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(54) HIGH-TURNING DIFFUSER STRUT WITH FLOW CROSS-OVER SLOTS

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(57) ABSTRACT

A turning strut for use in a diffuser of a turbine engine has a leading edge with first and second opposing surfaces depending therefrom that terminate at a trailing edge. Slots extend through the turning strut and reduce in volume from the first surface to the second surface. During turn down operation of the turbine engine, exhaust flow impacts the leading edge at a deviated swirl angle. This results in exhaust flow at the first surface being at a higher pressure than at the second surface, which causes exhaust flow to be induced through the slots. The reduction in slot volume causes exhaust flow through the slots to accelerate. This exhaust flow from the slots is combined with exhaust flow at the second surface. Thusly, momentum of exhaust flow at the second surface is increased to maintain the second laminar boundary layer at the second surface.

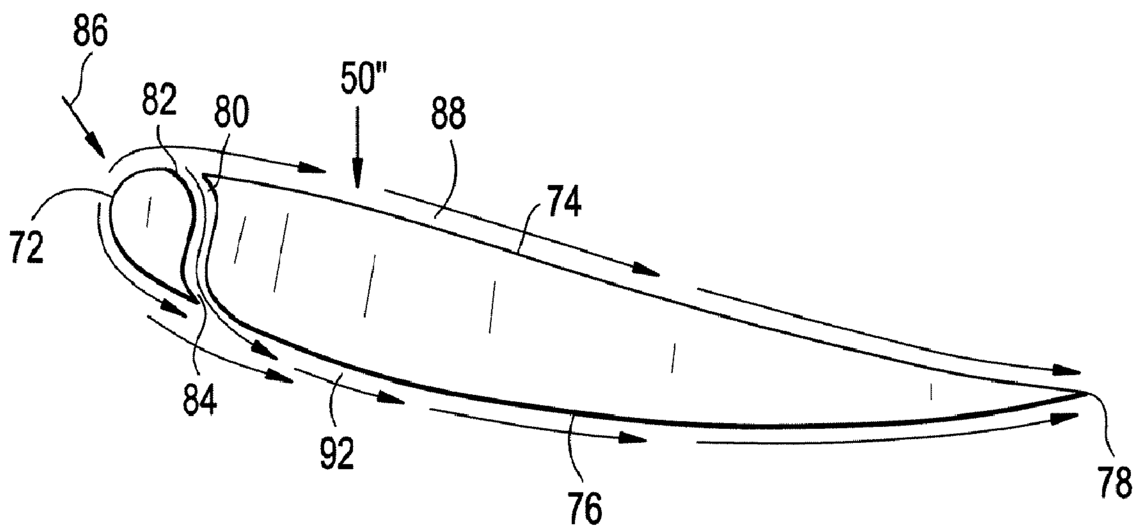


FIG. 1

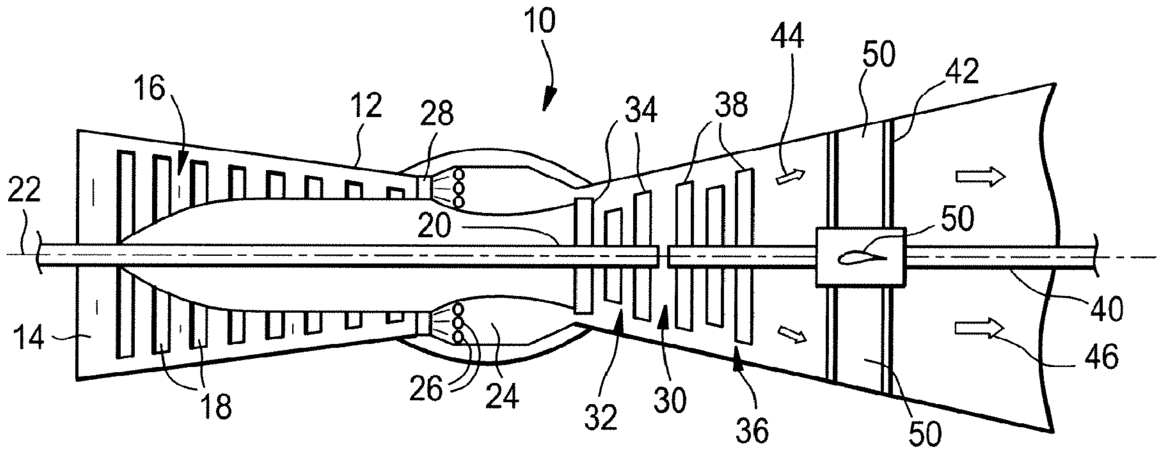


FIG. 2

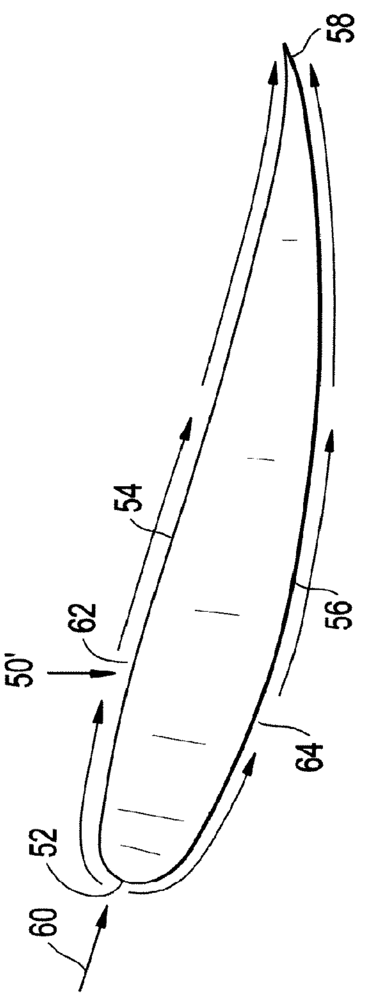
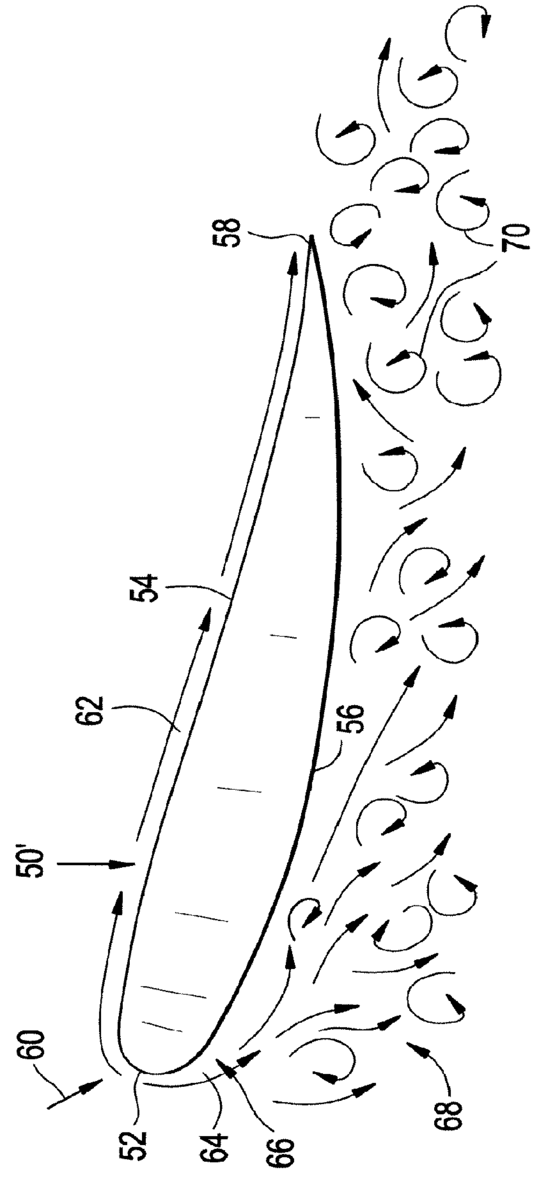


FIG. 3



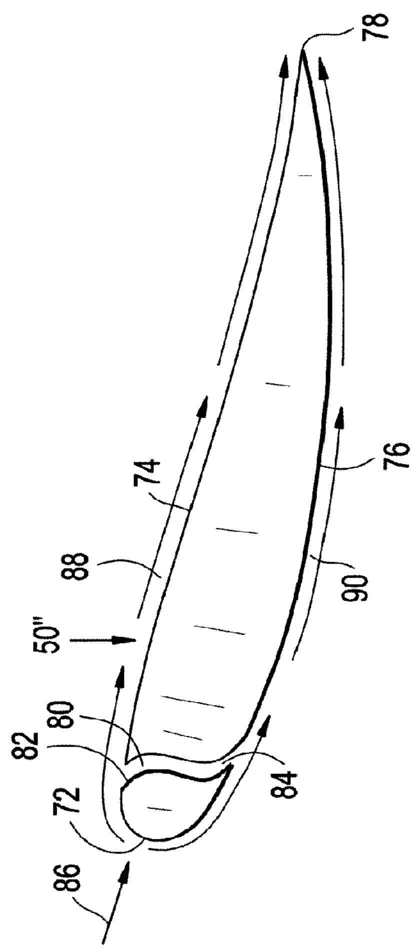


FIG. 4

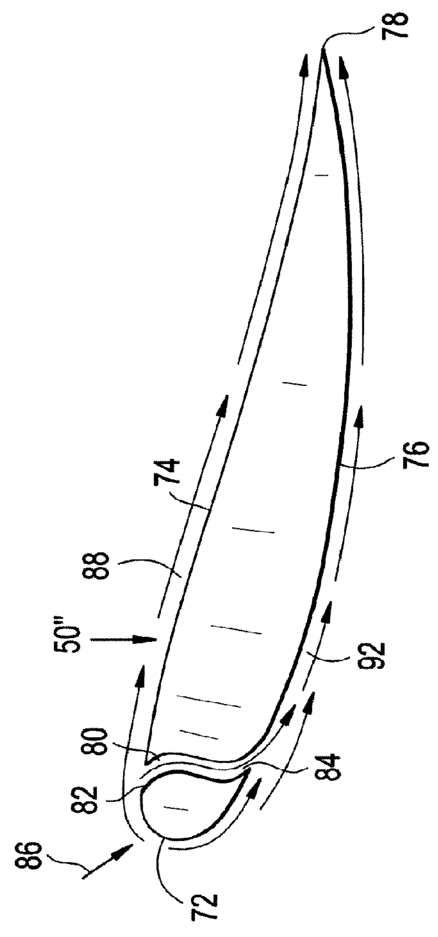


FIG. 7

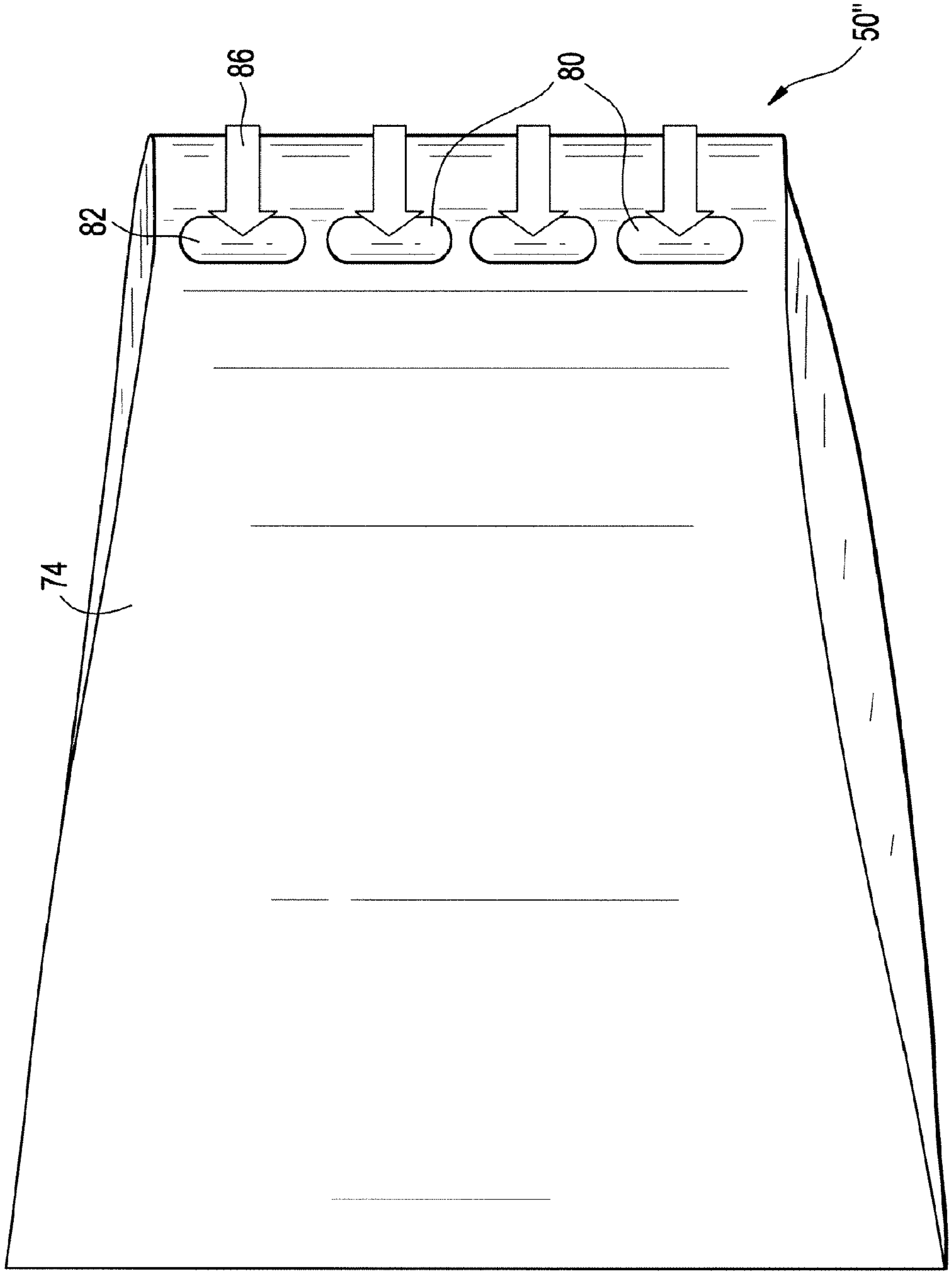
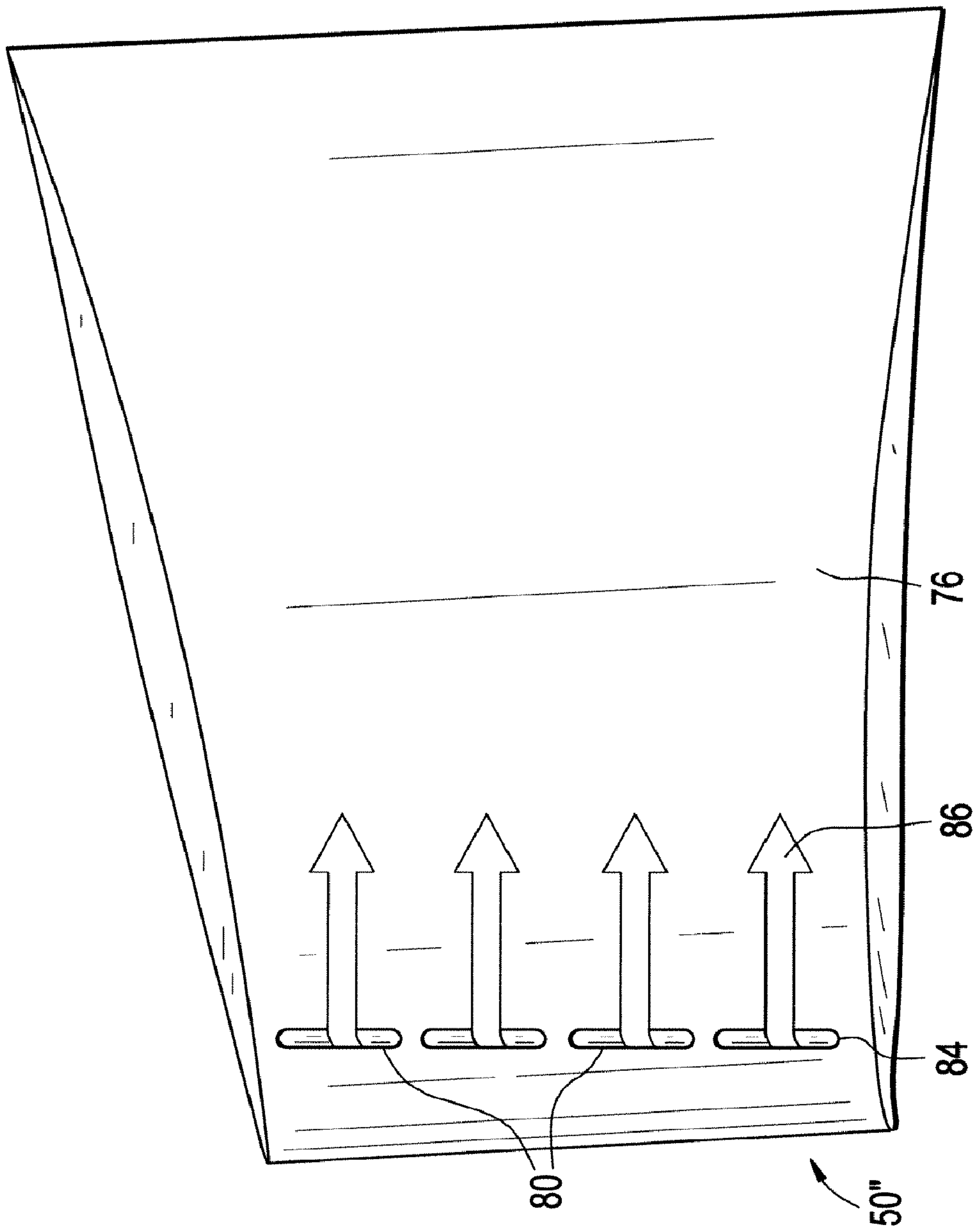


FIG. 5

FIG. 6



HIGH-TURNING DIFFUSER STRUT WITH FLOW CROSS-OVER SLOTS

BACKGROUND OF THE INVENTION

[0001] The subject matter described herein relates to turbine engines, and, more specifically, to turning struts in a diffuser of a turbine engine.

[0002] A gas turbine engine includes a compressor having a plurality of compressor blades disposed on a shaft, with the compressor blades and shaft configured to define a decreasing volume. Airflow ingested into the gas turbine is compressed as it passes through the compressor. A plurality of combustors are disposed downstream of the compressor, where air and fuel are mixed and the fuel is ignited, as is known. A multi-stage turbine is disposed downstream of the combustors. First stages of the multi-stage turbine are defined by a plurality of turbine vanes disposed on the shaft of the compressor. Final stages of the multi-stage turbine are defined by a plurality of turbine vanes disposed on an output drive shaft, which rotates independently of the shaft of the compressor. The heated compressed air flow from the combustors turns the multi-stage turbine. The rotation of the first stages of the multi-stage turbine rotates the shaft of the compressor. The rotation of the final stages of the multi-stage turbine rotates the output drive shaft, which in turn drives a generator. A diffuser is disposed aft of the final stages of the multi-stage turbine and is configured to decelerate the exhaust flow and convert dynamic energy to a static pressure rise. The diffuser includes a plurality of turning struts that consist of a support strut encased by an aerodynamic faring. The turning struts turn a flow from the multi-stage turbine towards the axial direction when the gas turbine engine is operated within a designed performance range. The turning struts are disposed circumferentially within the annulus of the diffuser.

BRIEF DESCRIPTION OF THE INVENTION

[0003] According to one aspect of the invention, a turning strut for use in a diffuser of a turbine engine has a curved leading edge, a first tapered surface depending at one end thereof from the curved leading edge, a second tapered surface depending at one end thereof from the curved leading edge, and a trailing edge defined at the other ends of the first and second tapered surfaces. The second tapered surface is disposed opposite the first tapered surface. At least one slot extends through the turning strut from the first tapered surface to the second tapered surface. The at least one slot reduces in volume from the first tapered surface to the second tapered surface. The at least one slot is disposed proximate the curved leading edge.

[0004] According to another aspect of the invention, a method of turning a flow in a diffuser of a turbine engine includes impacting the flow at a leading edge of the turning strut, at a swirl angle that is deviated from a design point swirl angle. The method further includes defining a first laminar boundary layer at a first tapered surface of the turning strut from the flow thereat and defining a second laminar boundary layer at a second surface of the turning strut from the flow thereat. The first tapered surface depending at one end thereof from the leading edge. The second tapered surface depending at one end thereof from the leading edge. The second surface is disposed opposite the first surface. The deviated swirl angle results a pressure differential between the flow at the first and second surfaces. The flow at the first surface is at a higher pressure than the flow at the second surface. The method includes inducing the flow through at least one slot that extends through the turning strut from the first surface to the second surface. The flow through the at least one slot is from the first surface to the second surface and is a result of the pressure differential between the flow at the first and second surfaces. The method further includes accelerating the flow through the at least one slot by a reduction of volume of the at least one slot from the first surface to the second surface. The method still further includes combining the flow from the at least one slot with the flow at the second surface. Momentum of the flow at the second surface is increased to maintain the second laminar boundary layer at the second surface.

[0005] According to yet another aspect of the invention, a turning strut for use in a diffuser of a turbine engine has a generally elongated tear drop shape defined by a leading edge having first and second surfaces depending therefrom, the second surface being disposed opposite the first surface, and the first and second surfaces terminating at a trailing edge. At least one slot extends through the turning strut from the first surface to the second surface. The at least one slot reduces in volume from the first surface to the second surface. The at least one slot is disposed proximate the leading edge.

[0006] These and other advantages and features will become more apparent from the following description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] 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:

[0008] FIG. **1** is a diagrammatic cross sectional view of a typical gas turbine engine with a diffuser;

[0009] FIG. **2** is a diagrammatic cross sectional view of a turning strut of the prior art operating at a design point swirl angle;

[0010] FIG. **3** is a diagrammatic cross sectional view of the turning strut of FIG. **2** operating at a swirl angle that is deviated from the design point swirl angle;

[0011] FIG. **4** is a diagrammatic cross sectional view of an embodiment of a turning strut of the invention operating at a design point swirl angle;

[0012] FIG. **5** is a partial side view of the turning strut of FIG. **4**;

[0013] FIG. **6** is another partial side view of the turning strut of FIG. **4**; and

[0014] FIG. **7** is a diagrammatic cross sectional view of the turning strut of FIG. **4** operating at a swirl angle that is deviated from the design point swirl angle.

[0015] 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

[0016] Referring to FIG. **1**, a heavy-duty gas turbine engine is shown generally at **10**. The gas turbine engine **10** has a generally annular shape defined by an outer turbine casing **12**. An inlet **14** is defined at one end of the gas turbine engine **10**. The inlet **14** leads to a compressor **16** that is defined by and a plurality of compressor blades **18** disposed within the casing

12. The compressor blades **18** are disposed on a shaft **20** that extends along a centerline **22** of the casing **12**, with the compressor blades **18** and shaft **20** configured to define a decreasing volume. Airflow ingested into the gas turbine engine **10** at the inlet **14** is compressed as it passes through the compressor **16**. A plurality of combustors **24** are disposed downstream of the compressor **16**, and are positioned axially about the shaft **20**. The combustors **24** have a premixing chamber and a combustion chamber (both of which are not shown). The airflow from the compressor **16** is ingested through entry ports **26** into the premixing chamber. Also, fuel from a fuel inlet **28** is delivered into the premixing chamber. This air and fuel are mixed within the premixing chamber to form a fuel and air mixture that flows into the combustion chamber where it is ignited, as is known. A multi-stage turbine **30** is disposed within the casing **12** downstream of the combustors **24**. First stages **32** of the multi-stage turbine **30** are defined by a plurality of turbine vanes **34** disposed on the shaft **20**. Final stages **36** of the multi-stage turbine **30** are defined by a plurality of turbine vanes **38** disposed on an output drive shaft **40**. The output drive shaft **40** also extends along the centerline **22** of the casing **12**, as it is axially aligned with the shaft **20**, but rotates independently thereof. The heated compressed air flow from the combustors **24** turns the multi-stage turbine **30**. The rotation of the first stages **32** of the multi-stage turbine **30** rotates the shaft **20**, which in turn drives the compressor **16**. The rotation of the final stages **36** of the multi-stage turbine **30** rotates the output drive shaft **40**, which in turn drives a generator (not shown). A diffuser **42** is disposed aft of the final stages **36** of the multi-stage turbine **30** and is configured to decelerate the exhaust flow and convert dynamic energy to a static pressure rise. The diffuser **42** includes a plurality of turning struts **50** that consist of a support strut encased by an aerodynamic faring. The turning struts **50** turn a flow **44** from the multi-stage turbine **30** towards the axial direction, resulting in a flow **46**, when the gas turbine engine **10** is operated within a designed performance range. The turning struts **50** are disposed circumferentially within the annulus of the diffuser **42**.

[0017] Referring to FIG. **2**, in the prior art turning struts designated **50'** are shown in a diagrammatic cross sectional view as having a generally elongated tear drop shape. The turning strut **50'** has a curved leading surface **52** that leads to tapered surfaces **54** and **56**, which meet at trailing edge **58**. The turning struts **50'** are designed to turn a flow **60** of exhaust with limited efficiency drop when the gas turbine **10** is operated within its a designed performance range. More specifically, the flow **60** impacts the curved leading surface **52** of the turning strut **50'** at a design point inlet swirl angle, such that the flow **60** around the turning strut **50'** is uniform. Thusly defining laminar boundary layers **62** and **64** at the surfaces of the turning strut **50'**. This is reliably achieved when the gas turbine engine **10** is operated within its designed performance range.

[0018] However, it is at times desirable to operate the gas turbine engine **10** below its designed performance range. This would include operation during off peak energy demand or other low energy demand conditions. When operated in this manner, often referred to as "turn-down" operation, the flow of exhaust about the turning struts **50'** is less than optimal.

[0019] Referring to FIG. **3**, turning strut **50'** is shown during turn down operation, where the flow **60** impacts the curved leading surface **52** of the turning strut **50'** at a swirl angle that is significantly deviated from the design point inlet swirl angle (FIG. **2**). The flow **60** at this deviated swirl angle impacts the curved leading surface **52** at the turning strut **50'**. The flow **60** continues along surface **54** defining the laminar boundary layer **62**. The flow **60** continues along surface **56** defining the laminar boundary layer **64**, which separates downstream at a point of separation **66**. When the momentum of flow in the laminar boundary layer **64** is reduced to the point where it is zero; the laminar boundary layer **64** then separates from the surface **56**. When the laminar boundary layer **64** separates from the surface **56**, it then causes reverse flow over the surface **56**. When the laminar boundary layer **64** separates, it produces a wake **68** that causes an increase of pressure drag, which adversely affects the efficiency of the system. Within the wake **68** a plurality of vortices **70** are created. When the vortices **70** begin to shed off the surface **56** they do so at a certain frequency. The shedding of the vortices **70** can cause vibrations in the strut **50'**, further adding to inefficiencies of the system, such as increased noise and back pressure.

[0020] Referring to FIGS. **4**, **5** and **6**, in an embodiment turning struts designated **50"** are shown in a diagrammatic cross sectional view (FIG. **4**) as having a generally elongated tear drop shape. The turning strut **50"** has a curved leading edge **72** that leads to tapered surfaces **74** and **76**, which meet at trailing edge **78**. A plurality of slots **80** extend through the turning strut **50"** from an inlet **82** at surface **74** (FIG. **5**) to an outlet **84** at surface **76** (FIG. **6**). The slots **80** are disposed proximate the leading edge **72** of the turning strut **50"**. The slots **80** are aligned and are shaped generally rectangular with rounded ends. The area of the inlet **82** is greater than that of the outlet **84**. Consequently the volume of the slots **80** reduces from inlet **82** to outlet **84**. A diagrammatic cross sectional view of the slots **80** (FIG. **4**) shows a generally compound curve that is generally Serpentine shaped. The turning struts **50"** are designed to turn a flow **86** of exhaust with limited efficiency drop when a gas turbine engine **10** is operated within its designed performance range. More specifically, the flow **86** impacts the curved leading surface **72** of the turning strut **50"** at a design point inlet swirl angle, such that the flow **86** around the turning strut **50"** is uniform. Laminar boundary layers **88** and **90** are formed at the surfaces **74** and **76**, respectively, of the turning strut **50"**. At the design point swirl angle the pressure differential of the flow from surface **74** to surface **76** is negligible, whereby any flow through slots **80** is de minimis.

[0021] Referring now to FIG. **7**, turning strut **50"** is shown during turn down operation, where the flow **86** impacts the curved leading edge **72** of the turning strut **50"** at a swirl angle that is significantly deviated from the design point inlet swirl angle (FIG. **4**). The flow **86** continues along surface **74** defining the laminar boundary layer **88**. The flow **86** continues along surface **76** defining a laminar boundary layer **92**. The deviated swirl angle results a pressure differential between the flow at surfaces **74** and **76**. A high-pressure flow is established at the surface **74** and low-pressure is established at surface **76**. This pressure differential between the surfaces **74** and **76** creates suction at the slots **80** resulting in flow through the slots. The reducing volume of the slots **80** causes the flow therethrough to increase in speed due to Bernoulli's principle. Bernoulli's principle states that the correlation between the velocity and pressure of a fluid; when fluid velocity increases pressure falls and likewise. Therefore, the flow entering the slots **80** at the inlet **82** accelerates through the slots **80** to the outlet **84**. The flow exiting the slots **80** is faster than the flow at the upstream end of surface **76**. These flows combine at the outlet **84**, whereby the flow at surface **76** downstream of the outlet **84** is accelerated. Unlike the above discussed prior art, this accelerated flow at surface **76** does not separate. The momentum of this flow is not reduced to zero; uniformity of the flow between the surfaces **74** and **76** is maintained. As described above, the slots **80** are Serpentine shaped in order facilitate flow into the inlet **82** and out of outlet **84**. More specifically, the direction of flow at the surface **74** leads to the inlet **82** and the outlet **84** follows the direction of flow at surface **76**. Accordingly, pressure drag is reduced, which will increase the efficiency of the diffuser **42** as well as reducing part stress.

[0022] 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 it is only limited by the scope of the appended claims.

1. A turning strut for use in a diffuser of a turbine engine, the turning strut comprising:

a curved leading edge;

a first tapered surface depending at one end thereof from the curved leading edge;

a second tapered surface depending at one end thereof from the curved leading edge, the second tapered surface being disposed opposite the first tapered surface;

a trailing edge defined at an other ends of the first and second tapered surfaces; and

at least one slot extending through the turning strut from the first tapered surface to the second tapered surface, the at least one slot reducing in volume from the first tapered surface to the second tapered surface, the at least one slot being disposed proximate the curved leading edge.

2. The turning strut of claim **1** wherein the at least one slot comprises a plurality of slots that are aligned.

3. The turning strut of claim **1** wherein the at least one slot has a generally rectangular shape with rounded ends.

4. The turning strut of claim **1** wherein the at least one slot has a generally compound curve shape.

5. The turning strut of claim **4** wherein the generally compound curve shape comprises a serpentine shape.

6. The turning strut of claim **1** wherein the at least one slot is disposed proximate the curved leading edge so as to maintain a laminar boundary layer at the second tapered surface during turn down operation of the turbine engine.

7. A method of turning a flow in a diffuser of a turbine engine, the method comprising:

impacting the flow at a leading edge of the turning strut, at a swirl angle that is deviated from a design point swirl angle;

defining a first laminar boundary layer at a first tapered surface of the turning strut from the flow thereat, the first tapered surface depending at one end thereof from the leading edge;

defining a second laminar boundary layer at a second surface of the turning strut from the flow thereat, the second tapered surface depending at one end thereof from the leading edge, the second surface being disposed opposite the first surface, wherein the deviated swirl angle results a pressure differential between the flow at the first and second surfaces, wherein the flow at the first surface is at a higher pressure than the exhaust flow at the second surface;

inducing the flow through at least one slot that extends through the turning strut from the first surface to the second surface, the flow through the at least one slot is from the first surface to the second surface and is a result of the pressure differential between the flow at the first and second surfaces;

accelerating the flow through the at least one slot by a reduction of volume of the at least one slot from the first surface to the second surface; and

combining the flow from the at least one slot with the flow at the second surface, wherein momentum of the flow at the second surface is increased to maintain the second laminar boundary layer at the second surface.

8. The method of claim **7** further comprising:

turning down the turbine engine, wherein the swirl angle of the flow deviates from the design point swirl angle.

9. The method of claim **7** wherein the at least one slot comprises a plurality of slots that are aligned.

10. The method of claim **7** wherein the at least one slot has a generally rectangular shape with rounded ends.

11. The method of claim **7** wherein the at least one slot has a generally compound curve shape.

12. The method of claim **11** wherein the generally compound curve shape comprises a serpentine shape.

13. The method of claim **7** wherein the first and second surfaces terminate at a trailing edge.

14. A turning strut for use in a diffuser of a turbine engine, the turning strut having a generally elongated tear drop shape defined by a leading edge having first and second surfaces depending therefrom, the second surface being disposed opposite the first surface, the first and second surfaces terminating at a trailing edge, at least one slot extending through the turning strut from the first surface to the second surface, the at least one slot reducing in volume from the first surface to the second surface, the at least one slot being disposed proximate the leading edge.

15. The turning strut of claim **14** wherein the at least one slot comprises a plurality of slots that are aligned.

16. The turning strut of claim **14** wherein the at least one slot has a generally rectangular shape with rounded ends.

17. The turning strut of claim **14** wherein the at least one slot has a generally compound curve shape.

18. The turning strut of claim **17** wherein the generally compound curve shape comprises a serpentine shape.

19. The turning strut of claim **14** wherein the at least one slot is disposed proximate the curved leading edge so as to maintain a laminar boundary layer at the second tapered surface during turn down operation of the turbine engine.

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