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(54) **SNUBBER CONFIGURATIONS FOR TURBINE ROTOR BLADES**

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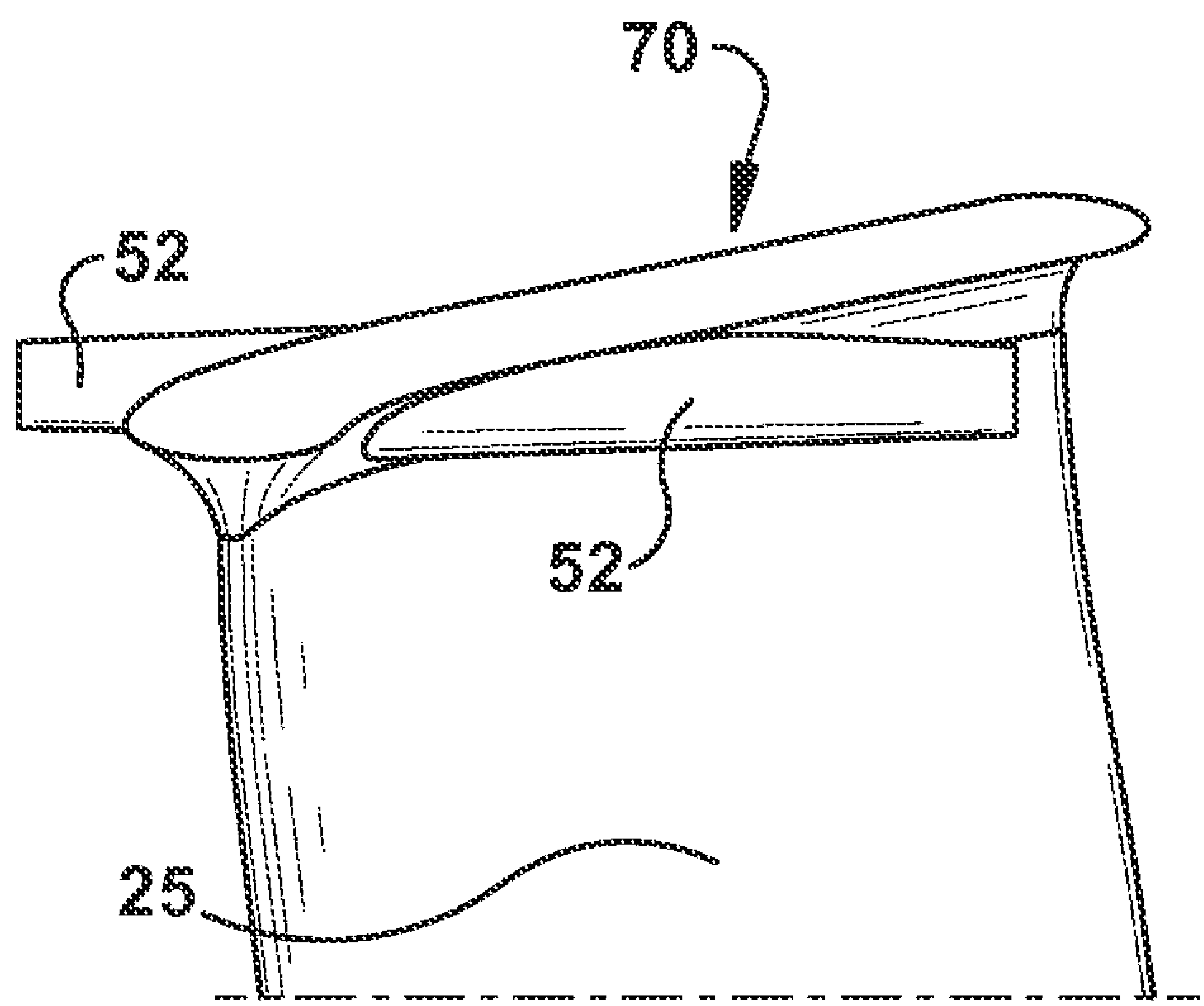
(57) **ABSTRACT**

A rotor blade for use in a turbine of a combustion turbine engine. The rotor blade may include an airfoil having a concave pressure sidewall and a convex suction sidewall extending axially between corresponding leading and trailing edges and radially between the root and an outboard tip. The rotor blade may further include dual snubber shrouds positioned on the airfoil. Each of the dual snubber shrouds may be configured to engage a corresponding snubber shroud on at least one neighboring rotor blade upon installation.



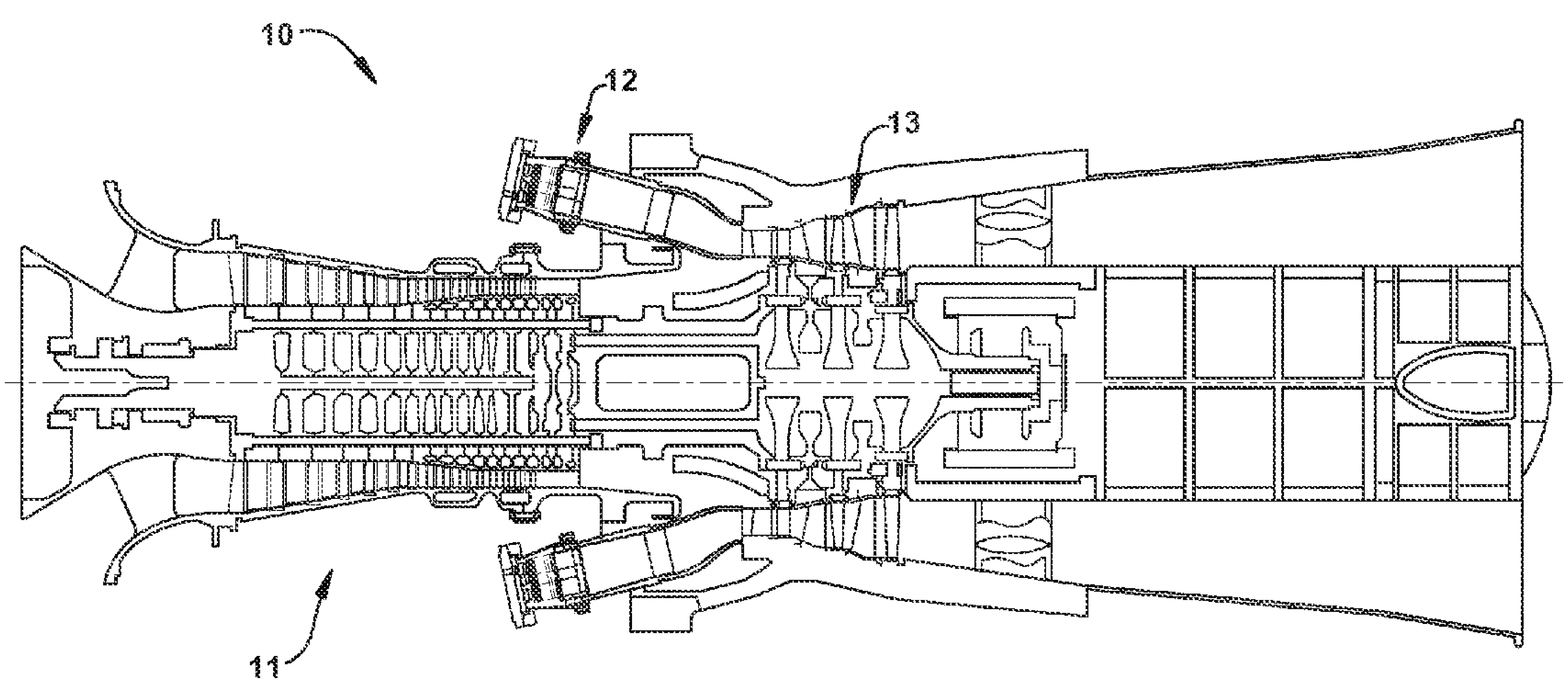


Figure1
(Prior Art)

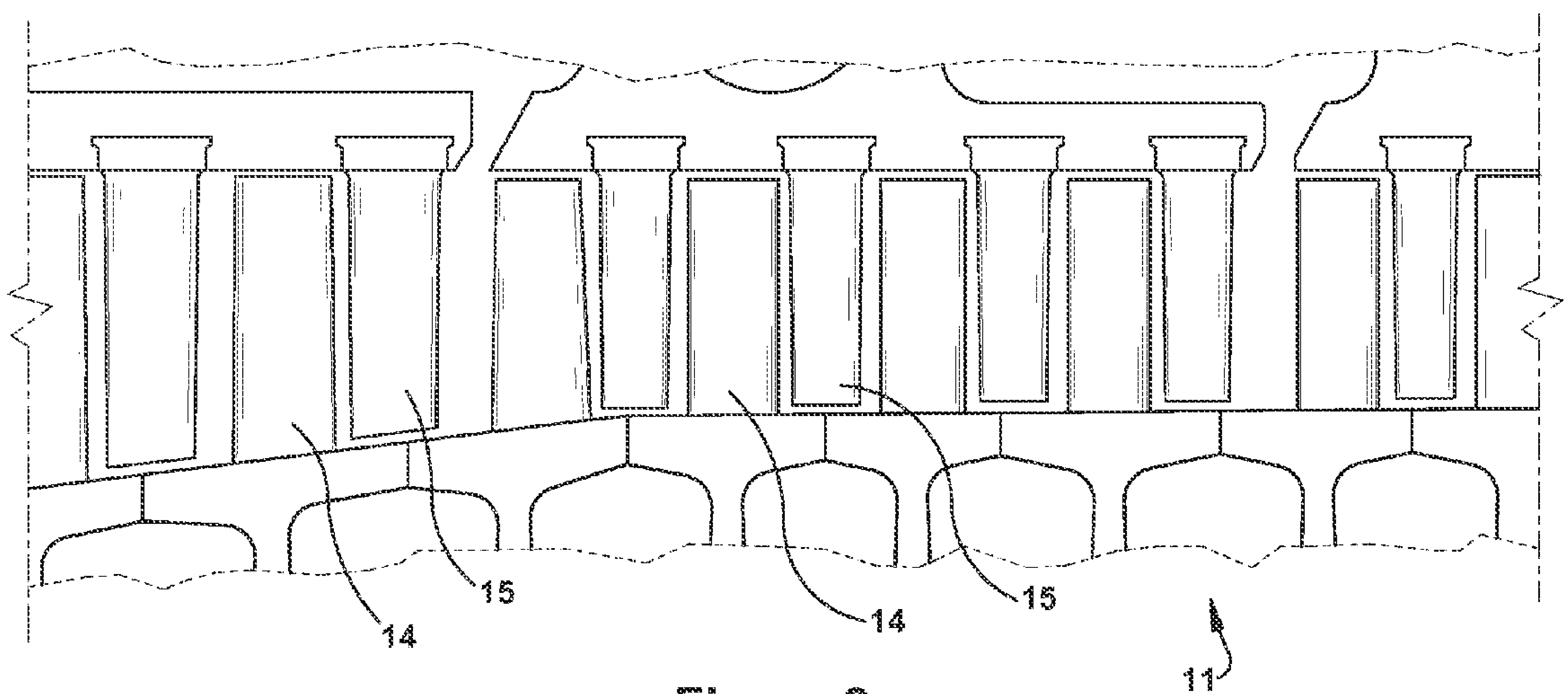


Figure 2
(Prior Art)

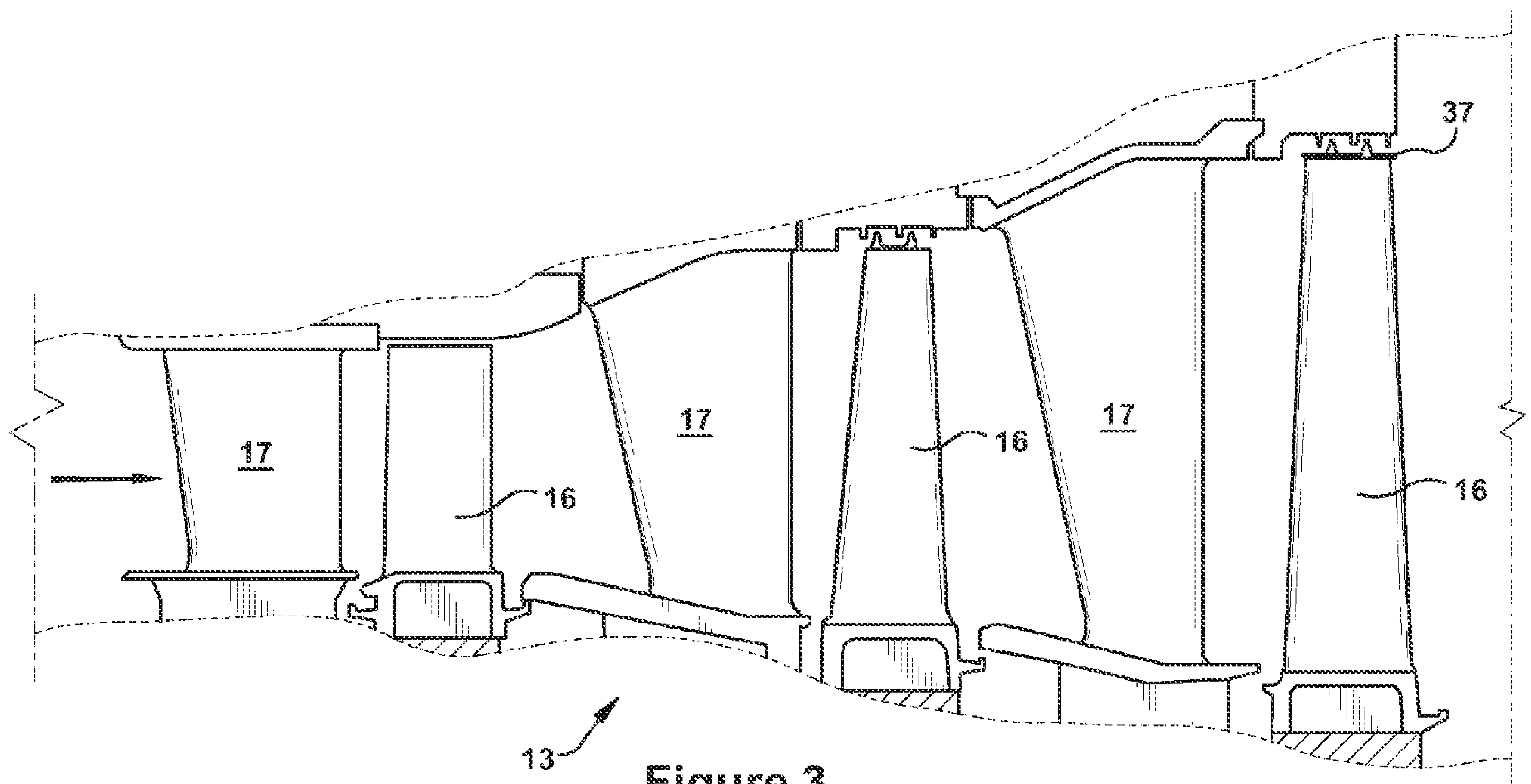


Figure 3
(Prior Art)

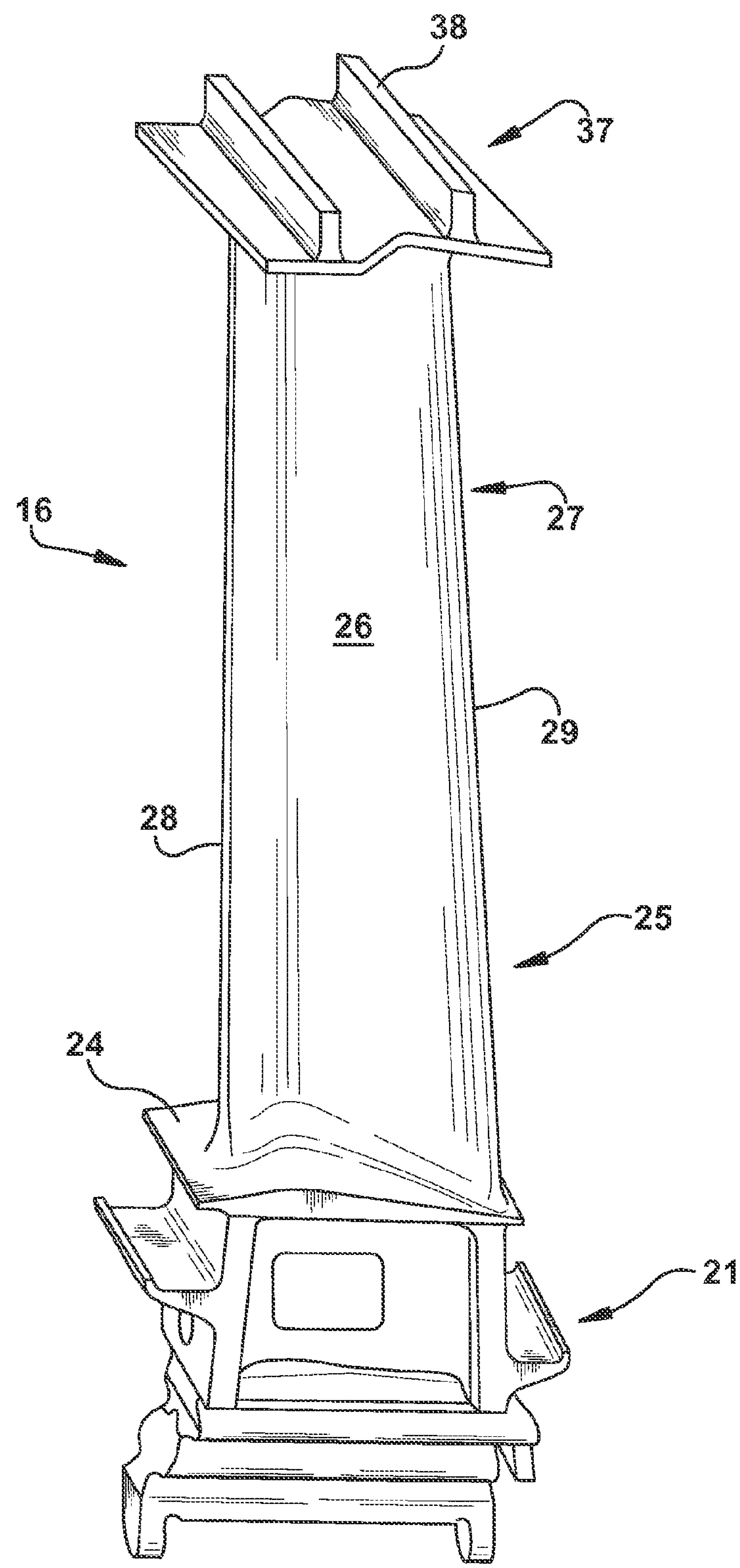


Figure 4
(Prior Art)

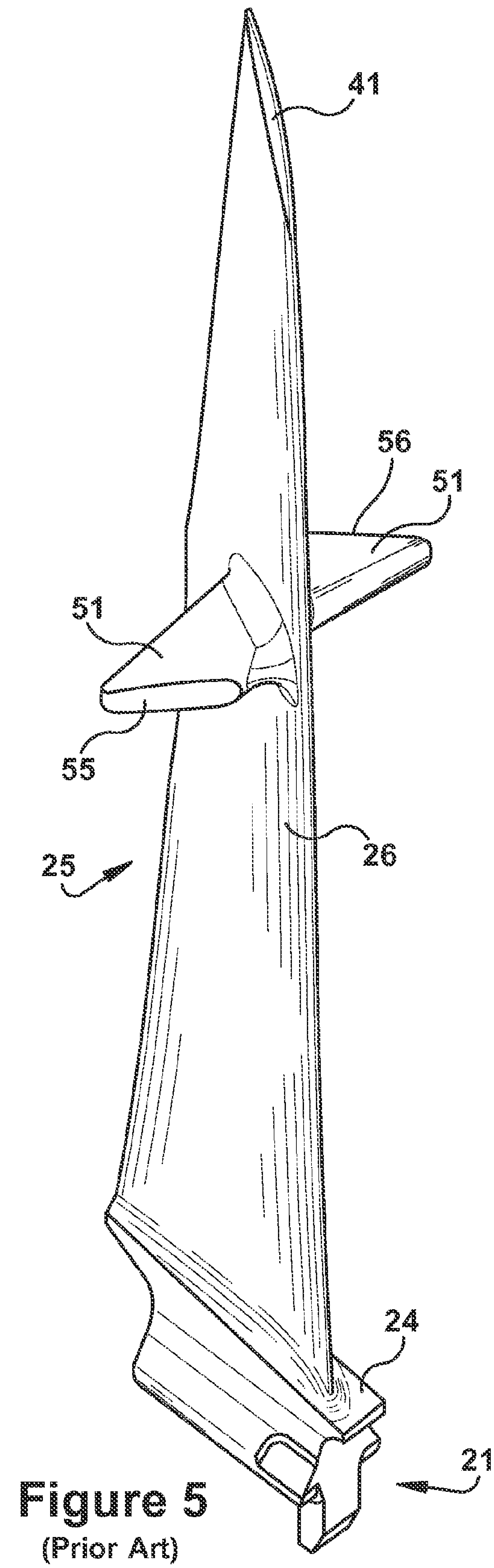


Figure 5
(Prior Art)

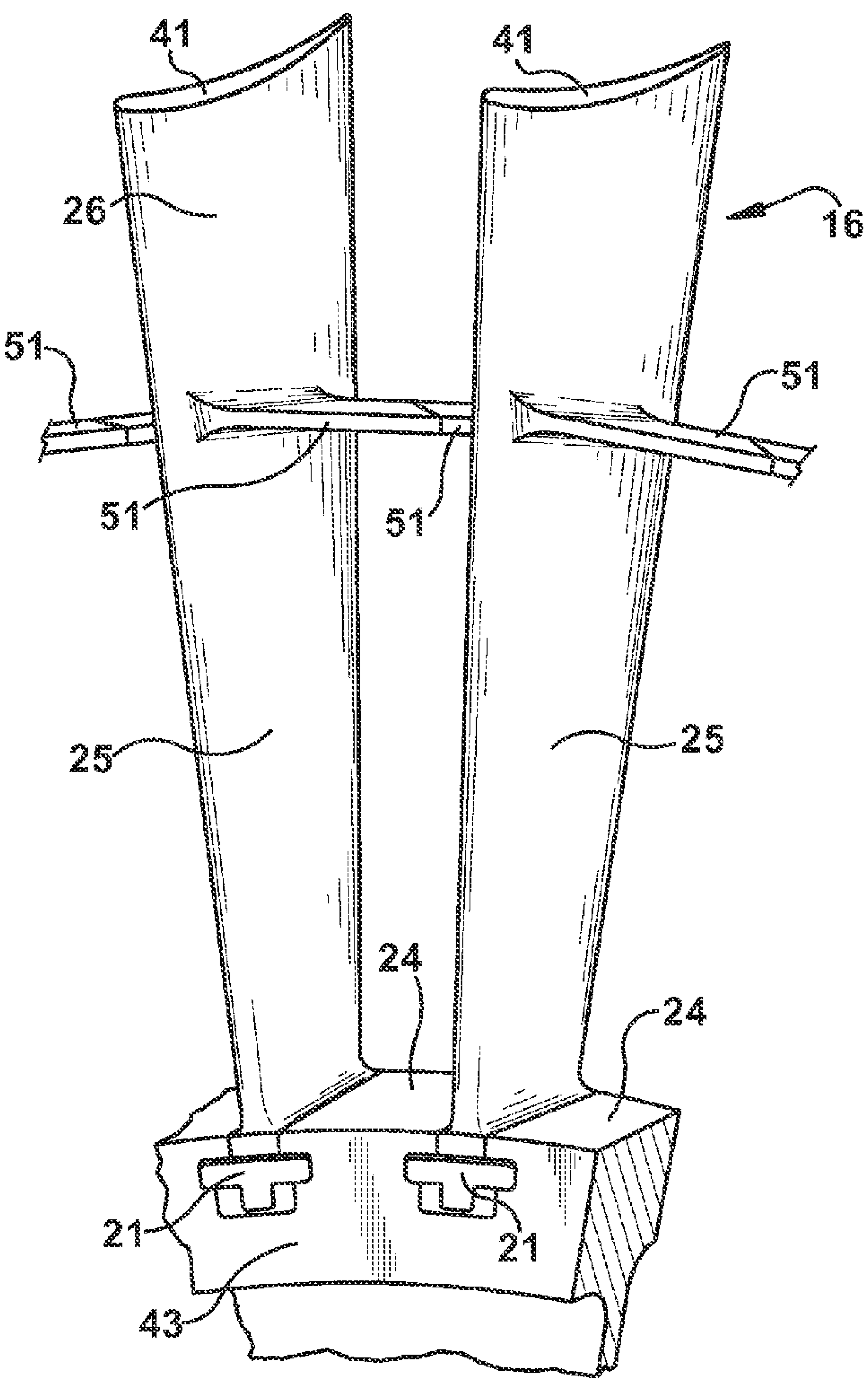


Figure 6
(Prior Art)

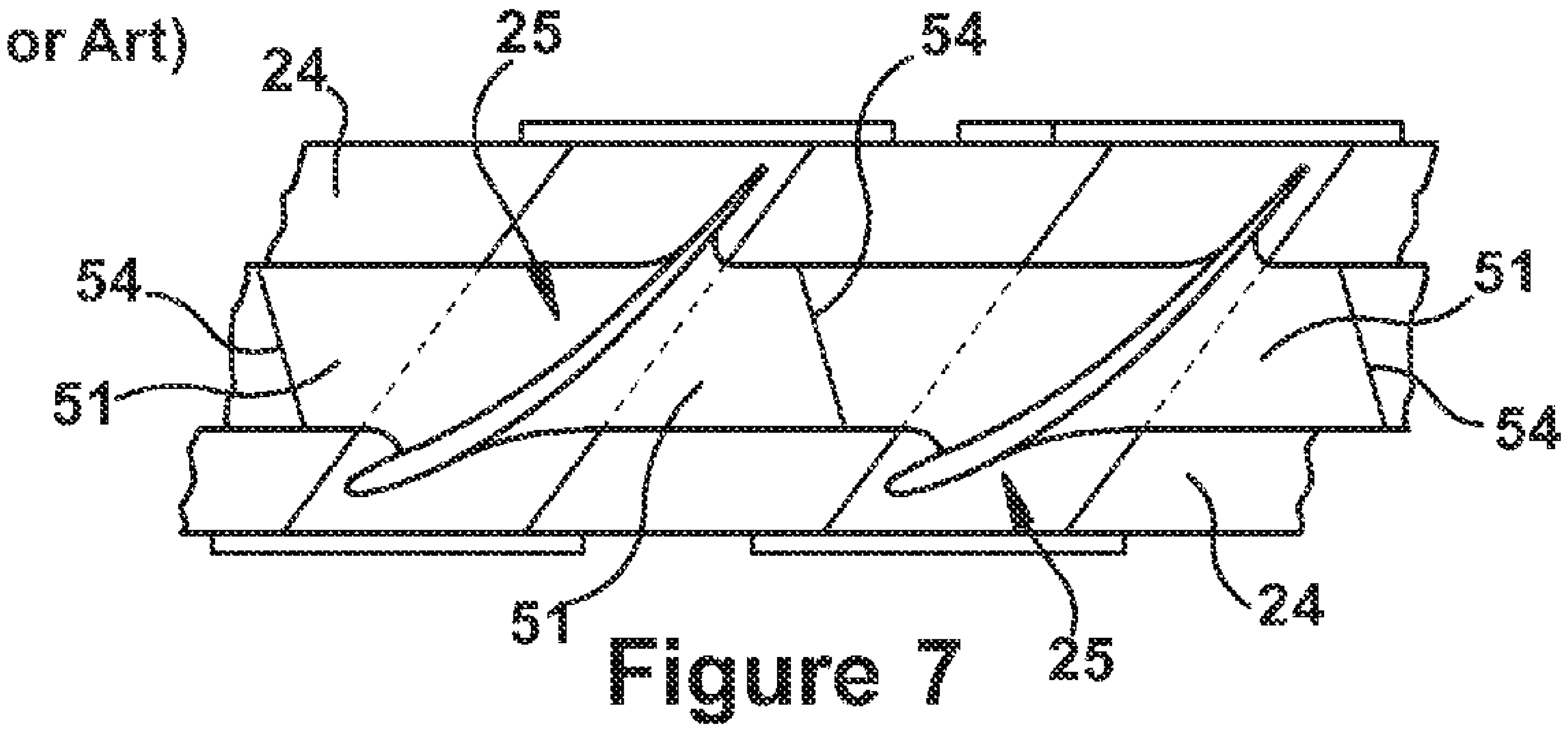


Figure 7
(Prior Art)

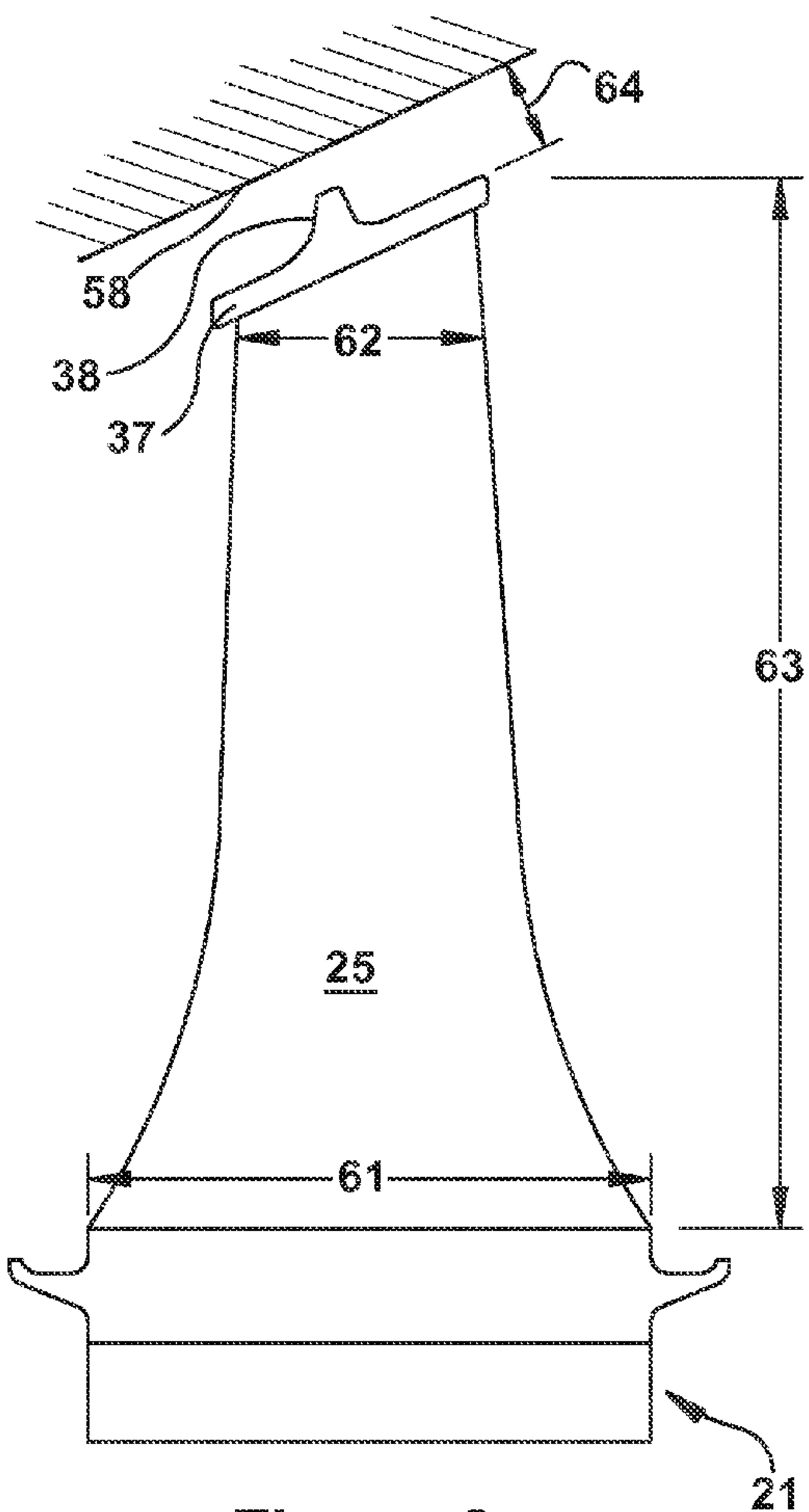


Figure 8
(Prior Art)

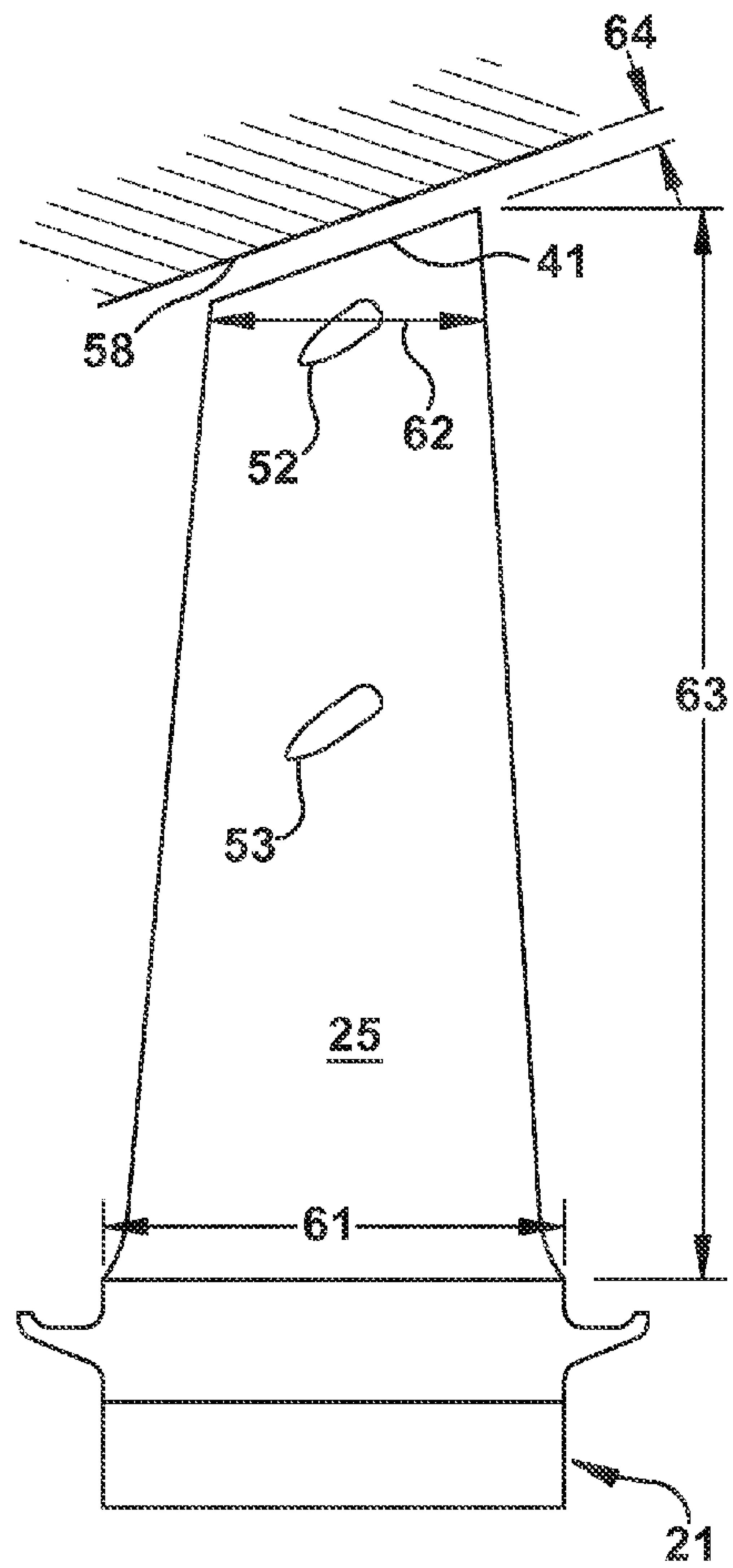


Figure 9

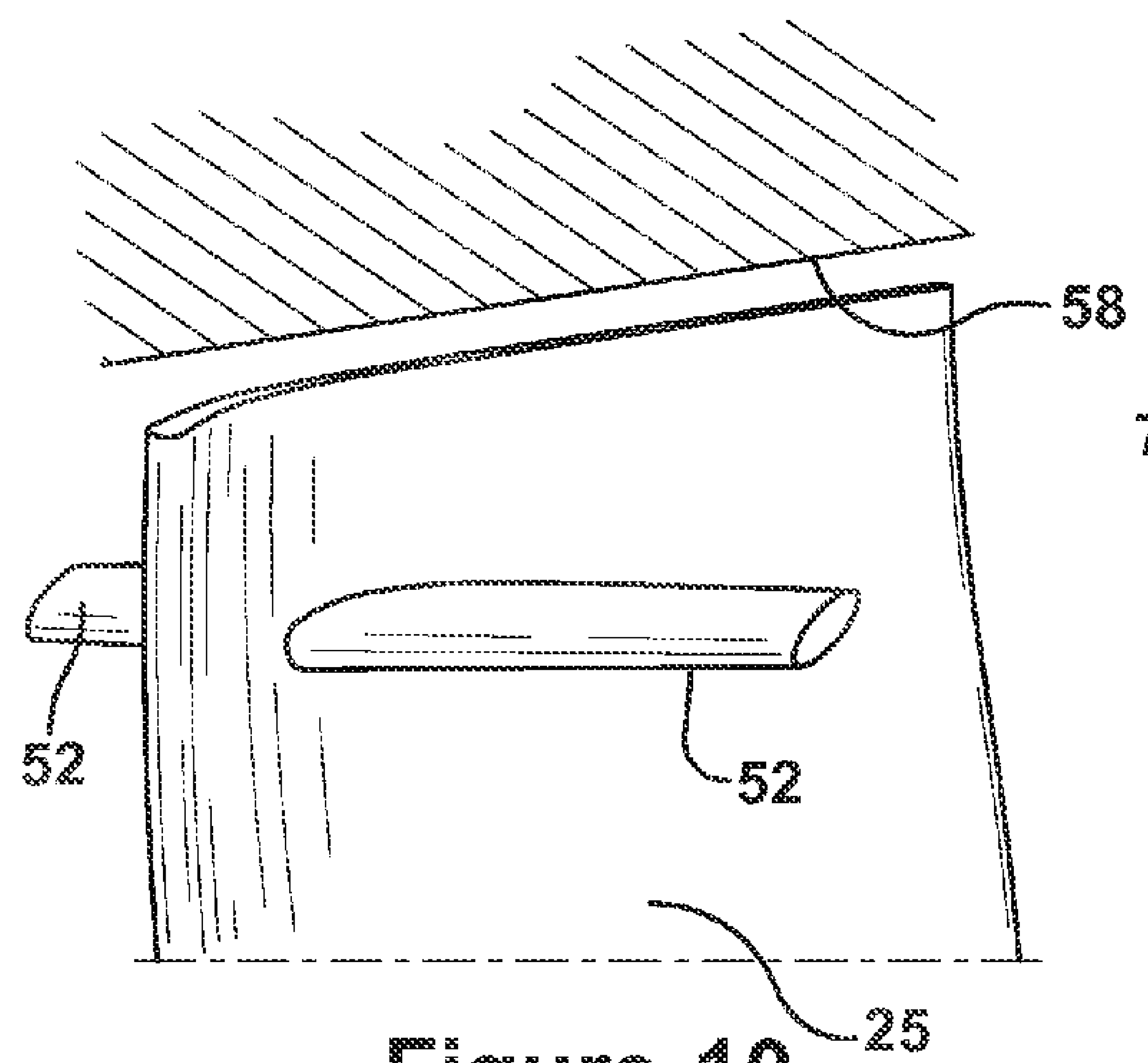


Figure 10

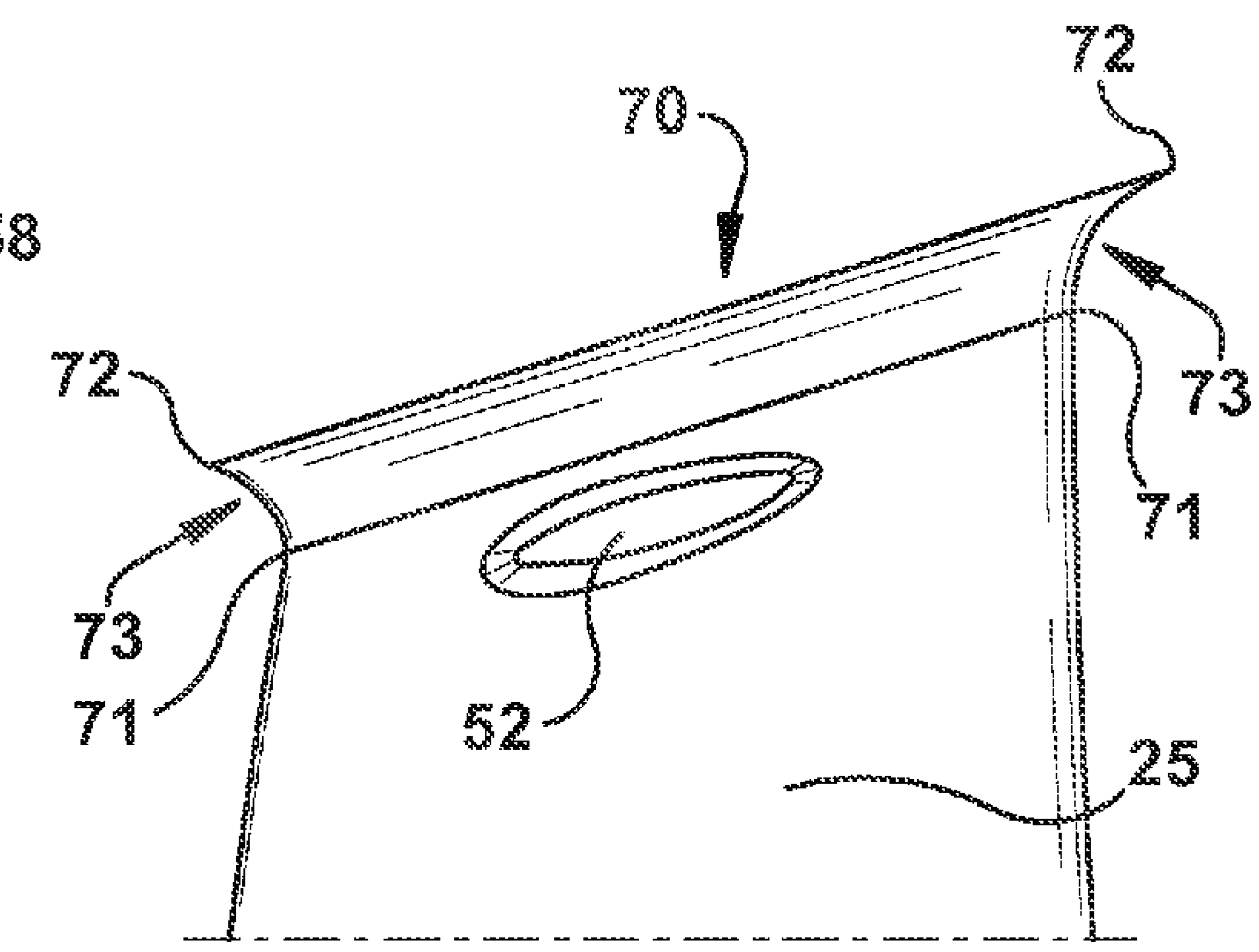


Figure 11

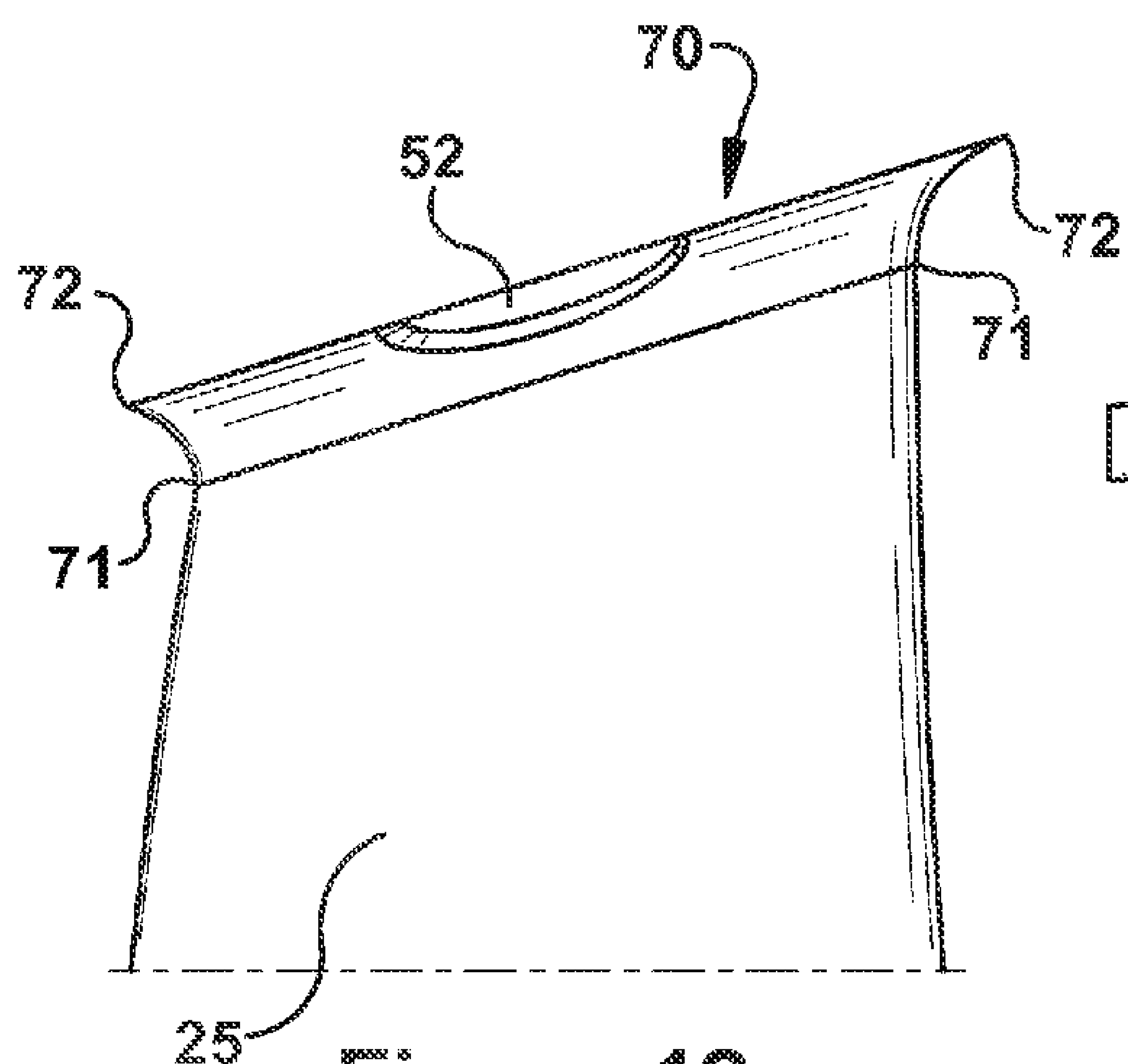


Figure 12

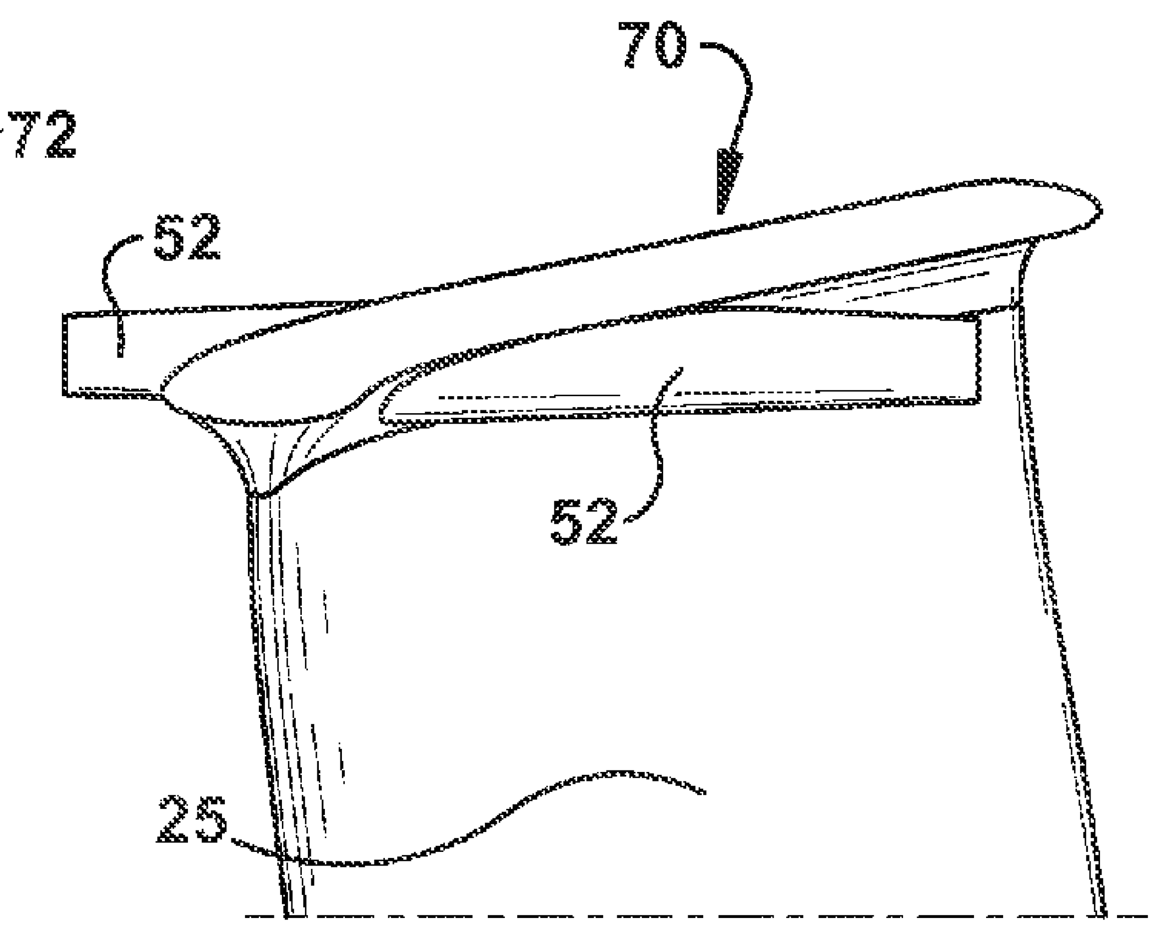


Figure 13

SNUBBER CONFIGURATIONS FOR TURBINE ROTOR BLADES

BACKGROUND OF THE INVENTION

[0001] The present application relates generally to apparatus, methods and/or systems concerning the design and manufacture of turbine rotor blades. More specifically, but not by way of limitation, the present application relates to apparatus and assemblies pertaining to turbine rotor blades having multiple snubber shrouds.

[0002] In a combustion turbine engine, it is well known that air pressurized in a compressor is used to combust a fuel in a combustor to generate a flow of hot combustion gases, whereupon such gases flow downstream through one or more turbines so that energy can be extracted therefrom. In accordance with such a turbine, generally, rows of circumferentially spaced rotor blades extend radially outwardly from a supporting rotor disc. Each rotor blade typically includes a dovetail that permits assembly and disassembly of the blade in a corresponding dovetail slot in the rotor disc, as well as an airfoil that extends radially outwardly from the dovetail and interacts with the flow of the working fluid through the engine. The airfoil has a concave pressure side and convex suction side extending axially between corresponding leading and trailing edges, and radially between a root and a tip. It will be understood that the blade tip is spaced closely to a radially outer stationary surface for minimizing leakage therebetween of the combustion gases flowing downstream between the turbine blades.

[0003] Shrouds at the tip of the airfoil or "tip shrouds" often are implemented on aft stages or rotor blades to provide a point of contact at the tip, manage bucket frequencies, enable a damping source (i.e., by connecting the tips of neighboring rotor blades), and to reduce the over-tip leakage of the working fluid. Given the length of the rotor blades in the aft stages, the damping function of the tip shrouds provides a significant benefit to durability. However, taking full advantage of the benefits is difficult considering the weight that the tip shroud adds to the assembly and the other design criteria, which include enduring thousands of hours of operation exposed to high temperatures and extreme mechanical loads. Thus, while large tip shrouds are desirable because of the effective manner in which they seal the gas path and robust connection they may form between neighboring rotor blades, one of ordinary skill in the art will appreciate that larger tip shrouds are troublesome because of the increased pull loads on the rotor disc, particularly at the base of the airfoil because it must support the entire load of blade.

[0004] Another consideration is that the output and efficiency of gas turbine engines improve as the size of the engine and, and more specifically, the amount of air able to pass through it increase. The size of the engine, however, is limited by the operable length of the turbine blades, with longer turbine rotor blades enabling enlargement of the flow path through engine. Longer rotor blades, though, incur increased mechanical loads, which place further demands on the blades and the rotor disc that holds them. Longer rotor blades also decrease the natural vibrational frequencies of the blades during operation, which increases the vibratory response of the rotor blades. This additional vibratory load place even greater demands on rotor blade design, which may further shorten the life of the component and, in some cases, may cause vibratory loads that damage other functions of the turbine engine. One way to address the vibratory load of longer rotor blades is through the use of shrouds that connect adjacent rotor blades to each other. As mentioned, though, the added weight of the shroud may negate much of the benefit.

[0005] One way to address this is to position the shroud lower on the airfoil of the rotor blade. That is, instead of adding the shroud to the tip of the rotor blade, the shroud is positioned near the middle radial portion of the airfoil. As used herein, such a shroud will be referred to as a "snubber shroud." At this lower (or more inboard) radius, the mass of the shroud causes a reduced level of stress to the rotor blade. However, this type of shroud leaves a portion of the airfoil of the rotor blade unrestrained (i.e., that portion of the airfoil that extends outboard of the snubber shroud). This cantilevered portion of the airfoil typically results in lower frequency vibration and increased vibratory loads, which may be damaging to the engine. Accordingly, a novel rotor blade design that reduced or limited these loads would have value in the market for such products.

BRIEF DESCRIPTION OF THE INVENTION

[0006] The present application thus describes a rotor blade for use in a turbine of a combustion turbine engine. The rotor blade may include an airfoil that extends from a connection with a root. The airfoil may include a concave pressure sidewall and a convex suction sidewall extending axially between corresponding leading and trailing edges and radially between the root and an outboard tip. The rotor blade may further include dual snubber shrouds positioned on the airfoil. Each of the dual snubber shrouds may be configured to engage a corresponding snubber shroud on at least one neighboring rotor blade upon installation.

[0007] The present application further describes a gas turbine engine having a turbine that includes a row of circumferentially spaced rotor blades. Each of the rotor blades may include an airfoil extending from a root that connects to a rotor disc. The airfoil may include a pressure sidewall and a suction sidewall extending axially between a leading edge and a trailing edges and radially between a platform that forms an outboard boundary of the root and an outboard tip of the airfoil. The airfoil of each of the rotor blades may further include dual snubber shrouds, an inboard snubber shroud and an outboard snubber shroud. Each of the snubber shrouds may have a position between the platform and the outboard tip of the airfoil and a configuration that connects each of the rotor blades to neighboring rotor blades positioned to each side. The outboard snubber shroud may be positioned near the outboard tip of the airfoil, and the inboard snubber shroud may be positioned near a radial mid-region of the airfoil.

[0008] These and other features of the present application will become apparent upon review of the following detailed description of the preferred embodiments when taken in conjunction with the drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] These and other features of this invention will be more completely understood and appreciated by careful study of the following more detailed description of exemplary embodiments of the invention taken in conjunction with the accompanying drawings, in which:

[0010] FIG. **1** is a schematic representation of an exemplary combustion turbine engine in which embodiments of the present application may be used;

[0011] FIG. **2** is a sectional view of the compressor in the combustion turbine engine of FIG. **1**;

[0012] FIG. **3** is a sectional view of the turbine in the combustion turbine engine of FIG. **1**;

[0013] FIG. **4** is a perspective view of an exemplary turbine rotor blade having a tip shroud of conventional design;

[0014] FIG. **5** is a perspective view of an exemplary turbine rotor blade having a conventional mid-span snubber;

[0015] FIG. **6** is a perspective view of installed turbine rotor blades connected via a conventional mid-span snubber;

[0016] FIG. **7** is a top view of installed turbine rotor blades connected via a conventional mid-span snubber;

[0017] FIG. **8** is a side view of an exemplary turbine rotor blade and stationary shroud assembly in which the rotor blade includes a conventional tip shroud;

[0018] FIG. **9** is a side view of an exemplary turbine rotor blade and stationary shroud assembly in which the rotor blade includes dual snubbers according to an exemplary embodiment of the present invention;

[0019] FIG. **10** is a perspective view of the outboard portion of the airfoil of FIG. **9**;

[0020] FIG. **11** is a side view of the outboard portion of an airfoil having an outboard snubber and a tip winglet according to an exemplary embodiment of the present invention;

[0021] FIG. **12** is a side view of the outboard portion of an airfoil having an outboard snubber and a tip winglet according to an alternative embodiment of the present invention;

[0022] FIG. **13** is a perspective view of the airfoil tip of the turbine rotor blade of FIG. **12**.

DETAILED DESCRIPTION OF THE INVENTION

[0023] While the following examples of the present invention may be described in reference to particular types of turbine engine, those of ordinary skill in the art will appreciate that the present invention may not be limited to such use and applicable to other types of turbine engines, unless specifically limited therefrom. Further, it will be appreciated that in describing the present invention, certain terminology may be used to refer to certain machine components within the gas turbine engine. Whenever possible, common industry terminology will be used and employed in a manner consistent with its accepted meaning. However, such terminology should not be narrowly construed, as those of ordinary skill in the art will appreciate that often a particular machine component may be referred to using differing terminology. Additionally, what may be described herein as being single component may be referenced in another context as consisting of multiple components, or, what may be described herein as including multiple components may be referred to elsewhere as a single one. As such, in understanding the scope of the present invention, attention should not only be paid to the particular terminology, but also the accompanying description, context, as well as the structure, configuration, function, and/or usage of the component, particularly as may be provided in the appended claims.

[0024] Several descriptive terms may be used regularly herein, and it may be helpful to define these terms at the onset of this section. Accordingly, these terms and their definitions, unless stated otherwise, are as follows. As used herein, "downstream" and "upstream" are terms that indicate direction relative to the flow of a fluid, such as, for example, the working fluid through the compressor, combustor and turbine sections of the gas turbine, or the flow coolant through one of the component systems of the engine. The term "downstream" corresponds to the direction of fluid flow, while the term "upstream" refers to the direction opposite or against the direction of fluid flow. The terms "forward" and "aft", without any further specificity, refer to directions relative to the orientation of the gas turbine, with "forward" referring to the forward or compressor end of the engine, and "aft" referring to the aft or turbine end of the engine. Additionally, given a gas turbine engine's configuration about a central axis as well as this same type of configuration in some component systems, terms describing position relative to an axis likely will be used. In this regard, it will be appreciated that the term "radial" refers to movement or position perpendicular to an axis. Related to this, it may be required to describe relative distance from the central axis. In this case, for example, if a first component resides closer to the center axis than a second component, it will be stated herein that the first component is "radially inward" or "inboard" of the second component. If, on the other hand, the first component resides further from the axis than the second component, it may be stated herein that the first component is "radially outward" or "outboard" of the second component. Additionally, it will be appreciated that the term "axial" refers to movement or position parallel to an axis. And, finally, the term "circumferential" refers to movement or position around an axis.

[0025] By way of background, referring now to the figures, FIGS. **1** through **3** illustrate an exemplary combustion turbine engine in which embodiments of the present application may be used. It will be understood by those skill in the art that the present invention is not limited to this type of usage. As stated, the present invention may be used in combustion turbine engines, such as the engines used in power generation and airplanes, steam turbine engines, and other type of rotary engines. FIG. **1** is a schematic representation of a combustion turbine engine **10**. In general, combustion turbine engines operate by extracting energy from a pressurized flow of hot gas produced by the combustion of a fuel in a stream of compressed air. As illustrated in FIG. **1**, combustion turbine engine **10** may be configured with an axial compressor **11** that is mechanically coupled by a common shaft or rotor to a downstream turbine section or turbine **13**, and a combustor **12** positioned between the compressor **11** and the turbine **12**.

[0026] FIG. **2** illustrates a view of an exemplary multi-staged axial compressor **11** that may be used in the combustion turbine engine of FIG. **1**. As shown, the compressor **11** may include a plurality of stages. Each stage may include a row of compressor rotor blades **14** followed by a row of compressor stator blades **15**. Thus, a first stage may include a row of compressor rotor blades **14**, which rotate about a central shaft, followed by a row of compressor stator blades **15**, which remain stationary during operation. The compressor stator blades **15** generally are circumferentially spaced one from the other and fixed about the axis of rotation. The compressor rotor blades **14** are circumferentially spaced and attached to the shaft; when the shaft rotates during operation, the compressor rotor blades **14** rotate about it. As one of ordinary skill in the art will appreciate, the compressor rotor blades **14** are configured such that, when spun about the shaft, they impart kinetic energy to the air or fluid flowing through the compressor **11**. The compressor **11** may have other stages beyond the stages that are illustrated in FIG. **2**. Additional stages may include a plurality of circumferential spaced compressor rotor blades **14** followed by a plurality of circumferentially spaced compressor stator blades **15**.

[0027] FIG. **3** illustrates a partial view of an exemplary turbine section or turbine **13** that may be used in the combustion turbine engine of FIG. **1**. The turbine **13** also may include a plurality of stages. Three exemplary stages are illustrated, but more or less stages may present in the turbine **13**. A first stage includes a plurality of turbine buckets or turbine rotor blades **16**, which rotate about the shaft during operation, and a plurality of nozzles or turbine stator blades **17**, which remain stationary during operation. The turbine stator blades **17** generally are circumferentially spaced one from the other and fixed about the axis of rotation. The turbine rotor blades **16** may be mounted on a turbine wheel or disc (not shown) for rotation about the shaft (not shown). A second stage of the turbine **13** also is illustrated. The second stage similarly includes a plurality of circumferentially spaced turbine stator blades **17** followed by a plurality of circumferentially spaced turbine rotor blades **16**, which are also mounted on a turbine wheel for rotation. A third stage also is illustrated, and similarly includes a plurality of turbine stator blades **17** and rotor blades **16**. It will be appreciated that the turbine stator blades **17** and turbine rotor blades **16** lie in the hot gas path of the turbine **13**. The direction of flow of the hot gases through the hot gas path is indicated by the arrow. As one of ordinary skill in the art will appreciate, the turbine **13** may have other stages beyond the stages that are illustrated in FIG. **3**. Each additional stage may include a row of turbine stator blades **17** followed by a row of turbine rotor blades **16**.

[0028] In use, the rotation of compressor rotor blades **14** within the axial compressor **11** may compress a flow of air. In the combustor **12**, energy may be released when the compressed air is mixed with a fuel and ignited. The resulting flow of hot gases from the combustor **12**, which may be referred to as the working fluid, is then directed over the turbine rotor blades **16**, the flow of working fluid inducing the rotation of the turbine rotor blades **16** about the shaft. Thereby, the energy of the flow of working fluid is transformed into the mechanical energy of the rotating blades and, because of the connection between the rotor blades and the shaft, the rotating shaft. The mechanical energy of the shaft may then be used to drive the rotation of the compressor rotor blades **14**, such that the necessary supply of compressed air is produced, and also, for example, a generator to produce electricity.

[0029] FIG. **4** is a perspective view of an exemplary turbine rotor blade **16** that has a tip shroud **37** of conventional design. The turbine rotor blade **16** generally includes a root **21**, which may include means by which the rotor blade **16** attaches to a rotor disc **41** (as shown in FIG. **6**), such as an axial dovetail configured for mounting in a corresponding dovetail slot in the perimeter of the rotor disc **41**. The root **21** may include a shank that extends between the dovetail and a platform **24**, with the platform **24** being disposed at the junction of the airfoil **25** and the root **21**. The platform **24** defines a portion of the inboard boundary of the flowpath through the turbine engine **10**. The airfoil **25** is the active component of the rotor blade **16** that intercepts the flow of the working fluid and induces the rotor disc **41** to rotate. As illustrated, at the outboard tip of the rotor blade **16**, the tip shroud **37** may be positioned. The tip shroud **37** essentially is an axially and circumferentially extending planar component that is perched atop the airfoil **25** and supported by it. As shown, positioned along the top of the tip shroud **37** may be one or more seal rails **38**. Generally, seal rails **38** project radially outward from the outboard surface of the tip shroud **37** and extend circumferentially between opposite ends of the tip shroud **37** in the general direction of rotation. Seal rails **38** are formed to deter the flow of working fluid through the gap between the tip shroud **37** and the inner surface of the surrounding stationary components of the turbine **13**. As discussed in more detail below, tip shrouds **37** may be formed with contact faces **55** such that the shrouds on adjacent rotor blades contact or engage each other, which typically damps vibration in the assembly and prolong the life of the rotor blade **16**. (Note that while a preferred embodiment of the present application is directed toward turbine rotor blades **16**, it will be understood that aspects of the present invention may be applicable to compressor rotor blades **14** and that, unless otherwise stated, the present invention should be understood to apply to each type of rotor blade **14**, **16**.)

[0030] FIG. **5** provides a perspective view of an exemplary turbine rotor blade **16** which has a snubber shroud **51** consistent with one that might be used with rotor blades **16** having an internal structural configurations in accordance with the present invention, as discussed in detail below. As is known in the art, a snubber or snubber shroud **51** such as the one shown may be used to connect adjacent rotor blades **16**. The linking of adjacent rotor blades **16** may occur between a shroud-to-shroud interface **54** (which is shown in FIG. **7**) at which a pressure side contact face **55** and a suction side contact face **56** contact each other. This linking of rotor blades **16** in this manner tends to increase the natural frequency of the assembly and damp operational vibrations, which means rotor blades **16** are subject to less mechanical stress during operation and degrade more slowing. Shrouds **51**, however, add weight to the assembly, which tends to negate some of these benefits, particularly when the shroud is located at the outboard tip **41** of the rotor blade **16**. As mentioned above, one way to lessen the impact of the added weight of the shroud is to position the shroud lower on the airfoil **25**, as shown in FIG. **5**. At this lower (or more inboard) radius, the mass of the shroud **51** causes a reduction in the applied stress to the rotor blade. However, a snubber shroud leaves a portion of the airfoil **25** unrestrained, i.e., the portion of the airfoil **25** that extends outboard of the snubber shroud **51**, and this cantilevered portion of the airfoil **25** results in a lower natural frequency and increased vibratory response during operation, which, as stated, increases may damage the rotor blades and the engine.

[0031] FIG. **6** is a perspective view of rotor blades **16** having snubber shrouds **51** as they might be arranged in an installed condition. FIG. **7** provides a top view of the same installed assembly. As shown, the snubber shrouds **51** are configured to link or engage the shrouds **51** of the rotor blades **16** that are adjacent to them. This linking or engagement may occur at shroud-to-shroud interfaces **54** between the pressure side contact face **55** and the suction side contact face **56**, as illustrated.

[0032] FIG. **8** is a side view of an exemplary turbine rotor blade **16** having a tip shroud **37** according to a conventional design. It will be appreciated that the mass tip shrouds add to the outboard portion of the airfoil significantly increases the mechanical forces acting on a rotating blade during operation. In order to sustain these additional stresses, conventional rotor blades are designed with airfoil structures that are strengthened by increasing the width of the airfoil base (i.e., the distance indicated by reference numeral **61**). Over time, though, the increased pull that results from weight of the tip shroud results in airfoil creep, with is a general stretching along its length (i.e., the distance indicated by reference numeral **63**). This increased elongation over the life of the rotor blade must be taken into account when designing the clearances between the outboard tips of rotor blade and the stationary structure that surrounds it (i.e., the gap indicated by reference numeral **64**). It will be appreciated that this necessarily results in wider gap clearances, which, because wider clearances result in increased leakage levels, negatively impacts the efficiency of the engine.

[0033] FIGS. **9** through **13** illustrate several aspects of the present invention. As illustrated in FIG. **9**, the present invention describes an airfoil **25** having dual snubber shrouds: an outboard snubber shroud **52** and an inboard snubber shroud **53**. The benefits of this arrangement are several, including an overall reduced tip mass as some of that mass is relocated closer to the axis of rotation, which reduces mechanical stress on the airfoil. This reduction in stress allows a reduction in the width of the airfoil, as indicated in FIG. **9**. Additionally, the reduction in stress enables tighter initial gap clearances between the rotor blade and stationary structure, as the airfoil will experience less elongation during operation. The reduced mechanical pull on the rotor blade also may allow longer blade life, as well as smaller rotor dovetail widths, which may reduce costs by further reducing the overall size of the rotor blade. In addition, the present invention results in tighter clearances and aerodynamic performance compared to conventional scalloped tip shrouds, which may be further improved with the addition of a winglet **70**, as discussed below.

[0034] The dual snubber shrouds of the present invention, as mentioned, may include an inboard snubber shroud **53** and an outboard snubber shroud **52**, with the inboard snubber shroud **53** being positioned radially inward relative to the outboard snubber shroud **52**. As shown, each of the snubber shrouds may have a narrower axial profile than other conventional shrouds, which, in preferred embodiments is less than half of the axial width of airfoil at the radial height of the snubber shroud.

[0035] The inboard snubber shroud **53** may be configured as a circumferentially extending projection that protrudes from one or both of the pressure sidewall **26** and the suction sidewall **27** of the airfoil **25**. Similarly, the outboard snubber shroud **52** may be configured as a circumferentially extending projection that protrudes from one or both of the pressure sidewall **26** and the suction sidewall **27** of the airfoil **25**. As previously discussed, each of the snubber shrouds may be configured to engage a snubber shroud formed on one or both neighboring rotor blades upon installation. It will be appreciated that the dual points of contact that the present invention enables may be used to advantageously limit the vibratory response of the rotor blades during operation. Accordingly, each of the inboard snubber shroud **53** and the outboard snubber shroud **52** may include pressure side contact faces **55** at distal ends of each circumferential projection on the pressure side of the airfoil **25**. Likewise, each of the inboard snubber shroud **53** and the outboard snubber shroud **52** may include suction side contact faces **56** at distal ends of each circumferential projection on the suction side of the airfoil **25**. Given this configuration, it will be appreciated that the two pressure side contact faces **55** of a particular airfoil **25** may engage the two suction side contact faces **56** of the neighboring airfoil **25** positioned to one side of it, and the two suction side contact faces **56** may engage the two pressure side contact faces **55** of the neighboring airfoil **25** position to the other side of it.

[0036] As indicated in FIG. **9**, the outboard snubber shroud **52** may be positioned near the outboard tip **41** of the airfoil **25**, while the inboard snubber shroud **53** may be positioned near the radial mid-region of the airfoil **25**. In an alternative embodiment, the outboard snubber shroud **52** is positioned just inside of the outboard tip **41** of the airfoil **25**, and the inboard snubber shroud **53** is positioned at approximately the radial mid-point of the airfoil **25**. In another embodiment, the radial positioning of the inboard and outboard snubber shrouds **52** is defined within a range of radial heights defined relative to the airfoil **25**. In one such embodiment, the inboard snubber shroud **53** may be positioned within a range of radial heights defined between an inboard boundary at 25% of a radial height of the airfoil **25** and an outboard boundary at 75% of the radial height of the airfoil **25**, and the outboard snubber shroud **52** may be positioned outside of an inboard boundary at 60% of the radial height of the airfoil **25**. In an alternative embodiment, the inboard snubber shroud **53** may be positioned within a range of radial heights defined between an inboard boundary at 40% of a radial height of the airfoil **25** and an outboard boundary at 60% of the radial height of the airfoil **25**, and the outboard snubber shroud **52** may be positioned within a range of radial heights defined between an inboard boundary at 75% of the radial height of the airfoil **25** and an outboard boundary that 95% of the radial height of the airfoil **25**. In another preferred embodiment, the inboard snubber shroud **53** may be positioned within a range of radial heights defined between an inboard boundary at 40% of a radial height of the airfoil **25** and an outboard boundary at 60% of the radial height of the airfoil **25**, and the outboard snubber shroud **52** may be positioned outside of an inboard boundary at 90% of the radial height of the airfoil **25**.

[0037] According to other embodiments of the present invention, as illustrated in FIGS. **10** through **13**, the outboard tip **41** of the airfoil **25** may include a winglet **70**. As used herein, a winglet **70** includes a flaring of the outboard tip **41** of the airfoil **25**. As indicated in FIGS. **11** and **12**, the flaring occurs within a narrow radial section that, on one side, is contiguous to the outboard tip **41**. It will be appreciated that the winglet **70** may be described as including an inboard edge **71** and an outboard edge **72**. Described in this manner, the outboard flaring of the winglet **70** may be oriented such that the cross-sectional area at the inboard edge **71** of the winglet **70** is smaller than that of the outboard edge **72** of winglet **70**. As indicated, the inboard edge **71** of the winglet **70** may be offset a constant distance from the outboard edge **72**, which as stated, may be the outboard tip **41** of the airfoil **25**.

[0038] As illustrated in FIG. **11**, the outboard snubber shroud **52** may be radial spaced apart from the winglet **70**. In this case, the outboard snubber shroud **52** is not connected to the winglet **70** and each are separated by a radial gap. In an alternative preferred embodiment, as illustrated in FIGS. **12** and **13**, the outboard snubber shroud **52** may be incorporated into the winglet **70**, i.e., the outboard snubber shroud **52** may extend from the winglet **70** and be connected to the winglet **70** at its base. As also shown, preferred embodiments of the winglet **70** include the outboard edge having a sharp edge that extends about the circumference to the airfoil **25**. Further, as indicated most clearly in FIGS. **12** and **13**, the outboard flaring of the winglet **70** preferably includes a concave surface profile **73**. Other profiles, such as linear, are also possible.

[0039] It will be appreciated that, pursuant to the several embodiments discussed above, the present invention provides a manner by which the vibratory response of turbine rotor blades may be reduced so to limit damaging vibrational mechanical loads while also allowing for improved aerodynamic/leakage preventing performance. That is, it will be understood that, according to the present invention, natural frequencies of the rotor blade structure may be raised and harmful vibratory responses avoided, thereby enabling longer turbine blades, which, in turn, may be used to enable larger turbine engines having greater output and efficiency. Additionally, the reduced tip mass enabled by the present invention and resulting mechanical pull may allow for a tighter clearance between the rotor blade and the surrounding stationary structure.

[0040] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

1. A rotor blade for use in a turbine of a combustion turbine engine, the rotor blade comprising an airfoil that extends from a connection with a root, the airfoil including a concave pressure sidewall and a convex suction sidewall extending axially between corresponding leading and trailing edges and radially between the root and an outboard tip, the rotor blade further comprising:

dual snubber shrouds positioned on the airfoil;

wherein each of the dual snubber shrouds is configured to engage a corresponding dual snubber shroud on at least one neighboring rotor blade upon installation.

2. The rotor blade according to claim **1**, wherein both of the dual snubber shrouds comprises a position at or outboard of a radial mid-region of the airfoil; and

wherein each of the dual snubber shrouds comprise an axial thickness that is less than half of an axial thickness that the airfoil has at a radial height of each of the snubber shrouds.

3. The rotor blade according to claim **2**, wherein the dual snubber shrouds include an inboard snubber shroud and an outboard snubber shroud, the inboard snubber shroud comprising an inboard position relative to the outboard snubber shroud;

wherein the inboard snubber shroud comprises a circumferentially extending projection from at least one of the pressure sidewall and the suction sidewall of the airfoil;

wherein the outboard snubber shroud comprises a circumferentially extending projection from at least one of the pressure sidewall and the suction sidewall of the airfoil; and

wherein the rotor blade comprises a turbine rotor blade.

4. The rotor blade according to claim **3**, wherein:

the inboard snubber shroud comprises circumferentially extending projections from each of the pressure sidewall and the suction sidewall of the airfoil; and

the outboard snubber shroud comprises circumferentially extending projections from each of the pressure sidewall and the suction sidewall of the airfoil.

5. The rotor blade according to claim **4**, wherein:

each of the inboard snubber shroud and the outboard snubber shroud comprises pressure side contact faces at distal ends of each of the circumferential projections extending from the pressure sidewall of the airfoil; and

each of the inboard snubber shroud and the outboard snubber shroud comprises suction side contact faces at distal ends of each of the circumferential projections extending from the suction sidewall of the airfoil.

6. The rotor blade according to claim **5**, wherein the inboard snubber shroud and the outboard snubber shroud are configured such that the pressure side contact faces correspond to the suction side contact faces so to form an interface therebetween when the rotor blade comprises an installed position between neighboring rotor blades having a same design as the rotor blade.

7. The rotor blade according to claim **5**, wherein the inboard snubber shroud and the outboard snubber shroud are configured such that the pressure side contact faces engage suction side contact faces of a first neighboring rotor blade if:

the first neighboring rotor blade comprises a same design as the rotor blade; and

the first neighboring rotor blade and the rotor blade comprise a predetermined installed position relative to each other;

wherein the inboard snubber shroud and the outboard snubber shroud are configured such that the suction side contact faces engage pressure side contact faces of a second neighboring rotor blade if:

the second neighboring rotor blade comprises the same design as the rotor blade; and

the second neighboring rotor blade and the rotor blade comprise a predetermined installed position relative to each other.

8. The rotor blade according to claim **4**, wherein the outboard snubber shroud comprises a position near the outboard tip of the airfoil and the inboard snubber shroud comprises a position near the radial mid-region of the airfoil.

9. The rotor blade according to claim **4**, wherein the outboard snubber shroud comprises a shroud positioned just inside of the outboard tip of the airfoil and the inboard snubber shroud comprises a shroud positioned near a radial midpoint of the airfoil.

10. The rotor blade according to claim **4**, wherein the inboard snubber shroud comprises one disposed within a first range of radial heights defined on the airfoil, wherein the first range includes an inboard boundary at 25% of a radial height of the airfoil and an outboard boundary at 75% of the radial height of the airfoil; and

wherein the outboard snubber shroud comprises one disposed within a second range of radial heights defined on the airfoil, wherein the second range includes an inboard boundary at 60% of the radial height of the airfoil.

11. The rotor blade according to claim **10**, wherein the inboard boundary of the first range comprises 40% of a radial height of the airfoil and the outboard boundary of the first range comprises 60% of the radial height of the airfoil; and

wherein the inboard boundary of the second range comprises 75% of the radial height of the airfoil and an outboard boundary of the second range comprises 95% of the radial height of the airfoil.

12. The rotor blade according to claim **10**, wherein the inboard boundary of the first range comprises 40% of a radial height of the airfoil and the outboard boundary of the first range comprises 60% of the radial height of the airfoil; and

wherein the inboard boundary of the second range comprises 90% of the radial height of the airfoil.

13. The rotor blade according to claim **12**, wherein an outboard tip of the airfoil comprises a winglet.

14. The rotor blade according to claim 13, wherein the outboard snubber shroud is radial spaced apart from the winglet.

15. The rotor blade according to claim 14, wherein the winglet comprises an outboard flaring disposed within a narrow radial section of the airfoil, the narrow radial section having a side contiguous with the outboard tip of the airfoil.

16. The rotor blade according to claim 15, wherein the outboard shroud extends from the winglet.

17. The rotor blade according to claim 15, wherein the winglet includes an inboard edge and an outboard edge, and wherein the outboard flaring includes the winglet having a smaller cross-sectional area at the inboard edge and a larger cross-sectional airfoil area at an outboard edge of winglet;

wherein the outboard edge of the winglet comprises the outboard tip of the airfoil and the inboard edge of the winglet is spaced a fixed distance from the outboard edge of the winglet about a circumference of the airfoil.

18. The rotor blade according to claim 17, wherein the outboard edge of the winglet comprises a sharp edge defined about the circumference to the airfoil; and

wherein the outboard flaring of the winglet comprises a concave surface profile.

19. A gas turbine engine having a turbine that comprises a row of circumferentially spaced rotor blades, wherein each of the rotor blades includes an airfoil extending from a root that connects to a rotor disc, the airfoil including a pressure sidewall and a suction sidewall extending axially between a leading edge and a trailing edges and radially between a platform that forms an outboard boundary of the root and an outboard tip of the airfoil, the airfoil of each of the rotor blades further comprising:

dual snubber shrouds, an inboard snubber shroud and an outboard snubber shroud;

wherein each of the snubber shrouds comprises a position between the platform and the outboard tip of the airfoil and a configuration that connects each of the rotor blades to neighboring rotor blades positioned to each side; and

wherein the outboard snubber shroud comprises a shroud positioned near the outboard tip of the airfoil and the inboard snubber shroud comprises a shroud positioned near a radial mid-region of the airfoil.

20. The gas turbine engine according to claim 19, wherein the inboard snubber shroud comprises circumferentially extending projections from each of the pressure sidewall and the suction sidewall of the airfoil, and the outboard snubber shroud comprises circumferentially extending projections from each of the pressure sidewall and the suction sidewall of the airfoil; and

wherein each of the inboard snubber shroud and the outboard snubber shroud comprises pressure side contact faces at distal ends of each of the circumferential projections extending from the pressure sidewall of the airfoil, and each of the inboard snubber shroud and the outboard snubber shroud comprises suction side contact faces at distal ends of each of the circumferential projections extending from the suction sidewall of the airfoil.

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