

Description

The present invention relates to an annular nacelle adapted to surround a gas turbine engine, said nacelle having an internal surface and an external surface, said external surface including an upstream portion and a downstream portion adapted to receive an unbounded flow of fluid thereover in the downstream direction, said internal and external surfaces extending downstream and forming a thin trailing edge of said nacelle, said trailing edge defining an outlet of said nacelle, and wherein, if said external surface was streamlined and smoothly convex over said downstream portion of its length to said trailing edge, two-dimensional streamwise boundary layer separation would occur over said downstream portion of said external surface during a selected operating condition. An annular nacelle of this type is disclosed in US-A-4,066,214.

Drag is the result of skin friction and surface pressure variations induced by viscous effects, especially those due to separation bubbles or regions (i.e., low pressure wakes). Separation regions occur when two and three dimensional boundary layers depart from the surface of the body. Bluff or blunt bodies have shapes which tend to promote a rapidly increasing downstream pressure gradient in the streamline flow around it which can cause the bulk flow to break loose from the surface of the body. The present invention is concerned with the elimination or reduction of "boattail" drag, which is the drag created by viscous losses due to streamwise two-dimensional boundary layer separation from the surface of convexly curved, streamlined ducts or casings surrounding, for example, gas turbine engines. In US-A-4,066,214, referred to, a nacelle having a smooth external surface is disclosed. Often length restrictions necessitate curvatures which are steeper than desirable and cause early two-dimensional boundary layer separation. As used in the specification and appended claims, "streamwise, two-dimensional boundary layer separation" means the breaking loose of the bulk fluid from the surface of a body, resulting in flow near the wall moving in a direction opposite the bulk fluid flow direction.

It has been a constant goal of aerodynamicists to reduce the drag and improve lift and stall characteristics on bodies disposed in a fluid moving relative thereto. A common way to avoid boundary layer separation on an airfoil (or other streamlined body) or to at least delay separation such that it occurs as far downstream along the surface of the airfoil as possible so as to minimize drag, is to reduce the pressure rise downstream such as by tailoring the surface contour along the length of the airfoil in the direction of the bulk fluid flow.

Another well known method for reducing the drag on airfoils is to create turbulence in the boundary layer so as to impart a greater average momentum of the boundary layer fluid, which carries it further downstream along the surface against an adverse pressure gradient, thereby delaying the separation point. One technique for increasing the momentum of the boundary layer is to generate streamwise vortices such as by using the ramp-type vortex generators shown in US-A-2,800,291.

US-A-4,455,045 describes elongated, expanding channels in the flow surface. The channels have sharp, lengthwise edges. The boundary layer on the surface flows into the channels, and the channel edges create streamwise vortices below the level of the normal flow surface which energize the flow in the channel to maintain boundary layer attachment of the flow along the floor of the channel.

In US-A-1,773,280 increased lift without increased drag is created for an aircraft wing by placing a plurality of side by side chordwise extending ridges along the top of the wing from its leading to its trailing edge, the ridges having their highest point near the thickest portion of the wing. The ridges themselves are airfoil shaped when viewed from above, tapering to a point at the trailing edge of the wing. This concept does not take into account viscous induced boundary layer separation effects and therefore could not be expected to avoid separation at high lift conditions.

US-A-3,588,005 uses chordwise extending ridges in the upper surface of an airfoil to delay the onset of separation by providing "channels of accelerated flow in the free stream flow direction to add energy to the boundary layer and maintain laminar flow in the region of normally adverse pressure gradient." The ridges protrude from the surface "to a height of the order of the boundary layer thickness". Cross flow components "are accelerated over the ridges and may reduce the likelihood of separation near the aft end ... of the body by allowing the flow to 'corkscrew' smoothly off the aft end rather than encounter the abrupt adverse pressure gradient in the free stream direction caused by a blunted aft end." As with the ridges of US-A-1,773,280 discussed above, flow is also accelerated between the ridges which further helps maintain laminar flow over the airfoil surface.

US-A-3,741,235 and 3,578,264 delay separation by creating vortices using a series of crests or concave depressions which extend substantially transverse to the streamwise flow direction with the maximum height of a crest or depth of a depression being preferably less than the boundary layer thickness.

In a paper titled "The Reduction of Drag by Corrugating Trailing Edges" by D. L. Whitehead,

M. Kodz, and P. M. Hield published by Cambridge University, England in 1982, blunt base drag of a blade (having a 508 mm (20-inch) span, 508 mm (20 inch) chord length, a constant thickness of 38 mm (1.5 inches) and a blunt trailing edge) is reduced by forming the last 177 mm (seven inches) of its chordwise length into streamwise extending, alternating troughs and ridges (corrugations). The trailing edge and any upstream cross-section across the corrugations has the shape of a sine wave with an 203 mm (8.0 inch) wavelength. The thickness of the blade material is maintained constant over the length of each trough and ridge, although the trough depth or ridge height (i.e., wave amplitude) transitions from a maximum of 50 mm (2.0 inches) at the trailing edge to zero upstream. A reduction of base drag of about one-third was realized when compared with a reference blade without corrugation. It is explained that spanwise vortices which were shed alternately from the top and bottom rear edges of the non-corrugated reference blade were eliminated by the corrugations. No mention is made in the paper of surface separation.

The prior publications referred to relate to the reduction of drag of airfoils, wings or the like, but have nothing to do with the reduction of "boattail" drag. With respect to US-A-3,588,005 it can even further be stated that it uses only ridges, and these have a maximum height which is only approximately the laminar boundary layer thickness. The mechanism of US-A-3,588,005 involves lateral flow of the laminar boundary layers over the ridges themselves, i. e. it involves energizing laminar boundary layer only by local acceleration of that boundary layer as it proceeds over the top of the ridges. Note that the airfoil of US-A-3,588,005 has ridges oriented normal to the streamwise flow direction, further the mechanism involved therein is the energizing of the boundary layer by having it flow over the ridges. This is similar in nature to the device described in US-A-3,578,264 wherein crests or depressions which are only the height of the boundary layer are oriented generally normal to the flow and simply energize the boundary layer by creating vortices which transfer their energy to the boundary layer. Other types of vortex generators which are well known in the prior art operate on the principal of transferring energy from the free stream into the frictionally decelerated boundary layer, thereby providing energy to aid the flow in overcoming the adverse pressure gradient. Unfortunately, vortex generators of the type which protrude into the fluid stream create their own drag which detracts from their effectiveness.

In US-A-4,066,214, already referred to, there is provided a lobed mixer for mixing the engine core and fan streams but this has nothing to do with

minimizing drag caused by fluids flowing over the external smooth surface of the annular nacelle. US-A-4,066,214 is not concerned with the external surface of the annular nacelle having an unbounded flow of fluid flowing thereover in the downstream direction. No provisions are made in US-A-4,066,214 to delay or eliminate or reduce "boattail" drag created by the fluid flowing over the curved external outer surface of the nacelle.

The object of the invention is to eliminate or delay the onset of streamwise two-dimensional boundary layer separation from the external surface of an engine casing or nacelle.

In accordance with the invention, to achieve this, the annular nacelle is characterized by a plurality of alternating, adjoining, smoothly undulating generally U-shaped ridges and troughs formed in said downstream portion of said external surface, said ridges and troughs extending downstream from said upstream surface portion to said trailing edge from a point upstream of where two-dimensional streamwise boundary layer separation would occur if said external surface was streamlined and smoothly convex over said downstream portion, said trailing edge being wave-shaped, said troughs in said external surface defining corresponding ridges in said internal surface and said ridges of said external surface defining corresponding troughs in said internal surface and said troughs and ridges being sized and contoured such that under said selected operating condition no significant streamwise two-dimensional boundary layer separation occurs on said external surface over the length of said troughs and ridges.

The trough and ridge construction of the present invention can delay the onset of separation or even eliminate it despite nacelle length restrictions.

To have the desired effect of preventing or reducing the area of streamwise two-dimensional boundary layer separation on the external surface of the nacelle, it is believed that the sum of the depth and height of the troughs and ridges respectively, at the trailing edge (i. e. the peak-to-peak wave amplitude at the trailing edge) will need to be at least about twice the 99 % boundary layer thickness immediately forward of the upstream ends of the troughs. Preferably, the trough depth and ridge height start at zero and increase toward the trailing edge to respective maximum dimensions.

It is believed that the trough and ridge construction delays or prevents the catastrophic effects of two-dimensional boundary layer separation by providing three-dimensional relief for the low momentum boundary layer flow. The local flow area variations created by the troughs and ridges produce local control of pressure gradients and allow

the boundary layer approaching and adverse pressure gradient region to move laterally instead of separating from the wall surface. It is believed that as the boundary layer flows downstream and encounters a ridge, it thins out along the top of the ridge and picks up lateral momentum on either side of the peak of the ridge toward the troughs. In corresponding fashion, the boundary layer flowing into the trough is able to pick up lateral momentum and move laterally on the walls of the trough on either side thereof. The net result is the elimination of two-dimensional boundary layer separation because the boundary layer is able to run around the pressure rise as it moves toward the trailing edge. The entire scale of the mechanism is believed to be inviscid in nature and not tied directly to the scale of the boundary layer itself.

It is believed that best results were obtained when peak-to-peak amplitude at the trailing edge is comparable to the separation bubble (or wake) thickness which would be expected to occur at the trailing edge if the casing did not incorporate the troughs and ridges. This will generally result in trough depth and ridge heights many times larger (often orders of magnitude larger) than the boundary layer thickness.

The primary effect of the troughs and ridges is to provide a path for the boundary layer to skirt around the adverse pressure gradient itself. It does not require an identifiable vortex structure in the trough or on the ridges of the nacelle. Neither does it require net flow over the ridges. As such the present invention is useful in preventing boundary layer separation for either turbulent or laminar flows.

The foregoing and other features and advantages of the annular nacelle will become more apparent in the light of the following detailed description of preferred embodiments thereof as illustrated in the accompanying drawing, in which:

Fig. 1 is a simplified perspective view, partly broken away, of a gas turbine engine having external casings incorporating the features of the present invention.

Fig. 2 is a simplified perspective view, partly broken away, of a bypass-type gas turbine engine of the prior art.

Fig. 3 is a simplified illustrative view taken generally in the direction 19-19 of Fig. 2.

Fig. 4 is a simplified illustrative view taken generally in the direction 20-20 of Fig. 1.

Referring first to prior art Figs. 2 and 3, a gas turbine engine 200 is of the fan bypass type and includes an annular casing or nacelle 202 surrounding and spaced from the core engine casing 204. The internal surface 206 of the nacelle 202 defines the outer surface of the fan bypass flow path 208, which has its outlet 209 at the thin,

downstream or trailing edge 210 of the nacelle 202. The external surface 212 of the nacelle has a streamlined smooth convex shape in cross section (taken in the plane of the engine axis) to reduce drag created by the external, unbounded flow of air over the surface in the downstream direction. As depicted in the drawing, despite the streamlined nacelle shape, under certain operating conditions, such as at cruise which is where the engine (i.e., the aircraft) operates most of the time, two-dimensional boundary layer separation of the flow over the external surface 212 may initiate at the plane S at an axial distance Y upstream from the trailing edge. This is usually due to an excessive convex curvature required in order to achieve a particular cross-sectional area C (shown cross-hatched in Fig. 3) at the trailing edge for a particular nacelle length. The separation region, which often extends over a significant portion of the downstream part of the nacelle, has a thickness T, which is the radial distance from the trailing edge to the outer edge of the separation region as measured in a plane passing through the trailing edge and perpendicular to the engine axis. This separation region creates the well known and highly undesirable "boattail" drag already referred to.

The present invention, best shown in Figs. 1 and 4, moves the initiating point for separation closer to the trailing edge and may even eliminate it entirely. Initiating upstream of where prior art separation would normally occur, a plurality of alternating, adjoining, smoothly undulating, generally U-shaped troughs 214 and ridges 216 are disposed in the external surface 212' (primed reference numerals correspond to the same numbered elements of prior art Figs. 2, 3) and extend downstream, increasing gradually in depth and height, respectively to a maximum at the outlet 209'. Since the trailing edge 210' is thin, the troughs in the external surface 202' create corresponding ridges in the internal surface 206'; and the ridges in the external surface define corresponding troughs in the internal surface.

In Fig. 4 the core engine is omitted for purposes of clarity. The outlet area C' is the same as the outlet area C, to avoid changing the bypass ratio. The troughs and ridges are sized and contoured to flow full over at least a significant portion of and preferably over their entire length, whereby streamwise two-dimensional boundary layer separation from the external surface 212' is eliminated, or its onset is at least delayed (e. g. separation initiates at a distance Z upstream of the trailing edge, where Z is significantly less than Y or is preferably zero).

The troughs and ridges are U-shaped at any cross section taken perpendicular to their length, and they blend with each other (i.e. no sharp

edges) so that the nacelle surface is a series of relatively smooth undulations which minimize the formation of drag producing axial vortices. The shape and contour of the ridges and troughs along their length are preferably selected to assure that two-dimensional boundary layer separation does not occur anywhere on the surface, such that the troughs flow full along their entire length. For the same reason the rate of increase in trough depth and the rate of increase in ridge height cannot be excessive. Optimizing the size and shape of the troughs and ridges may have to be done by trial and error. In some cases amplitude M at the trailing edge of only about twice the 99 % boundary layer thickness (measured immediately upstream of the upstream ends of the troughs) may be sufficient. Preferably M should be at least about four times the 99 % boundary layer thickness. It is believed that best results will be obtained when the amplitude M at the trailing edge is at least the same as and most preferably about twice the maximum thickness T of the separation region which would have formed using a smooth convex external surface according to the prior art. An amplitude M which is too small may result in delaying the onset of separation, without preventing it completely. The present invention is intended to encompass any amplitude which provides beneficial results.

If W is the distance between the peaks of adjacent ridges at the trailing edge (i.e. the "wavelength" at the trailing edge), the ratio of W to M is preferably no greater than about 4.0 and no less than about 0.5, in order to induce sufficient lateral pressure gradients without encountering significant viscous losses.

In a circular nacelle the wave amplitude M is measured radially, and the wave length W or spacing between troughs will be an average of the radially outermost peak-to-peak arc length and the radially innermost peak-to-peak arc length.

The sidewalls of the troughs in the outer surface converge toward the trailing edge to create convergent passages. The convergent passages have an accelerating effect on the flow within the troughs. The acceleration of the bulk fluid flow within converging troughs is believed to add momentum to the boundary layer, although the advantages would be only secondary to those provided by the existence of the troughs and ridges themselves.

Also, it follows that the converging troughs in the outer surface will necessarily result in diverging trough portions in the inner surface.

As shown in Fig. 1, the core engine casing 204' also has an unbounded flow of fluid over its external surface. The casing 204' surrounds and is spaced radially outwardly from an engine tail plug 217 and forms part of the flowpath for the primary

or core engine stream. Troughs and ridges according to the present invention are also incorporated in the trailing edge region 218 of the external surface of the casing 204' to eliminate or at least delay the onset of streamwise two-dimensional boundary layer separation.

In the embodiment of Fig. 1 the undulations formed in the casing 204' extend around the entire periphery of the outlet, and appear as a wave-shape when viewed from aft of the engine. If the engine casing had a rectangular outlet, such as for an engine having a two-dimensional exhaust nozzle, one or more of the sides of the casing could incorporate the troughs and ridges, since benefits will occur over whatever portion of the casing the troughs and ridges are used.

Claims

1. An annular nacelle (202') adapted to surround a gas turbine engine, said nacelle (202') having an internal surface (206') and an external surface (212'), said external surface (212') including an upstream portion and a downstream portion adapted to receive an unbounded flow of fluid thereover in the downstream direction, said internal and external surfaces (206', 212') extending downstream and forming a thin trailing edge (210') of said nacelle (202'), said trailing edge (210') defining an outlet (209') of said nacelle (202'), of cross-sectional area C, and wherein, if said external surface (212') was streamlined and smoothly convex over said downstream portion of its length to said trailing edge (210'), two-dimensional streamwise boundary layer separation would occur over said downstream portion of said external surface (212') during a selected operating condition,

characterized by a plurality of alternating, adjoining, smoothly undulating generally U-shaped ridges (216) and troughs (214) formed in said downstream portion of said external surface (212'), said ridges (216) and troughs (214) extending downstream from said upstream surface portion to said trailing edge (210') from a point upstream of where two-dimensional streamwise boundary layer separation would occur if said external surface (212') was streamlined and smoothly convex over said downstream portion, said trailing edge (210') being wave-shaped, said troughs (214) in said external surface (212') defining corresponding ridges in said internal surface and said ridges (216) of said external surface (212') defining corresponding troughs in said internal surface (206'), and said troughs (214) and ridges (216) being sized and contoured



edges) so that the nacelle surface is a series of relatively smooth undulations which minimize the formation of drag producing axial vortices. The shape and contour of the ridges and troughs along their length are preferably selected to assure that two-dimensional boundary layer separation does not occur anywhere on the surface, such that the troughs flow full along their entire length. For the same reason the rate of increase in trough depth and the rate of increase in ridge height cannot be excessive. Optimizing the size and shape of the troughs and ridges may have to be done by trial and error. In some cases amplitude M at the trailing edge of only about twice the 99 % boundary layer thickness (measured immediately upstream of the upstream ends of the troughs) may be sufficient. Preferably M should be at least about four times the 99 % boundary layer thickness. It is believed that best results will be obtained when the amplitude M at the trailing edge is at least the same as and most preferably about twice the maximum thickness T of the separation region which would have formed using a smooth convex external surface according to the prior art. An amplitude M which is too small may result in delaying the onset of separation, without preventing it completely. The present invention is intended to encompass any amplitude which provides beneficial results.

If W is the distance between the peaks of adjacent ridges at the trailing edge (i.e. the "wavelength" at the trailing edge), the ratio of W to M is preferably no greater than about 4.0 and no less than about 0.5, in order to induce sufficient lateral pressure gradients without encountering significant viscous losses.

In a circular nacelle the wave amplitude M is measured radially, and the wave length W or spacing between troughs will be an average of the radially outermost peak-to-peak arc length and the radially innermost peak-to-peak arc length.

The sidewalls of the troughs in the outer surface converge toward the trailing edge to create convergent passages. The convergent passages have an accelerating effect on the flow within the troughs. The acceleration of the bulk fluid flow within converging troughs is believed to add momentum to the boundary layer, although the advantages would be only secondary to those provided by the existence of the troughs and ridges themselves.

Also, it follows that the converging troughs in the outer surface will necessarily result in diverging trough portions in the inner surface.

As shown in Fig. 1, the core engine casing 204' also has an unbounded flow of fluid over its external surface. The casing 204' surrounds and is spaced radially outwardly from an engine tail plug 217 and forms part of the flowpath for the primary

or core engine stream. Troughs and ridges according to the present invention are also incorporated in the trailing edge region 218 of the external surface of the casing 204' to eliminate or at least delay the onset of streamwise two-dimensional boundary layer separation.

In the embodiment of Fig. 1 the undulations formed in the casing 204' extend around the entire periphery of the outlet, and appear as a wave-shape when viewed from aft of the engine. If the engine casing had a rectangular outlet, such as for an engine having a two-dimensional exhaust nozzle, one or more of the sides of the casing could incorporate the troughs and ridges, since benefits will occur over whatever portion of the casing the troughs and ridges are used.

Claims

1. An annular nacelle (202') adapted to surround a gas turbine engine, said nacelle (202') having an internal surface (206') and an external surface (212'), said external surface (212') including an upstream portion and a downstream portion adapted to receive an unbounded flow of fluid thereover in the downstream direction, said internal and external surfaces (206', 212') extending downstream and forming a thin trailing edge (210') of said nacelle (202'), said trailing edge (210') defining an outlet (209') of said nacelle (202'), of cross-sectional area C, and wherein, if said external surface (212') was streamlined and smoothly convex over said downstream portion of its length to said trailing edge (210'), two-dimensional streamwise boundary layer separation would occur over said downstream portion of said external surface (212') during a selected operating condition,

characterized by a plurality of alternating, adjoining, smoothly undulating generally U-shaped ridges (216) and troughs (214) formed in said downstream portion of said external surface (212'), said ridges (216) and troughs (214) extending downstream from said upstream surface portion to said trailing edge (210') from a point upstream of where two-dimensional streamwise boundary layer separation would occur if said external surface (212') was streamlined and smoothly convex over said downstream portion, said trailing edge (210') being wave-shaped, said troughs (214) in said external surface (212') defining corresponding ridges in said internal surface and said ridges (216) of said external surface (212') defining corresponding troughs in said internal surface (206'), and said troughs (214) and ridges (216) being sized and contoured



such that under said selected operating condition no significant streamwise two-dimensional boundary layer separation occurs on said external surface (212') over the length of said troughs (214) and ridges (216).

2. An annular nacelle according to claim 1 characterized in that the sum of the depth of one of said troughs (214) and height of an adjacent ridge (216) at said trailing edge (210') is between one and two times the thickness that the separated boundary layer would have been at the trailing edge (210') if said external surface (212') was streamlined and smoothly convex over said downstream portion.
3. An annular nacelle according to claim 1 or 2, characterized in that the ratio of the wave length (W) of said troughs (214) and ridges (216) to the wave amplitude (M) of the troughs (214) and ridges (216) at the trailing edge (210') is preferably no greater than about 4.0 and no less than about 0.5.
4. An annular nacelle according to any one of claims 1 to 3, characterized in that said internal surface defines at least a portion of an exhaust gas path for a gas turbine engine.

Revendications

1. Une nacelle annulaire (202') apte à entourer un moteur à turbine à gaz, ladite nacelle (202') comportant une surface intérieure (206') et une surface extérieure (212'), ladite surface extérieure (212') comportant une partie amont et une partie aval aptes à recevoir un courant non limité de fluide passant sur elles dans la direction de l'aval, lesdites surfaces intérieure et extérieure (206', 212') s'étendant en aval et formant un mince bord de fuite (210') de ladite nacelle (202'), ledit bord de fuite (210') définissant une sortie (209') de ladite nacelle (202') dont la surface en coupe transversale est C, et dans laquelle, si ladite surface extérieure (212') était profilée et uniformément convexe sur ladite partie aval de sa longueur vers ledit bord de fuite (210'), il apparaîtrait sur ladite partie aval de ladite surface extérieure (212'), au cours d'une condition choisie de fonctionnement, une séparation de couche limite à deux dimensions selon le sens du courant

caractérisée par une pluralité de nervures (216) disposées en alternance, contiguës, ondulant de façon uniforme, généralement en forme de U et d'auges (214) formées dans ladite partie aval de ladite surface extérieure (212'), lesdites nervures (216) et auges (214)

s'étendant en aval, depuis ladite partie de surface amont vers ledit bord de fuite (210'), à partir d'un point en amont de l'emplacement où il apparaîtrait une séparation de couche limite à deux dimensions selon le sens du courant si ladite surface extérieure (212') était profilée et uniformément convexe sur ladite partie aval, ledit bord de fuite (210') étant en forme d'ondes, lesdites auges (214) dans ladite surface extérieure (212') définissant des nervures correspondantes dans ladite surface intérieure et lesdites nervures (216) de ladite surface extérieure (212') définissant des auges correspondantes dans ladite surface intérieure (206'), et lesdites auges (214) et nervures (216) étant de dimensions et de contours tels que, dans ladite condition choisie de fonctionnement, il n'apparaît sur ladite surface extérieure (212'), sur la longueur desdites auges (214) et nervures (216), aucune séparation significative de couche limite à deux dimensions selon le sens du courant.

2. Une nacelle annulaire selon la revendication 1, caractérisée en ce que la somme de la profondeur de l'une desdites auges (214) et de la hauteur d'une nervure adjacente (216) audit bord de fuite (210') est comprise entre une et deux fois ce qui aurait été l'épaisseur de la couche limite séparée au bord de fuite (210') si ladite surface extérieure (212') était profilée et uniformément convexe sur ladite partie aval.
3. Une nacelle annulaire selon la revendication 1 ou 2, caractérisée en ce que le rapport entre la longueur d'onde (W) desdites auges (214) et nervures (216) et l'amplitude d'onde (M) des auges (214) et nervures (216) au bord de fuite (210') n'est, de préférence, ni supérieur à environ 4,0 ni inférieur à environ 0,5.
4. Une nacelle annulaire selon l'une quelconque des revendications 1 à 3, caractérisée en ce que ladite surface interne définit au moins une partie d'un trajet de gaz d'échappement d'un moteur à turbine à gaz.

Patentansprüche

1. Ringförmige Gondel (202') zum Umschließen eines Gasturbinenriebwerks, wobei die Gondel (202') eine innere Oberfläche (206') und eine äußere Oberfläche (212') hat, wobei die äußere Oberfläche (212') einen stromaufwärtigen Teil und einen stromabwärtigen Teil aufweist und dazu dient, eine über sie hinweggehende unbegrenzte Strömung von Fluid in stromabwärtiger Richtung zu empfangen, wobei die Innere



- und äußere Oberfläche (206', 212') sich stromabwärts erstrecken und eine dünne Hinterkante (210') der Gondel (202') bilden, wobei die Hinterkante (210') einen Auslaß (209') der Gondel (202') mit einer Querschnittsfläche C begrenzt, und wobei, wenn die äußere Oberfläche (212') über dem stromabwärtigen Teil ihrer Länge bis zu der Hinterkante (210') stromlinienförmig und stetig konvex wäre, eine zweidimensionale Grenzschichtablösung in Strömungsrichtung über dem stromabwärtigen Teil der äußeren Oberfläche (212') während eines ausgewählten Betriebszustands auftreten würde, gekennzeichnet durch mehrere abwechselnde, aneinander anschließende, sich stetig wellende, im Querschnitt insgesamt U-förmige bergückenartige Erhebungen (216) und talartige Vertiefungen (214), die in dem stromabwärtigen Teil der äußeren Oberfläche (212') gebildet sind, wobei sich die Erhebungen (216) und die Vertiefungen (214) von dem stromaufwärtigen Oberflächenteil aus stromabwärts zu der Hinterkante (210') von einem stromaufwärtigen Punkt aus erstrecken, an dem die zweidimensionale Grenzschichtablösung in Strömungsrichtung erfolgen würde, wenn die äußere Oberfläche (212') über dem stromabwärtigen Teil stromlinienförmig und stetig konvex wäre, wobei die Hinterkante (210') wellenförmig ist, wobei die Vertiefungen (214) in der äußeren Oberfläche (212') entsprechende Erhebungen in der inneren Oberfläche und die Erhebungen (216) der äußeren Oberfläche (212') entsprechende Vertiefungen in der inneren Oberfläche (206'') bilden und wobei die Vertiefungen (214) und Erhöhungen (216) so bemessen und konturiert sind, daß in dem ausgewählten Betriebszustand keine nennenswerte zweidimensionale Grenzschichtablösung in Strömungsrichtung an der äußeren Oberfläche (212') über der Länge der Vertiefungen (214) und Erhöhungen (216) erfolgt.
2. Ringförmige Gondel nach Anspruch 1, dadurch gekennzeichnet, daß die Summe der Tiefe einer der Vertiefungen (214) und der Höhe einer benachbarten Erhebung (216) an der Hinterkante (210') zwischen dem Ein- und Zweifachen der Dicke liegt, die die abgelöste Grenzschicht an der Hinterkante (210') gehabt hätte, wenn die äußere Oberfläche (212') über dem stromabwärtigen Teil stromlinienförmig und stetig konvex gewesen wäre.
3. Ringförmige Gondel nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß das Verhältnis der Wellenlänge (W) der Vertiefungen (214) und Erhebungen (216) zu der Wellenamplitude (M) der Vertiefungen (214) und Erhebungen (216) an der Hinterkante (210') vorzugsweise nicht größer als etwa 4,0 und nicht kleiner als etwa 0,5 ist.
4. Ringförmige Gondel nach einem der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß die innere Oberfläche wenigstens einen Teil eines Abgasweges für ein Gasturbinenriebwerk bildet.