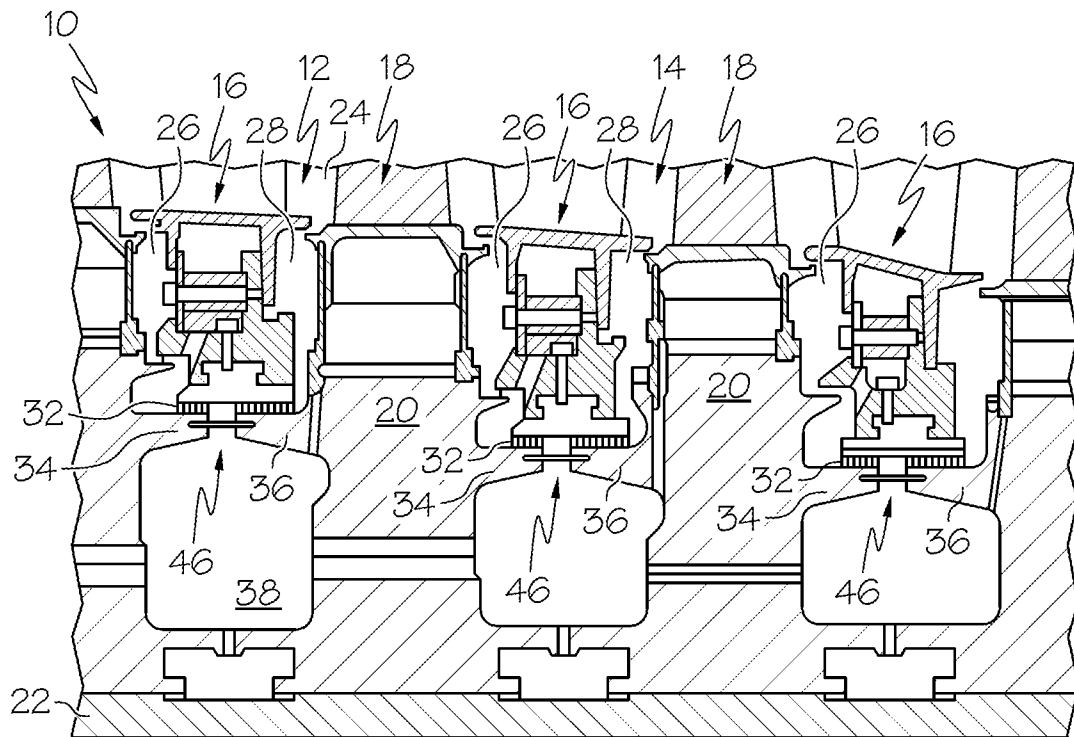


FIG. 1

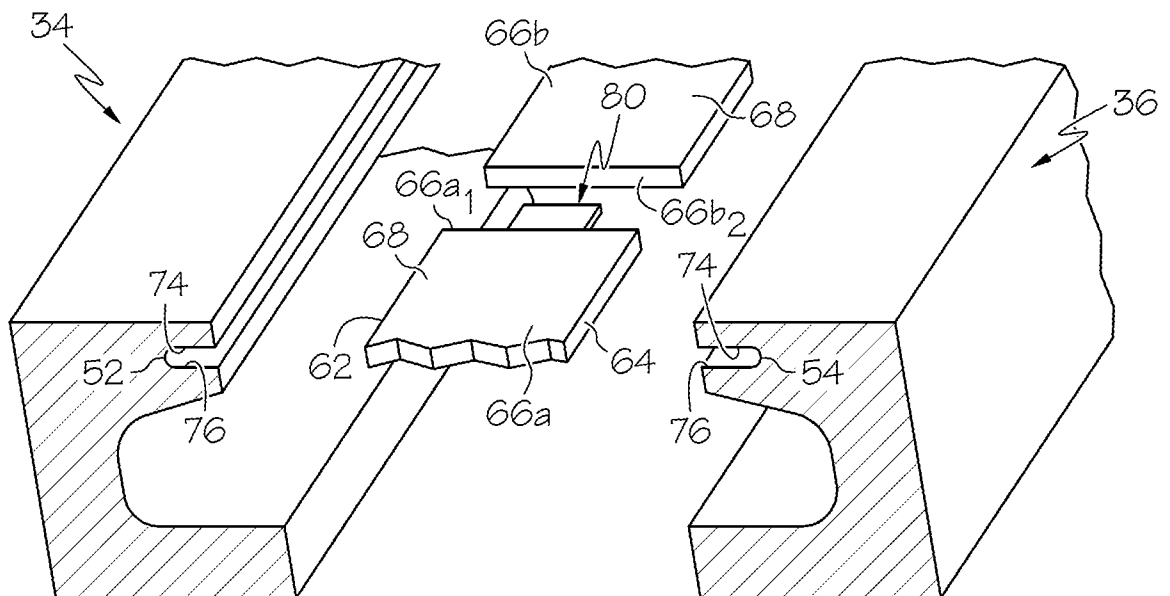


FIG. 2

2 / 3

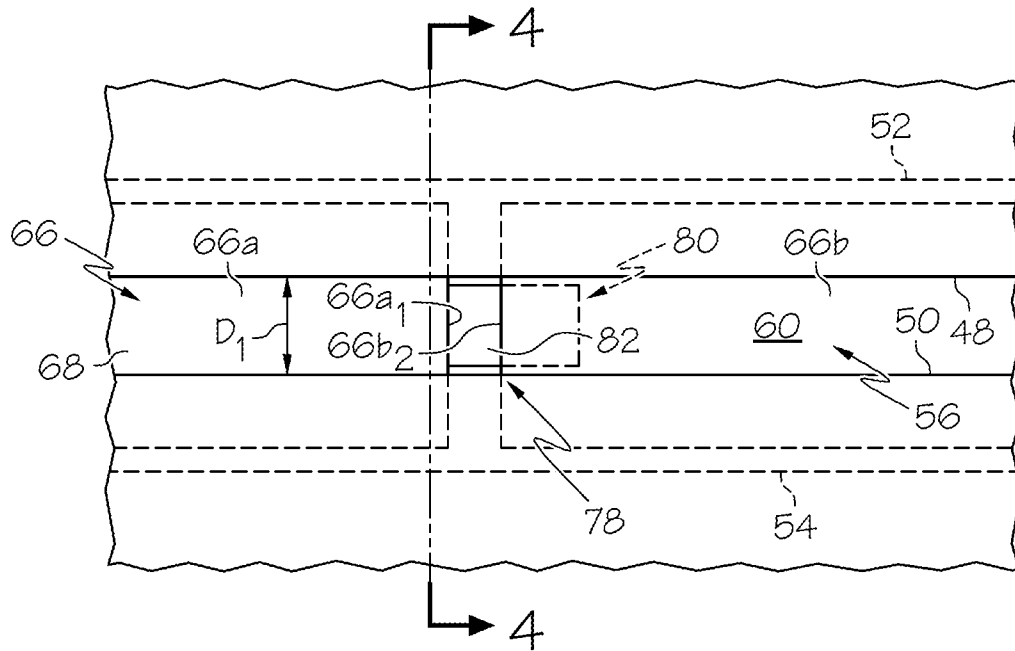


FIG. 3

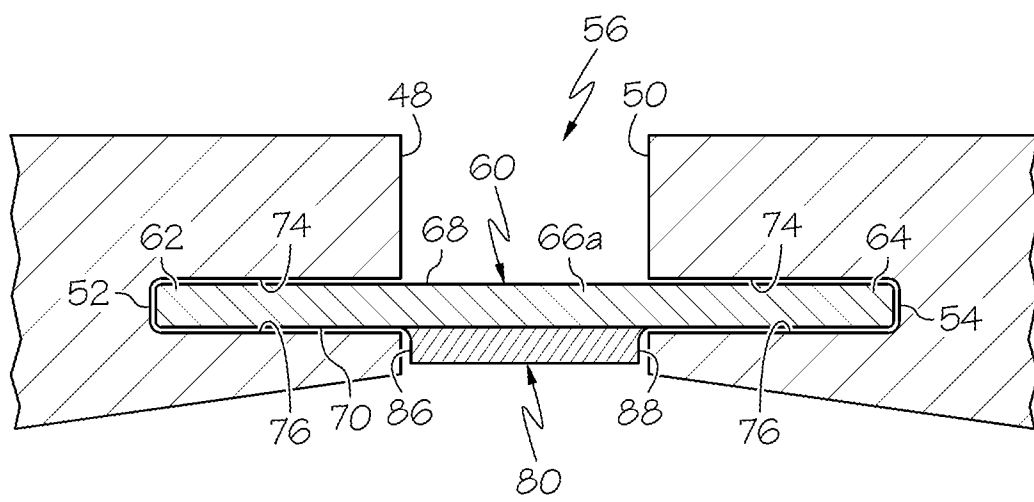


FIG. 4

3 / 3

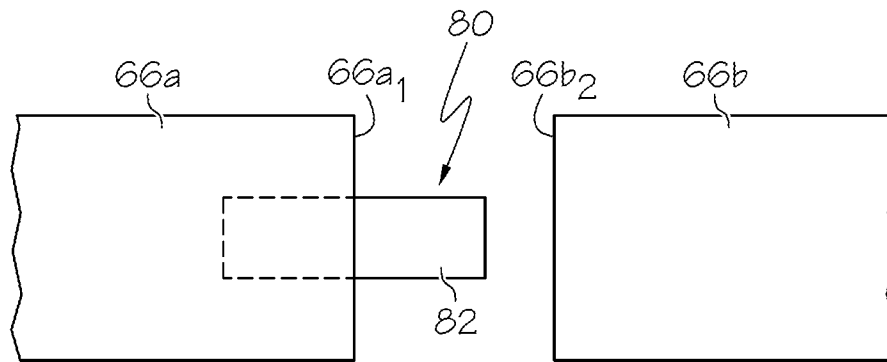


FIG. 5A

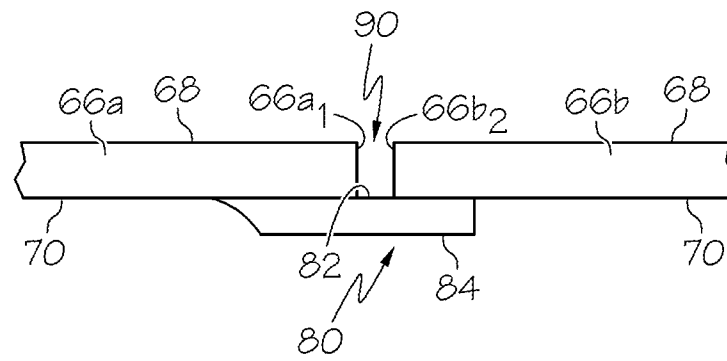


FIG. 5B

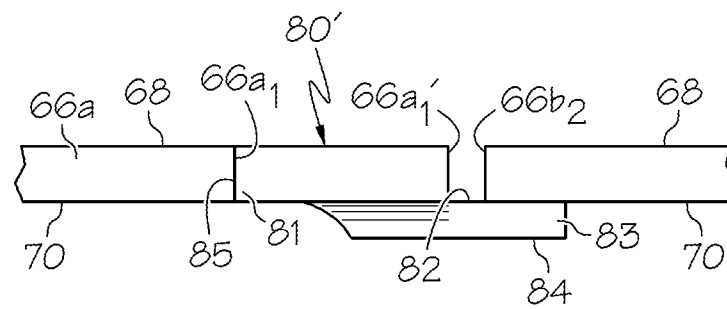


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/064907

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01D5/06 F01D11/00
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)
F01D

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)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 979 961 A1 (MITSUBISHI HEAVY IND LTD [JP]) 16 February 2000 (2000-02-16) abstract; figures 1,2,5,6 -----	1-17
X	KR 2011 0035507 A (KOREA ELECTRIC POWER CORP [KR]) 6 April 2011 (2011-04-06) figures 1-4 -----	1,10
A	US 7 581 931 B2 (SHAEFER DAVID M [US] ET AL) 1 September 2009 (2009-09-01) cited in the application abstract; figures 2,3 -----	1-17

☐

Further documents are listed in the continuation of Box C.

☒

See patent family annex.

* Special categories of cited documents :

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

24 March 2014

Date of mailing of the international search report

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Name and mailing address of the ISA/

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Avramidis, Pavlos

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0979961	A1	16-02-2000	CA 2287509 A1 10-09-1999
			DE 69931113 T2 30-11-2006
			EP 0979961 A1 16-02-2000
			JP 3643692 B2 27-04-2005
			JP H11247999 A 14-09-1999
			US 6315301 B1 13-11-2001
			WO 9945297 A1 10-09-1999

KR 20110035507	A	06-04-2011	NONE

US 7581931	B2	01-09-2009	NONE
