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(54) **INTER-STAGE SEAL FOR A TURBOMACHINE**

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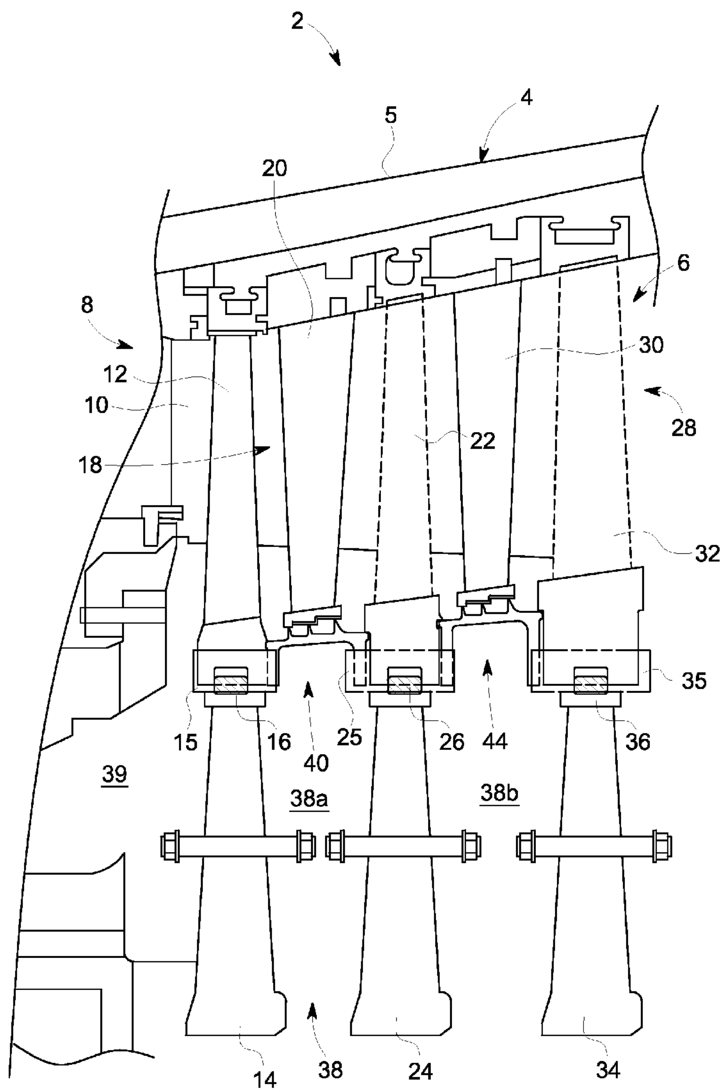
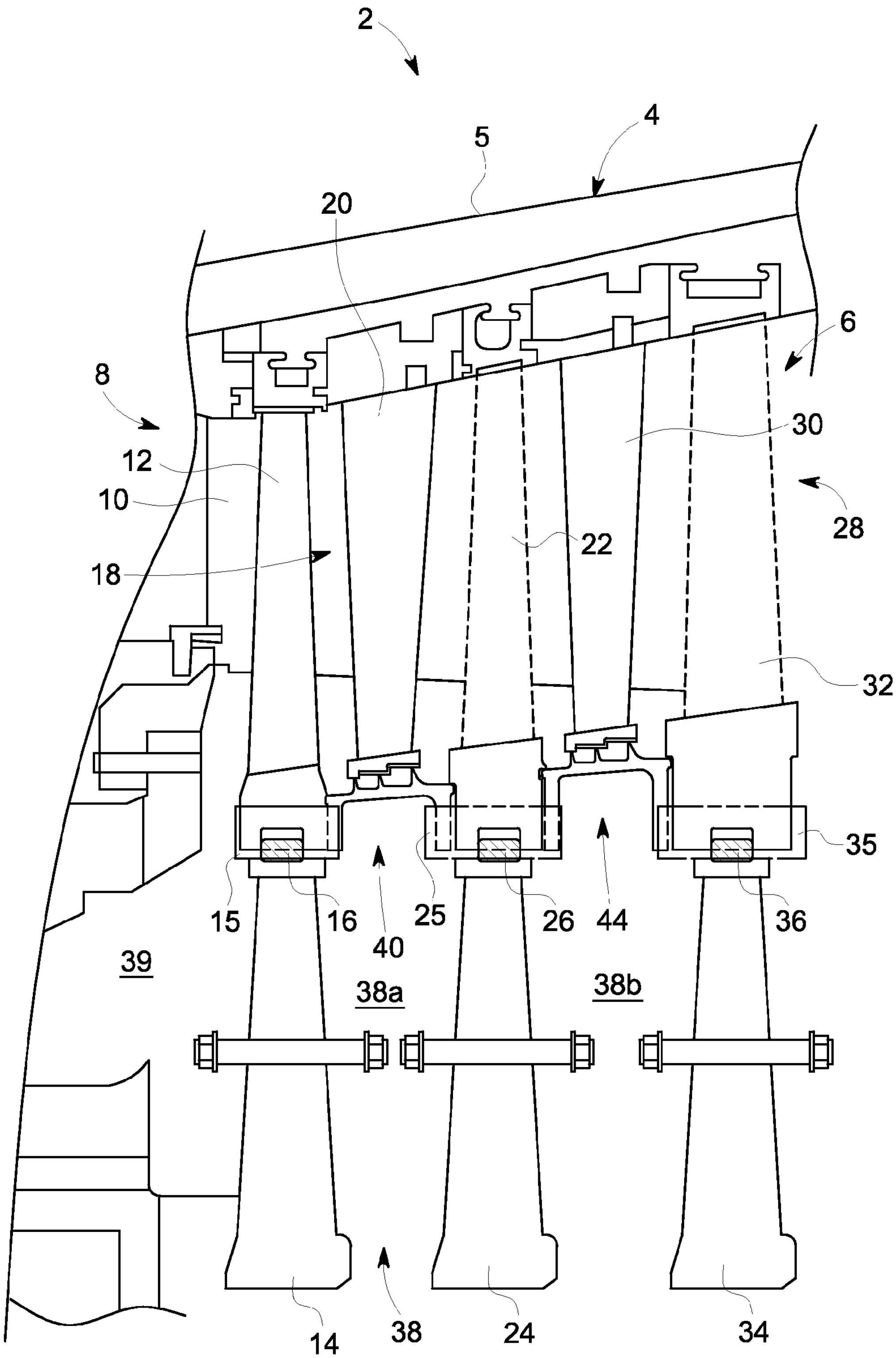
(57) **ABSTRACT**

An inter-stage seal for a turbomachine includes a sealing member extending from a first end to a second end through an intermediate portion having a sealing surface, a first mounting member extending from a first end portion coupled to the sealing member adjacent the first end to a second, cantilevered end portion having a first rotor mounting element, and a second mounting member extending from a first end portion coupled to the sealing member adjacent the second end to a second, cantilevered end portion having a second rotor mounting element.

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38a
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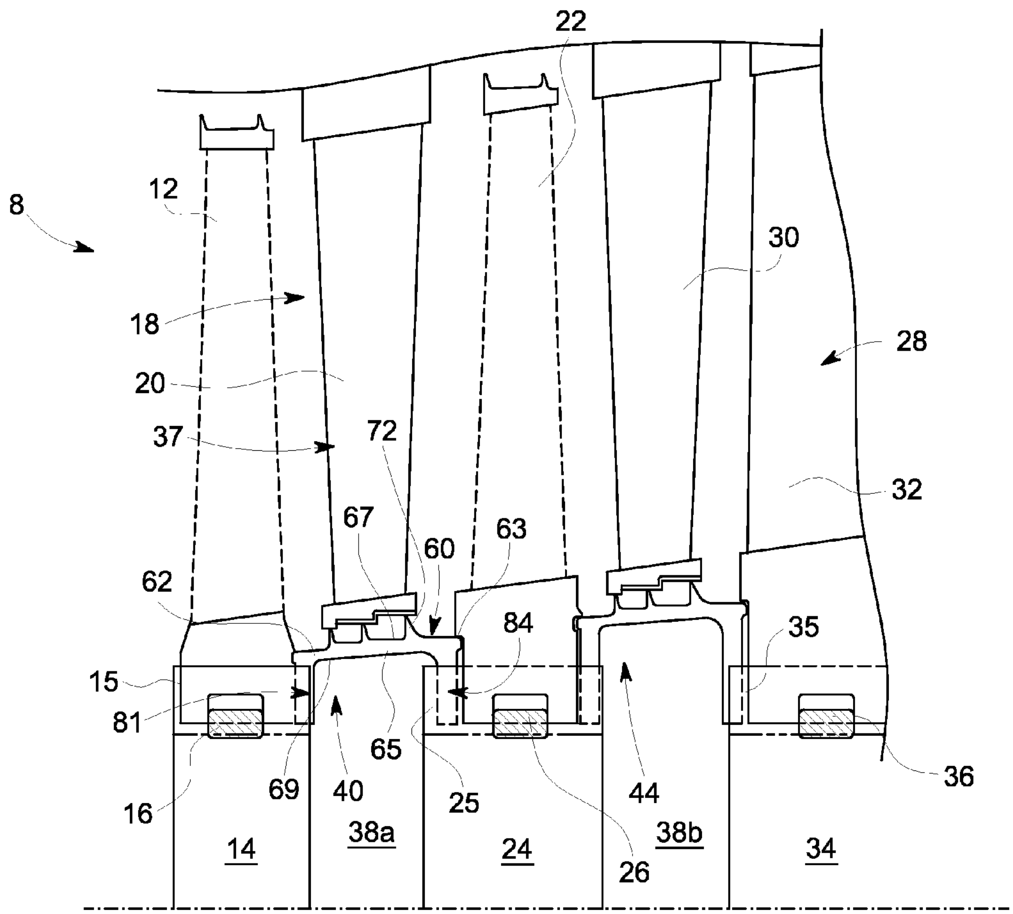
FIG. 1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38a
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38b
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FIG. 2

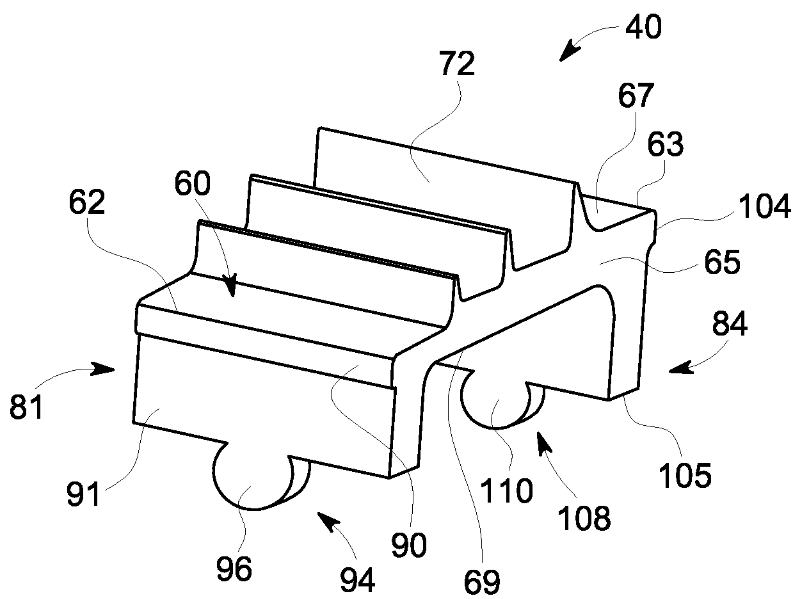
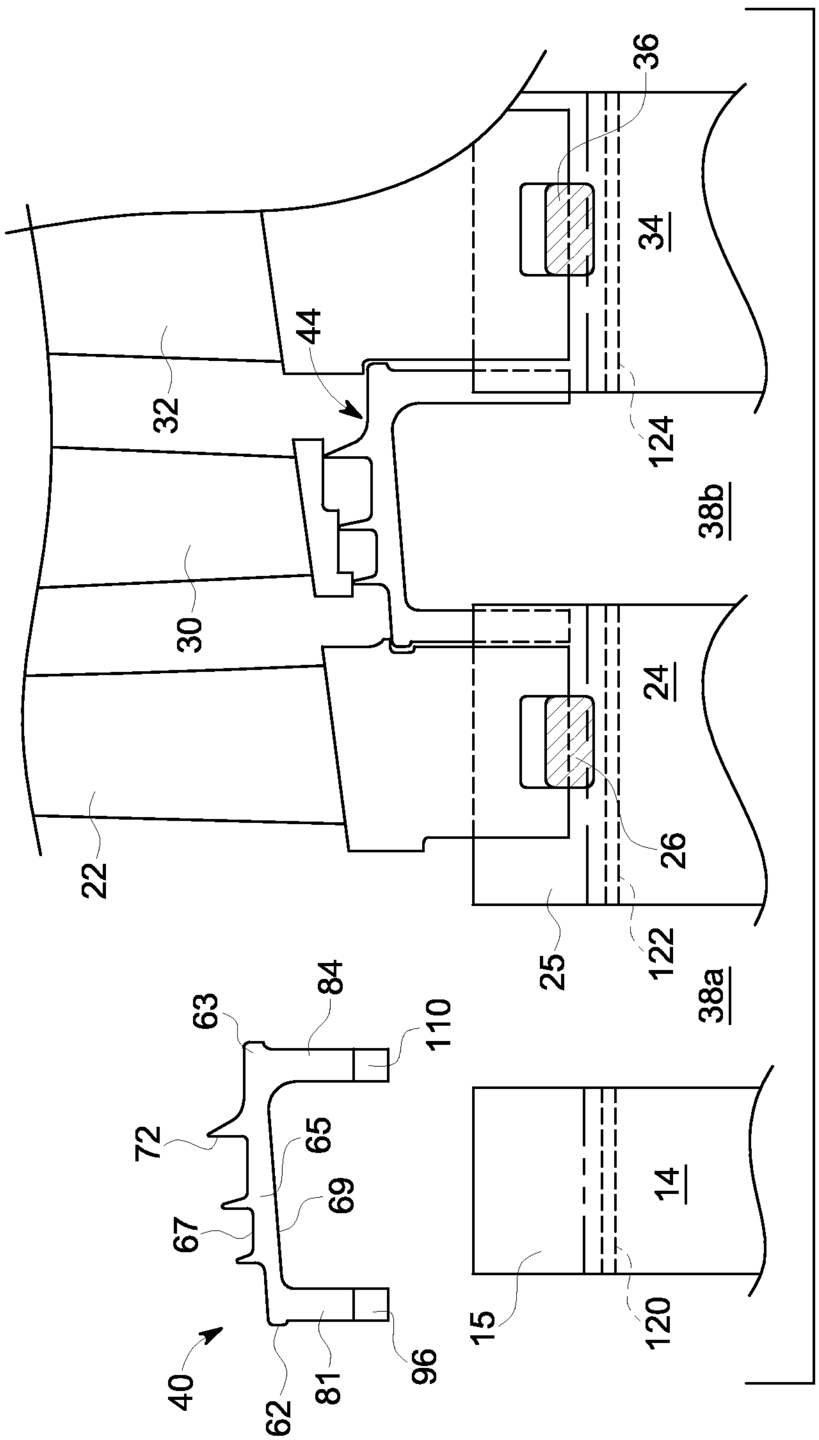


FIG. 3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38b
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122
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14
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120
40
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81
96

FIG. 4

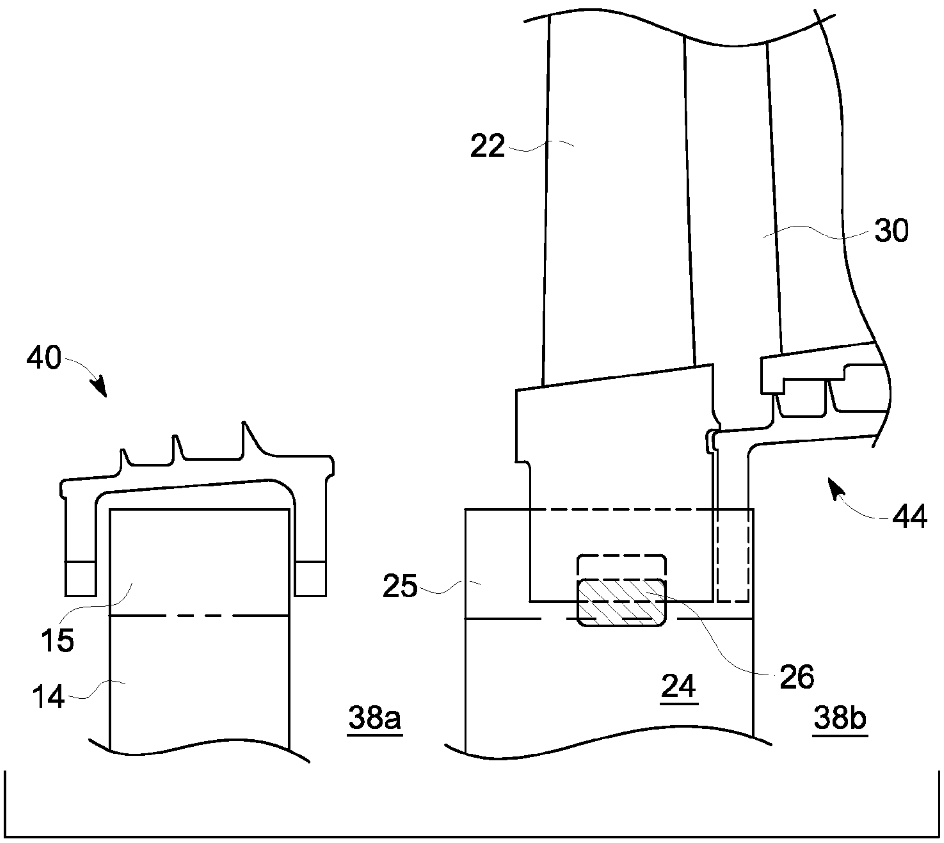

FIG. 5

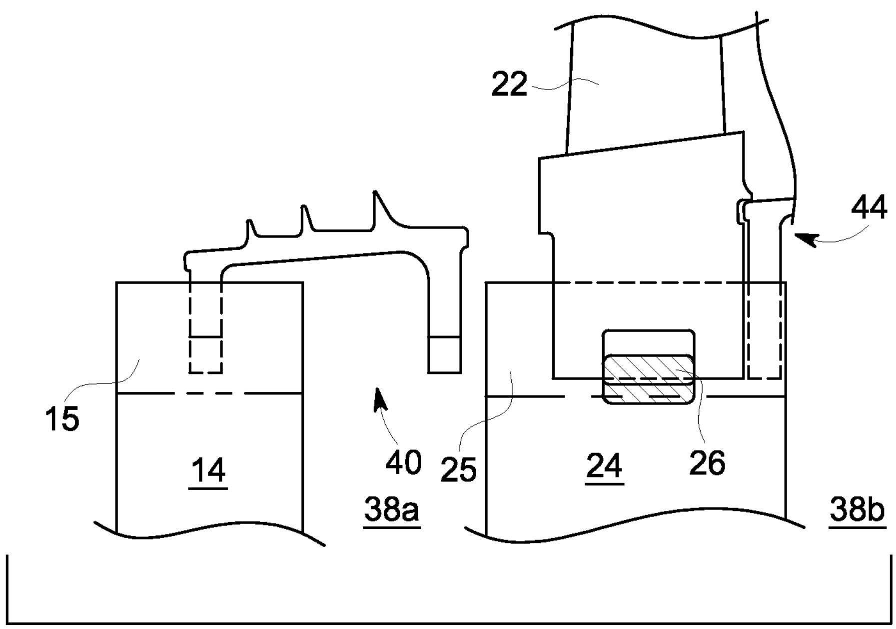

FIG. 6

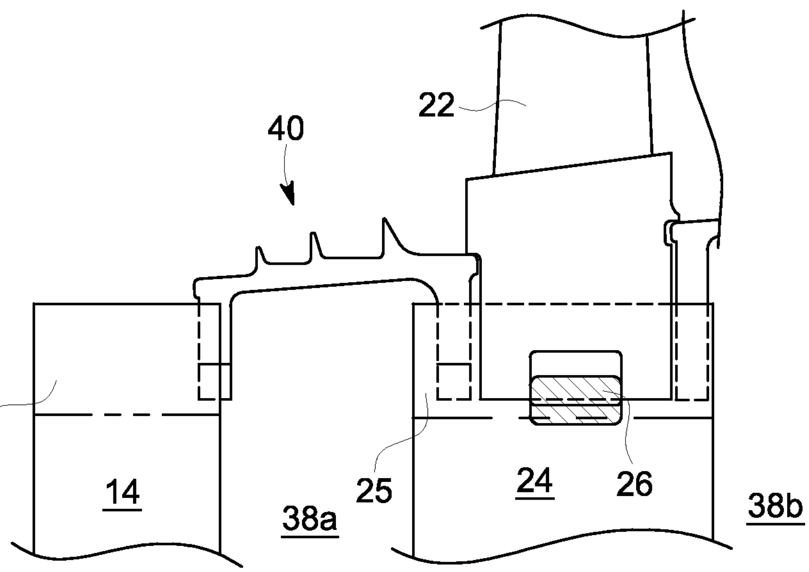

FIG. 7

INTER-STAGE SEAL FOR A TURBOMACHINE

BACKGROUND OF THE INVENTION

[0001] The subject matter disclosed herein relates to the art of turbomachines and, more particularly, to an inter-stage seal for a turbine portion of a turbomachine.

[0002] Turbomachines include a compressor portion linked to a turbine portion through a common compressor/turbine shaft and a combustor assembly. An inlet airflow is passed through an air intake toward the compressor portion. In the compressor portion, the inlet airflow is compressed through a number of sequential stages toward the combustor assembly. In the combustor assembly, the compressed airflow mixes with a fuel to form a combustible mixture. The combustible mixture is combusted in the combustor assembly to form hot gases. The hot gases are guided along a hot gas path of the turbine portion through a transition piece. The hot gases expand through a number of turbine stages acting upon turbine buckets mounted on wheels to create work that is output, for example, to power a generator, a pump, or to provide power to a vehicle. Exhaust gases from the turbine portion are often times passed to a heat recovery steam generator which creates a steam flow that is passed to a steam turbine portion.

[0003] Additional gases, in the form of compressor air, may pass into the turbine portion, or in the form of lower temperature air, may enter wheel spaces in turbine portion to cool a rotor and/or a wheel. In a steam turbine, lower temperature steam may be fed into wheel spaces of early stages to cool the rotor that supports rotating buckets. In either case, inter-stage seals substantially isolate the hot gases, or working fluids, flowing along the hot gas path and the fluids used for cooling purposes. The inter-stage seals typically include axial outwardly extending arms that cooperate with turbine blade angel wings to reduce leakage. Typical angel wing seals involve a rotating seal tooth or sealing face mating with a stationary counterpart. There typically exists a clearance between a rotating component and a stationary component to reduce contact or rubbing. The clearance may allow leakage to flow between the rotating component and the stationary component. The leakage flow may increase cooling requirements that may negatively impact turbomachine efficiency. Reducing working fluid leakage increases turbomachine efficiency.

BRIEF DESCRIPTION OF THE INVENTION

[0004] According to one aspect of the exemplary embodiment, an inter-stage seal for a turbomachine includes a sealing member extending from a first end to a second end through an intermediate portion having a sealing surface, a first mounting member extending from a first end portion coupled to the sealing member adjacent the first end to a second, cantilevered end portion having a first rotor mounting element, and a second mounting member extending from a first end portion coupled to the sealing member adjacent the second end to a second, cantilevered end portion having a second rotor mounting element.

[0005] According to another aspect of the exemplary embodiment, a turbomachine includes a turbine portion having a first stage rotor supporting a plurality of first stage turbine blades and a second stage rotor supporting a plurality of second stage turbine blades. At least one inter-stage seal extends between the first and second stage rotors. The at least one inter-stage seal includes a sealing member extending from a first end to a second end through an intermediate portion having a sealing surface, a first mounting member extending from a first end portion coupled to the sealing member adjacent the first end to a second, cantilevered end portion having a first rotor mounting element connected to the first stage rotor, and a second mounting member extending from a first end portion coupled to the sealing member adjacent the second end to a second, cantilevered end portion having a second rotor mounting element connected to the second stage rotor.

[0006] According to yet another aspect of the exemplary embodiment, a method of sealing between adjacent stages in a turbomachine includes positioning an inter-stage seal across a rotor, axially shifting the inter-stage seal across the rotor, arranging a sealing member of the inter-stage seal across a gap extending between the rotor and an adjacent rotor, connecting a first mounting member extending from a first end of the sealing member with the rotor, and connecting a second mounting member extending from a second end of the sealing member to the another rotor.

[0007] These and other advantages and features will become more apparent from the following description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0008] The subject matter, which is regarded as the invention, is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

[0009] FIG. **1** is a cross-sectional side view of a turbomachine including an inter-stage seal, in accordance with an exemplary embodiment;

[0010] FIG. **2** is a partial plan view of a turbine portion of the turbomachine of FIG. **1**;

[0011] FIG. **3** is a perspective view of the inter-stage seal of FIG. **1**;

[0012] FIG. **4** is a plan view of an inter-stage seal being positioned across a rotor of the turbomachine of FIG. **1**;

[0013] FIG. **5** is a plan view of the inter-stage seal straddling the rotor of FIG. **4**;

[0014] FIG. **6** is a plan view of the inter-stage seal axially shifting toward another rotor of the turbomachine; and

[0015] FIG. **7** is a plan view of the inter-stage seal connected to the rotor and the another rotor, in accordance with an exemplary embodiment.

[0016] The detailed description explains embodiments of the invention, together with advantages and features, by way of example with reference to the drawings.

DETAILED DESCRIPTION OF THE INVENTION

[0017] A turbomachine, in accordance with an exemplary embodiment, is indicated generally at **2**, in FIG. **1**. Turbomachine **2** takes the form of a turbine portion **4** having a housing **5** that surrounds a plurality of turbine stages **6**. Turbine stages **6** include a first stage **8**. First stage **8** includes a plurality of first stage vanes or nozzles, one of which is indicated at **10**, and a plurality of first stage axial entry buckets or blades, one of which is indicated at **12**. Blades **12** are mounted to a first stage rotor **14** through a plurality of dovetail slots **15**. First stage rotor **14** includes one or more axial locking members **16** that constrain axial movement of blades **12**.

[0018] Plurality of turbine stages **6** also include a second stage **18** arranged downstream of first stage **8**. Second stage **18** includes a plurality of second stage vanes or nozzles, one of which is indicated at **20**, and a plurality of second stage axial entry buckets or blades, one of which is indicated at **22**. Blades **22** are mounted to a second stage rotor **24** through a plurality of dovetail slots **25**. Second stage rotor **20** includes one or more axial locking members **26** that constrain axial movement of blades **22**. A third stage **28** is arranged downstream of second stage **18**. Third stage **28** includes a plurality of third stage vanes or nozzles, one of which is indicated at **30**, and a plurality of third stage axial entry buckets or blades, one of which is indicated at **32**. Blades **32** are mounted to a third stage rotor **34** through a plurality of dovetail slots **35**. Third stage rotor **34** includes one or more axial locking members **36** that constrain axial movement of blades **32**. Blades **12**, **22**, and **32** extend along a hot gas path **37** of turbine portion **8**.

[0019] A working fluid, in the form of hot gases that may include products of combustion or steam, expands through turbine stages **6** to an outlet (not separately labeled) acting upon the first, second, and third stage blades **12**, **22**, and **32**. The force of the hot gases impacting the first, second, and third stage blades **12**, **22** and **32** is transmitted to first, second, and third stage rotors **14**, **24** and **34** which rotate. Rotational energy from the first, second, and third stage rotors **14**, **24**, and **34** is transmitted to a load (not shown) through a shaft (not separately labeled). In addition to the working fluid, a cooling fluid is passed through a wheelspace portion **38** of turbine portion **4**. Wheelspace portion **38** may include inter-rotor spaces between adjacent rotors **14**, **24** and **24**, **34** such as shown at **38***a* and **38***b* respectively. Wheelspace portion **38** may also include a portion **39** that exists between stationary components (not separately labeled) and rotor **14**.

[0020] In order to limit hot gas ingestion into spaces **38***a* and **38***b* and other inter-wheel spaces (not shown), and to reduce leakage of the cooling fluid, turbine portion **4** includes a first inter-stage seal **40** arranged between first and second rotors **14** and **24** in stages **8** and **18** respectively, and a second inter-stage seal **44** arranged between rotors **24** and **44** in second and third stages **18** and **28**, respectively. In accordance with an aspect of the invention, a conventional angel wing seal (not shown) may be placed on an upstream side (not separately labeled) of first stage rotor **14**. Of course it should be understood that other types of seals, including an inter-stage seal **40** could be used. At this point it should be understood that the number of stages and inter-stage seals may vary.

[0021] Reference will now be made to FIGS. **2-3** in describing first inter-stage seal **40**, in accordance with an exemplary embodiment, with an understanding that second inter-stage seal **44** may include similar structure. First inter-stage seal **40** includes a sealing member **60** that extends from a first end **62** to a second end **63** through an intermediate portion **65**. Intermediate portion **65** includes a sealing surface **67** and an opposing, cooling surface **69**. Sealing surface **67** includes one or more radially outwardly projecting sealing elements **72**. When installed, sealing elements **72** extend toward a bottom surface of, for example, second stage nozzles **20**.

[0022] Inter-stage seal **40** also includes a first mounting member **81** that interfaces with first stage rotor **14** and a second mounting member **84** that interfaces with second stage rotor **24**, as will be detailed more fully below. First mounting member **81** extends from a first end portion **90** to a second, cantilevered, end portion **91**. First end portion **90** extends from first end **62** and second end portion **91** includes a first rotor mounting element **94**. First rotor mounting element **94** takes the form of a dovetail member **96** that is configured to slidingly engage with dovetail slot **15**. Second mounting member **84** extends from a first end portion **104** to a second, cantilevered, end portion **105**. First end portion **104** extends from second end **63** and second end portion **105** includes a second rotor mounting element **108**. Second rotor mounting element **108** takes the form of a dovetail member **110** that is configured to slidingly engage with dovetail slot **25**. In the exemplary embodiment, first and second rotor mounting elements **94** and **108** are shown as complete dovetails. It should be readily understood that first and second rotor mounting elements **94** and **108** can also take the form of partial or whole form dovetails having various geometries that structurally match dovetail slots on the rotor. First and second ends **62** and **63** abut, or nearly abut, base portions (not separately labeled) of corresponding ones of first stage blades **12** and second stage blades **22**. In accordance with an aspect of the exemplary embodiment, inter-stage seal **40** rotates together with first and second stage blades **12** and **22**. Accordingly, gaps between abutting surfaces may be set to very small dimensions that effectively fluidically separate inter-rotor spaces **38***a* and **38***b* from hot gas path **37**.

[0023] Reference will now be made to FIGS. **4-7** in describing a method of installing inter-stage seal **40**, in accordance with an aspect of the exemplary embodiment. As shown in FIG. **4**, inter-stage seal **40** is positioned at first stage rotor **14** prior to the installation of first stage blades **12**. Inter-stage seal **40** is moved into position such that first and second mounting members **81** and **84** straddle first stage rotor **14**, as shown in FIG. **5**. Inter-stage seal **40** is axially shifted causing dovetail member **96** to pass into dovetail slot **15**, as shown in FIG. **6**. Inter-stage seal **40** is further axially shifted until dovetail member **110** enters dovetail slot **25** in second rotor **24**, as shown in FIG. **7**. At this point, additional inter-stage seals may be mounted to first stage rotor **14**, or first stage rotor blades **12** may be installed and locked into position. In the exemplary embodiment, each rotor wheel may include balance holes **120**, **122**, and **124** formed in first, second, and third stage rotors **14**, **24**, and **34**. Balance holes **120**, **122**, and **124**may pass cooling flow between inter-rotor spaces **38***a* and **38***b* and the like.

[0024] At this point it should be understood that the exemplary embodiments describe an inter-stage seal for a turbine. The inter-stage seal joins adjacent rotors doing away with the need for turbine wheels and corresponding seals. The particular shape of the inter-stage seal also removes the need for angel wings provided on the rotor blades for sealing purposes. The inter-stage seal, in accordance with the exemplary embodiment, contributes to an overall reduction in axial length of a turbine while maintaining a desired separation between working fluid and cooling fluid flows. At this point it should be understood that the inter-stage seal, in accordance with exemplary embodiment, may be employed in a gas turbine or a steam turbine. It should be further understood that the particular geometry of the inter-stage seal may vary and should not be limited to the geometries shown.

[0025] While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

What is claimed is:

1. An inter-stage seal for a turbomachine comprising:

a sealing member extending from a first end to a second end through an intermediate portion having a sealing surface;

a first mounting member extending from a first end portion coupled to the sealing member adjacent the first end to a second, cantilevered end portion having a first rotor mounting element; and

a second mounting member extending from a first end portion coupled to the sealing member adjacent the second end to a second, cantilevered end portion having a second rotor mounting element.

2. The inter-stage seal according to claim **1**, further comprising: a plurality of sealing elements extending outwardly from the sealing surface.

3. The inter-stage seal according to claim **1**, wherein the first end is cantilevered from the first mounting member.

4. The inter-stage seal according to claim **1**, wherein the second end is cantilevered from the second mounting member.

5. The inter-stage seal according to claim **1**, wherein each of the first and second rotor mounting elements comprise dovetail members.

6. A turbomachine comprising:

a first stage rotor supporting a plurality of first stage turbine blades and a second stage rotor supporting a plurality of second stage turbine blades;

at least one inter-stage seal extending between the first and second stage rotors, the at least one inter-stage seal comprising:

a sealing member extending from a first end to a second end through an intermediate portion having a sealing surface;

a first mounting member extending from a first end portion coupled to the sealing member adjacent the first end to a second, cantilevered end portion having a first rotor mounting element connected to the first stage rotor; and

a second mounting member extending from a first end portion coupled to the sealing member adjacent the second end to a second, cantilevered end portion having a second rotor mounting element connected to the second stage rotor.

7. The turbomachine according to claim **6**, further comprising: a plurality of sealing elements extending outwardly from the sealing surface.

8. The turbomachine according to claim **7**, wherein the at least one inter-stage seal is arranged in a turbine portion of the turbomachine, the plurality of sealing elements extending toward a nozzle.

9. The turbomachine according to claim **6**, wherein the first end is cantilevered from the first mounting member.

10. The turbomachine according to claim **6**, wherein the second end is cantilevered from the second mounting member.

11. The turbomachine according to claim **6**, wherein each of the first and second rotor mounting elements comprise dovetail members.

12. The turbomachine according to claim **6**, further comprising: at least one axial locking member provided on one of the first and second stage rotors, the at least one axial locking member constraining axial movement of one or more of the first and second stage blades.

13. A method of sealing between adjacent stages in a turbomachine, the method comprising:

positioning an inter-stage seal across a rotor;

axially shifting the inter-stage seal across the rotor;

arranging a sealing member of the inter-stage seal across a gap extending between the rotor and an adjacent rotor;

connecting a first mounting member extending from a first end of the sealing member with the rotor; and

connecting a second mounting member extending from a second end of the sealing member to the adjacent rotor.

14. The method of claim **13**, wherein connecting the first mounting member to the rotor includes sliding a dovetail member provided on the first mounting member into a dovetail slot formed in the rotor.

15. The method of claim **14**, further comprising: installing an axial entry blade member into the dovetail slot formed in the rotor.

16. The method of claim **15**, further comprising: installing an axial locking member to the rotor to constrain axial movement of the blade member.

17. The method of claim **14**, wherein connecting the second mounting member to the adjacent rotor includes sliding a dovetail member provided on the second mounting member into a dovetail slot formed in the adjacent rotor.

18. The method of claim **13**, further comprising: abutting a portion of the sealing member with a blade member provided in the adjacent rotor.

19. The method of claim **13**, wherein positioning the inter-stage seal across the rotor includes straddling the rotor with the first and second mounting members extending axially inwardly on opposing sides of the rotor.

20. The method of claim **13**, wherein positioning the inter-stage seal across the rotor includes positioning the inter-stage seal in a turbine portion of the turbomachine.

* * * * *